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Intermodal Competition on Some Routes in Transportation Networks: The Case of Inter Urban Buses and Railways

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Abstract

This paper analyzes the effect of inter urban buses competing on a few routes against trains within an established railway network. In line with expectations, we show that this can lead to unprofitable train service on these routes. However, within an established railway network with every track being profitable, competition on just some tracks can result in a collapse of the entire network. External effects of individual routes on the railway network are fundamental for the profitability of the network. Hence, weakening these network effects might be crucial. As a result, efficient intermodal competition on some routes might cause the abandoning of other routes that are not facing any competition. This effect has to be taken into account by political actors when liberalization of inter urban bus travel is considered.

Keywords: Transportation, intermodal competition, network effects.

JEL classification numbers: K2, L1, L5, R4.

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1 Introduction

Liberalization of land passenger transport markets is an enduring issue in worldwide politics. Although major markets of bus and railway transport have undergone radical changes and extensive deregulations in recent years, compared to other network industries like telecommunications liberalization of transport markets advances considerably slower. While empirical studies find that regulative steps towards market liberalization tends to be beneficial in terms of efficiency and productivity (e.g. Cantos, Pastor, & Serrano, 2010), in some countries concerns against full liberalization still prevail, even within the European Union. This also includes facilitation of intermodal competition in passenger transport markets. Uncertainty regarding the outcome of competition between different transportation modes or even the fear of unpleasant consequences seem to be reasons for political hesitation. An interesting example is provided by the ongoing discussion on liberalization of interurban bus transport markets in Germany. Until now, a general German passenger transport law prohibits interurban bus service when the intended relation is already served by rail.[1] Hence, intermodal competition between buses and railways is currently precluded by law, almost completely inhibiting interurban bus transport in Germany. Discussions on enabling long distance bus travel in Germany reveal concerns of policy makers about the resulting effect on the profitability of existing railway service.

This paper examines possible consequences of intermodal competition that might be caused by deregulation on an established railway infrastructure network. By making use of a model of competition between bus and rail services, we show that the entry of bus travel on one relation is able to endanger the profitability of routes not facing any competition or in an extreme case the entire railway network. Regarding this effect, for political actors it is important to consider conditions, under which intermodal competition is efficient and/or can lead to a collapsing of the existing railway system.

The analyzed issue of intermodal competition between bus an rail services can be linked to local as well as to long distance passenger transport markets. However, for local transportation the impact of authority planned transport routes is usually much higher, while in long distance transport more countries allow operators to come up with their ideas of markets to be served. Such market initiatives are usually characterized by higher dynamics, which means that entry of new operators on one

[1] § 13 of German Passenger transport law (Personenbeförderungsgesetz) restricts direct on-the-route competition between transport operators by not licensing bus operators, when there is already train service on the route in question.

route occurs quite suddenly and intermodal competition is able to develop rapidly. Thus, we will focus on long distance passenger transport markets where political influence is usually limited to the general decision of either fully allowing on-the-route competition of rail and bus services or restricting intermodal competition by law.

Regarding liberalization of transport markets, especially European bus and railway markets are often highly regulated. This often goes along with a dominant position of one mostly state owned company. Nevertheless, recently an increasing development trend towards open-access competition can be noticed. Driven by EU directive 91/440, in the 1990th some countries started to vertically separate infrastructure and transport services and began to allow private transport companies to enter the market. Trailblazers in Europe where Sweden and Great Britain, being the first to implement full separation and opening transport markets to competition in the EU. With EU directive 1370/2007, since 2011 EU-wide passenger cabotage transport is mandatory for all member states. Most European countries have already gone further and liberalized their interurban passenger transport markets completely for rail competition.

Liberalization of bus markets causes further effects on transport markets in general and railway markets in particular. Bus market deregulation in the United Kingdom provides again a prime real world example on the consequences of complete liberalization. Deregulation was generally introduced in Great Britain by 1980's Transport Act, while 1985's Transport Act eliminates an erstwhile obligate prior authority notification. In other European countries deregulation was implemented less absolute. Building on the British experience, theoretical and empirical research shows that coordination of competing services is a crucial issue in bus markets. Studies like Mackie, Preston, and Nash (1995); Ellis and Silva (1998); Oldale (1998); Gomez-Lobo (2007) find that firms primarily do not compete in prices but in frequency. This may lead to destructive behavior in competition. For example, bus companies have a strong incentive to always arrive at a stop just before the competitor. However, Van Reeven and Janssen (2006) develop a model of short and long distance operators showing that a greater scope for quality differentiation on inter urban travel diminishes incentives for competing in frequency, arrivals at stops, respectively. Hence, destructive competition is less likely for long distance bus travel. In general due to a higher impact of price and quality parameters compared to customers' waiting (and transfer) cost it seems intuitive that interurban bus competition is more functional.

However, markets for interurban bus travel are not generally liberalized in EU-countries. There exists basically two forms of market organization: Authority initiative and market initiative route planning. In Spain for example the authority controls transport services and tenders private concessions for bus routes. Great Britain, Sweden, Norway, Italy and Poland have liberalized their markets, while Germany and France have strong regulation regimes preventing most of the interurban bus services in practice. There exist various forms of regulatory interventions that may limit free market access (see Van De Velde, 2010). This includes requirements like not allowing parallel services or the protection of the government-financed railway system.

By liberalizing bus and railway markets, competition between transportation companies on different transport modes evolves. Key difference between intermodal and intramodal competition regarding the aspects considered here is that bus companies other than railway companies do not need to make use of the existing and costly rail infrastructure network.[2]

As not in every European country the regulatory regime allows for intermodal competition on interurban transport, policy makers must have concerns about liberalization. However, existing literature offers few possible arguments against deregulation of long distance buses. Studies mainly focus on pricing decisions of active market participants.[3] There has been some research into complicated networks with varying degrees of connectivity. Economides and Salop (1992) show that competition among producers of complements like operators of serial links leads to higher prices than a single monopoly. However, the effect of introducing a product that is a substitute to one and a complement to another of the competitor's products is not considered. More recently there have been a number of studies that have applied the analysis to policy decisions, such as studies on computer operating systems (Gisser & Allen, 2001; McHardy, 2006) and video games (Clements & Ohashi, 2005). Gabszewicz, Sonnac, and Wauthy (2001) consider price equilibria where products are each indivisible but their joint consumption results in a higher utility than the sum of the utilities when the products are consumed in isolation. There is also a history of such analysis in the transport literature like Else and James (1994) look-

[2]Buses need to make use of roads, of course. However, different to rail tracks roads do not primarily serve inter urban buses and hence can in our framework be taken as given and financed. In road networks individual (and freight) traffic dominates such that inter urban bus transport does not have a significant impact on network cost and hence charges (e.g. in case of highway tolls).

[3]For example, the classic contribution of Braeutigam (1979) shows that when infrastructure costs are financed by Ramsey pricing, welfare optimizing prices depend on cross-price elasticities (even of stand alone competitive transport modes). Extensions of this work like Zhang, Levinson, and Zhu (2008); Liu, Guo, and Yang (2008) focus on optimal prices in intermodal transport systems taking congestion into account. Empirical findings of existing intermodal competition scenarios analyze the degree of substitution dependening on policy settings and demand systems (Roman, Espino, & Martin, 2010; Friederiszick, Gantumur, Jayaraman, Röller, & Weinmann, 2009; Adler, Pels, & Nash, 2010).

ing at railways, and McHardy and Trotter (2006) considering airlines. Nevertheless, this literature focuses on pricing effects.

To the best of our knowledge papers analyzing possible effects of intermodal competition on some routes within an existing infrastructure network for one mode of transportation does not exist. Due to different service requirements of interurban buses and railways i.e., the need for rail tracks and stations, financing this infrastructure is crucial. Hence, rail-service operators have to pay considerable service charges to use the rail infrastructure. However, the infrastructure manager can cross finance some routes with revenue from other routes. This might especially be the case for feeder lines that are not individually profitable. These tracks have positive external effects for the attractiveness of other tracks. When charging infrastructure these external effects can and will be taken into account. Thus, overall not the individual routes but the infrastructure network as a whole has to be profitable. The same argument applies on the transportation level for transport companies and their served railway system. That is to say not every offered transport service on an certain route has to be be beneficial, but the served network of connections as a whole needs to be profitable. Thus, it might be reasonable to provide connections whose revenue does not cover the respective infrastructure charges. Thereby an external network effect on the transportation level is established. Moreover, the amount of service (e.g. in terms of frequency) determines access charges. Hence, for rail transport companies providing additional services reduces the costs of all existing services. To analyze consequences of this effect when intramodal competition develops, we study a stylized model of a monopolistic railway company serving a network of connections. When allowing for interurban bus travel competition between train and bus travel on one connection is established. We show that due to introduced competition rail service not only on this connection but also on routes that are not facing any competition can become unprofitable such that these routes are abandoned. In an extreme case intermodal competition is able to endanger the whole railway network. This effect has to be taken into account by policy makers when considering liberalization long distance bus markets.

The paper is structures as follows. In the next section we will present the developed model and results. Section 3 discusses determinants of this effect, scope for analyzing consequences for policy advice, and some implications. Section 4 concludes.

2 The Model

Transportation services can be differentiated by different modes of transportation and different routings that connect origins with destinations. A railway or bus company can transport passengers via different cities including the need for transfer, or offers direct nonstop service. These differentiated services yield different cost of operation to the firms and provide different levels of satisfaction to customers. The object of this paper is to analyze how different modes of transport affect the optimal route and network service. Our approach tries to identify the effect of liberalization of inter urban bus transport on the profitability of rail networks in a stylized model designed to capture the essentials of the problem.

Let's consider a simple existing railway network connecting the three cities X, Y, an Z, where Y is on the way from X to Z. Suppose inter urban rail tracks connect the cities X and Y as well as Y and Z. Customers are able to travel on route 1 from X to Y, on route 2 from Y to Z as well as directly from X to Z on route 3. Figure 1 illustrates this railway network connecting the three cities. However, we assume that for transport from X to Z the tracks (and trains) of connections 1 and 2 are used and the railway company serves only inter urban trains from X to Z stopping at Y that all customers use.

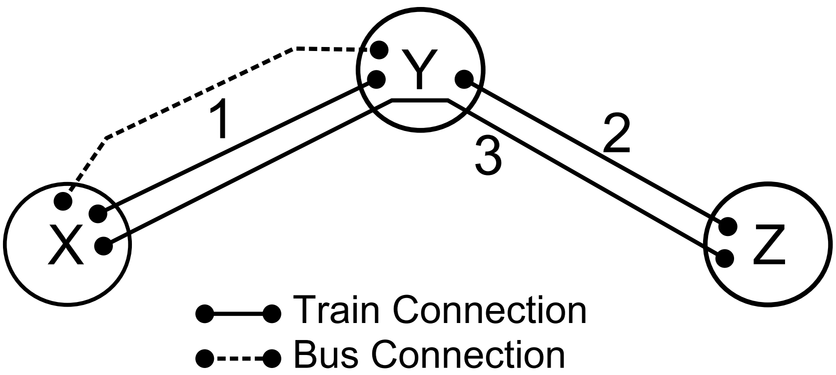

Figure 1: Network structure.

To analyze the demand effect of the provided network, we build on the established passengers' demand approach of Shy (1996, pp. 443). Suppose that each consumer's utility from traveling route i for price p_i is given as

$$U_i = A_i - p_i \quad \forall i \in \{1, 2, 3\}$$

for a mass of n_i potential consumers willing to travel each of the offered routes. Hence, each potential consumer's willingness to pay is given by A_i. To secure reasonable preferences, $\max\{A_1, A_2\} \leq A_3 \leq A_1 + A_2$ holds. The utility function results in discrete choice demand d_i given as:

$$d_i(p_i) = \begin{cases} n_i, & \text{for } p_i \leq A_i, \\ 0, & \text{else.} \end{cases}$$

This established way of modeling allows to identify potential external effects within a network. However, supply by one monopolist instead of several competitors does not result in a dead weight loss. Hence, the model does not allow for reasonable welfare analyzes, which is not purpose of this paper. Nevertheless, as long as under monopoly all routes are supplied, an economy's willingness to pay exceeds the cost of operation such that closing down railway tracks can never be socially beneficial if these tracks are voluntarily operated by the monopolist.

Regarding transportation services it is a well established fact, that due to the network structure, the railway technology is exhibiting economies of scope, i.e., the cost of operation of a firm providing connections between all three cities is lower that the sum of costs of three individual firms, each offering a direct connection between two cities. Thus, we assume that only one rail company is providing transport service on the respective network. This monopolistic rail company is facing variable costs c_i and fixed cost F_i for providing service on a physical track, such that no additional fixed costs occur for serving route 3 from X to Z.[4] These costs are captured in F_1 and F_2. We suppose that $A_i > c_i \forall i$ and total railway costs are lower than total benefits such that the operation of the rail network is principally profitable. The firm will optimally choose $p_i = A_i \forall i \in \{1, 2, 3\}$ (with $\max\{p_1, p_2\} \leq p_3 \leq p_1 + p_2$) such that all consumer surplus is detracted and profit Π of the firm – equaling welfare W – is given by

$$\Pi = W = \sum_{i=1}^{3} n_i(A_i - c_i) - F_1 - F_2, \tag{1}$$

which is positive by assumption.

Let's now suppose market entry of a bus company with buses operating on route 1 from X to Y at variable cost $c_1^b < c_1$ and fixed cost F^b (see figure 1). Thus, these buses are competing with the trains. However, due to lacking quality compared to the train, customers prefer traveling by rail such that utility for bus travel at price

[4]Note that with this way of modeling an integrated railway company as well as a separated transport company can be illustrated. As already describes in the introduction the argument of external effects of some routes on others applies on the transportation level for transport companies and their served railway system as well as on the infrastructure managing level.

p_1^b of consumers willing to travel route 1 is given as

$$U_1^B = \beta_k A_1 - p_1^b = A_1 - p_1^b - (1 - \beta_k)A_1.$$

Hence, $\beta_k < 1$ is the loss of utility for bus travel. For mathematical convenience, define $B \equiv (1 - \beta_k)A_1$.

Due to the lower prices, with the offer of a bus on route 1, also customers willing to travel from X to Z might use the bus from X to Y and change to the train on route 2 to Z, as $p_3 \leq p_1^b + p_2$ might not hold. However, transfer at Y as well as the lower quality bus trip results in losses of utility and thus lower willingness to pay compared to the direct travel by train. Let's assume transfer reduces consumers' willingness to pay by an amount of T, while using the bus on route 1 imposes the same decrease for these customers as for travelers only riding from X to Y, i.e. B. Thus,

$$U_3^B = A_3 - T - B - p_1^b - p_2.$$

Note that with competition on one connection only, rail prices need no longer necessarily suffice $p_3 \leq p_1 + p_2$ such that traveling by train on route 1 and 2 and transferring at Y could in principal be optimal over traveling on connection 3 without transfer. The rail company could set $p_1 < p_1^b + B < p_3 - p_2$ to detract route-1-customers from the bus. However, it can never be optimal for the railway company to set a price p_3 such that $p_3 > p_1 + p_2 + T^t$ with $T^t > 0$ as additional cost for not booking the direct connection[5] as this forces route-3-customers to incur transfer costs T^t resulting in a lower willingness to pay and thus revenue for the company. Hence, in equilibrium $p_3 \leq p_1 + p_2 + T^t$ always holds.

In equilibrium service on route 1 will be offered either by the bus or the rail company. Thus, we would have to distinguish different cases of parameter combinations yielding the respective outcomes. However, for the intended analysis of this paper, it is sufficient to consider the case of $c_1 > \beta A_1 > c_1^b$. In this instance, the rail company cannot compete with the bus as the later can always set a profitable price p_1^b below the train operator's variable costs. In practice this might be the case for connections where the rail track is rather costly to operate e.g. due to detours, ascending and descending slopes or other disadvantages compared to the road link. This case also considers that kind of routes where a bus company most reasonably enters the market as these routes provide the best perspective for gaining profits.[6] Price in equi-

[5]These additional cost could be real cost of transfer if such a transfer is possible or just the additional transaction cost of needing two different tickets.

[6]This also shows why full liberalization of interurban buses will only lead to market entry on some links such that rail companies don't face up to intermodal competition on all connections.

librium is thus $p_1^{b*} = \beta A_1$. The overall demand for bus travel depends on whether route-3-customers are willing to use the combined bus-train-transfer-connection and thus on prices p_2^* and p_3^*. However, in equilibrium there are no customers traveling on route 1 by train.

Nevertheless, it might not be profitable for the rail company to abandon the tracks of this route to save on the fixed costs F_1 while shutting down the track would also force route-3-customers to use inter urban buses and transfer to rail service at Y. In the following we initially analyze the case where abandoning a track is not profitable.

On connection 2 not only route-2 but also route-3-customers might travel due to the low priced bus offer on route 1. However, it is never optimal to set a price $p_2 \neq A_2$. A price lower than customers' willingness to pay to detract customers from route 3 can not be beneficial for the rail company as these route-3-customers suffer additional losses in utility by this transfer connection which reduces the firm's possible revenue. Hence, $p_2^* = A_2$ and demand depends on prices p_1^{b*} and p_3^*.

Consumers willing to travel from X to Z can principally choose between two different alternatives: The direct rail connection or using a combination of bus and train with transferring at Y. Utility of these customers is given as $U_3 = A_3 - \min\left\{p_3, p_1^b + p_2 + B + T\right\}$. However, with $p_1^{b*} = \beta A_1$, for the rail company setting $p_3^* = A_3$ is still an equilibrium as $A_3 < \beta A_1 + p_2 + B + T = A_1 + A_2 + T$ is always fulfilled by assumption such that $d_3 = n_3$ and customers are not making use of the combined connection.

In this case it in not profitable for the rail company to abandon the tracks of route 1 to save on the fixed costs F_1 as these costs are financed by customers on route 3.

The following lemma results:

Lemma 1. *Market entry of a bus company on route 1 with $c_1 > \beta A_1 > c_1^b$ leading to an equilibrium where the rail company does not abandon tracks is given by prices $p_1^{b*} = \beta A_1$, $p_2^* = A_2$, and $p_3^* = A_3$. This yields equilibrium demand for the individual routes of $d_1^{b*} = n_1$, $d_1^* = 0$, $d_2^* = n_2$, and $d_3^* = n_3$. Then, the bus company realizes profit $\Pi^b = (\beta A_1 - c_1^b)n_1 - F^b$ while the rail company's profit under competition is*

$$\Pi^c = \sum_{i=2}^{3} n_i(A_i - c_i) - F_1 - F_2. \tag{2}$$

All consumer surplus is detracted to the firms.

This is captured in the presented model by no perspective for interurban buses on route 2.

The railway company's profit under bus competition is strictly smaller than profit without bus competition (1) and it might even be negative. Thus, for the rail company it might generally be beneficial to abandon one track or even the entire network and we will in the following relax the assumption above of abandoning a track not being profitable. As connection 1 is no longer individually served by train, it is natural to consider abandoning the respective track to save on fixed costs F_1. Abandoning the track would result in that all route-3-customers either refrain from traveling at all or need to take the bus on route 1 and transfer to train 2 at Y. Customers are willing to do that if $A_3 - p_1^b - p_2 - B - T \geq 0$. This is not fulfilled for $p_1^{b*} = \beta A_1$ and $p_2^* = A_2$. Hence, abandoning track 1 resulting in no traveling of route-3-customers is optimal when the rail company's profit with $p_1^{b*} = \beta A_1$ and $p_2^* = A_2$ and $d_3 = 0$ results in higher profits than before, i.e. if $(A_3 - c_3)n_3 < F_1$, and lower profits than in case of reduced prices.

Otherwise, the rail company, the bus company or both firms might lower their prices such that route-3-customers are served when rout 1 is abandoned, i.e., $p_1^b + p_2 = A_3 - B - T$. With the companies cutting prices, a continuum of equilibria within certain bounds can result.[7] Following the arguments and assumptions above for an equilibrim $p_1^{b**} \in [c_1^b, \beta A_1]$, and $p_2^{**} \in [c_2, A_2]$ have to be fulfilled. Additionally, lowering prices beneath the willingness to pay of customers traveling the respective section has to be beneficial for the firms, i.e. gains in profit due to attracted customers have to overcompensate for lower revenues per customer. Thus, $\Pi^b(p_1^{b**}, p_2^{**}) \geq \Pi^b(p_1^{b*}, p_2^{**}) = n_1(\beta A_1 - c_1) - F^b$ and $\Pi(p_1^{b**}, p_2^{**}) \geq \Pi(p_1^{b**}, p_2^{*}) = n_2(A_2 - c_2) - F_2$. Besides, equilibrium profit of the bus company given by $\Pi^b(p_1^{b**}, p_2^{**}) = (n_1 + n_3)(p_1^{b**} - c_1^b) - F^b$ need to be nonnegative while profit $\Pi(p_1^{b**}, p_2^{**}) = (n_2 + n_3)(p_2^{**} - c_2) - F_2$ for the rail company must also be higher than before.

Altogether, the following lemma characterizes the corresponding set of equilibria:

Lemma 2. *An equilibrium featuring the rail company abandoning track 1 results under new prices p_1^{b**} and p_2^{**}*

1. *such that route-3-customers refrain from traveling for*

    (i) $p_1^{b**} = \beta A_1$ *and* $p_2^{**} = A_2$,

    (ii) $(A_3 - c_3)n_3 < F_1$

[7]With $p_2^* = A_2$ the bus company might even have an incentive to deviate to $p_1^{b*} = A_3 - A_2 - B - T$ if the resulting decline in margin is overcompensated by increase in demand, i.e. $n_1(\beta A_1 - c_1^b) < (n_1 + n_3)(A_3 - A_2 - A_1(1-\beta) - T - c_1^b) \Leftrightarrow \frac{n_1}{n_3} < \frac{\beta A_1 - c_1^b - 1}{A_1 + A_2 - A_3 + T}$. The bus company's profit becomes $\Pi^b = (n_1 + n_3)(A_3 - A_2 - B - T - c_1^b) - F^b$ while the rail company's profit would be $\Pi^c = (n_2 + n_3)(A_2 - c_2) - F_2$ as track 1 is no longer in use and will be abandoned.

(iii) $n_2(A_2 - c_2) - F_2 > 0$ *and* $n_2A_2 > (n_2 + n_3)p_2' - n_3c_2 \forall p_2' \in [c_2, A_2]$

2. *such that this connection is substituted by bus travel for*

   (i) $A_3 - B - T - p_1^{b**} - p_2^{**} = 0,$

   (ii) $p_1^{b**} \leq \beta A_1$ *and* $p_2^{**} \leq A_2,$

   (iii) $n_3(p_1^{b**} - c_1^b) - n_1(\beta A_1 - p_1^{b**}) \geq 0$
   $\Leftrightarrow p_1^{b**} \geq \frac{n_1\beta A_1 + n_3c_1^b}{n_3+n_1}(\in [c_1, \beta A_1]),$

   (iv) $n_3(p_2^{**} - c_2) - n_2(A_2 - p_2^{**}) \geq 0$
   $\Leftrightarrow p_2^{**} \geq \frac{n_2A_2+n_3c_2}{n_2+n_3}(\in [c_2, A_2]),$

   (v) $p_1^{b**} \geq c_1^b + \frac{F^b}{n_1+n_3}$ *and* $p_2^{**} \geq c_2 + \frac{F_2}{n_2+n_3},$

   (vi) $(n_2 + n_3)(p_2^{**} - c_2) - F_2 \geq +n_2(A_2 - c_2) + n_3(A_3 - c_3) - F_1 - F_2$
   $\Leftrightarrow p_2^{**} \geq \frac{n_2A_2+n_3c_2}{n_2+n_3} + \frac{n_3(A_3-c_3)-F_1}{n_2+n_3}.$

To see, that these conditions specify a nonempty set of equilibria also for the second case, consider the special cases of only one company lowering its price compared to the case of all tracks remaining active. For example, an equilibrium results when only the rail company's price is marked down to $p_2 = A_3 - \beta A_1 - B - T = A_3 - A_1 - T$ while $p_1^{b*} = \beta A_1$ remains. This is profitable if

$$\Pi(p_1^b = \beta A_1, p_2 = A_3 - A_1 - T) = (n_2 + n_3)(A_3 - A_1 - T - c_2) - F_2$$
$$> (A_2 - c_2)n_2 - F_2 = \Pi(p_1^b = \beta A_1, p_2 = A_2).$$

With $(A_3 - c_3)n_3 < F_1$ this is the case if $(n_2 + n_3)(A_3 - A_1 - T) - n_2A_2 - n_3c_2 = n_2(A_3 - A_2 - A_1 - T) + n_3(A_3 - A_1 - T - c_2) > 0$ which is unsurprisingly fulfilled for rather small T and c_2 and large F_1.

Accordingly, an equilibrium could results when only the bus company lowers its price to $p_1^b = A_3 - A_2 - B - T = A_3 - A_1 - A_2 - T + \beta A_1$ which has to be larger than c_1^b while $p_2 = A_2$. This is profitable if

$$\Pi^b(p_1^b = A_3 - A_2 - B - T, p_2 = A_2) = (n_1 + n_3)(A_3 - A_2 - B - T - c_1^b) - F^b$$
$$> (\beta A_1 - c_1^b)n_1 - F^b = \Pi^b(p_1^b = \beta A_1, p_2 = A_2),$$

which is the case if $n_1(A_3 - A_2 - A_1 - T) + n_3(A_3 - A_2 - B - T - c_1^b) > 0.$

Under these conditions, as a result of the introduced intermodal competition, the rail company shuts down track 1. Due to the specified preferences, this is also socially beneficial. Moreover, as firms might want to keep route-3-customers prices are lowered beneath some customers' willingness to pay. This is true for the second case of Lemma 2. Here, as both companies wish to keep the common customers, individual customers benefit and welfare gains are redistributed to consumers. Different to before, not all consumer surplus is detracted to the firms. This result can be summarized in the following corollary:

Corollary 1. *Market entry of inter urban buses competing on a few routes against trains within an established railway network can lead to unprofitable train service on these routes and thus to abandoning these tracks. This can be accompanied by redistribution of welfare gains to the customers.*

This result is not very surprising as inter urban bus travel might be – and in this case indeed is – more efficient than train travel. However, we will show in the following section, that this result can have drastic consequences for the railway network as a whole.

In case of nonexistence of equilibria of the type of proposition 1, it might be the case, that due to bus competition the rail company can no longer gain profits in the market, no matter whether track 1 is abandoned or not. According to the arguments above the following lemma characterizes the resulting equilibrium conditions:

Lemma 3. *An equilibrium where the rail company exits the market results for*

(i) $\Pi^c = \sum_{i=2}^{3} n_i(A_i - c_i) - F_1 - F_2 < 0$,

(ii) $\Pi(p_1^{b**}, p_2^{**}) = (n_2+n_3)(p_2^{**}-c_2)-F_2 < 0 \quad \forall\, p_2^{**} = A_3 - B - T - p_1^{b**}$ *with* $p_2^{**} \in [\max\{\frac{n_2A_2+n_3c_2}{n_3+n_2}, c_2 + \frac{F}{n_2+n_3}\}, A_2]$ *and* $p_1^{b**} \in [\max\{\frac{n_1\beta A_1+n_3c_1^b}{n_3+n_1}, c_1^b + \frac{F^b}{n_1+n_3}\}, \beta A_1]$, *and*

(iii) $n_2(A_2 - c_2) - F_2 < 0$.

To see that this is a nonempty set of equilibria, consider the railway company not changing its price, i.e. $p_2^{**} = A_2$. This yields that the train company will no longer be profitable if $(n_2 + n_3)(A_2 - c_2) - F_2 < 0$. If this is fulfilled condition *(iii)* will also hold and condition *(i)* is satisfied for a large set of parameters, especially for rather small n_2, n_3, and A_2 and high cost parameters c_2 and F_2. If on the other side the bus company sticks to its price, i.e. $p^{b**} = \beta A_1$ such that $p_2^{**} = A_3 - A_1 - T$, the train company will not be able to gain any money if $n_2(A_2 - c_2) - F_2 < 0$ and $(n_2 + n_3)(A_3 - A_1 - T - c_2) - F_2 < 0$. As $A_3 - A_1 < A_2$ simultaneous fulfillment of both conditions is possible for a extensive set of parameters. This is the case for A_2 and hence $A_3 - A_1$ being rather small, large F_2 and T and small n_2 and n_3.

For assessing characteristics that increase the likelihood of the rail company existing the market we consider the special case where this company does not change its price, i.e. it achieves the most profitable outcome of the bargaining game, and still needs do leave the market. This is case for

(i) $n_2(A_2 - c_2) + n_3(A_3 - c_3) - F_1 - F_2 < 0,$

(ii) $(n_2 + n_3)(A_2 - c_2) - F_2 < 0,$

(iii) $n_1(A_1 - c_1) + n_2(A_2 - c_2) + n_3(A_3 - c_3) - F_1 - F_2 > 0$

as by assumption the company was gaining profits before entry of the inter urban bus. Ignoring the rather weak constraint (i), it is necessary that

$$n_1(A_1 - c_1) + n_3(A_3 - A_2 - c_3 + c_2) - F_1 > F_2 - (n_2 + n_3)(A_2 - c_2) > 0 \tag{3}$$

holds. This shows that market exit is likely for high but not too high fixed costs for track 2 and small but not too small margins of route 2. Besides, a rather high contribution margin $n_1(A_1 - c_1)$ of customers traveling on connection 1 increases the likelihood of a breakdown of the network. Additionally, given an extensive contribution margin of route 1 high fixed cost and low contribution margins of the other routes work on this likelihood in the same way.

To illustrate conditions under which the above equilibrium evolves, figure 2 depicts the conditions of the presented special case where the rail company does not change its prices.

The graphs show that very different characteristics of equilibrium conditions are possible and straightforward comparative statics can not be done. For instance, a higher margin on route 3 might change the conditions for a market exit of the rail company drastically yielding adverse effects of increasing fixed costs or numbers of passengers on the chances of a network collapse.

The figure also illustrates that the effect of a subsidy to the rail industry to compensate for the extra competition is not clear. This subsidy might be the absorption of maintenance costs reducing the effective fixed cost for the company. The graphs show that a reduction of F_2 does not necessarily reduce the likelihood of a breakdown of the railway network. In can even facilitate such a collapse.

The main result of the presented analysis is summarized in the following corollary:

Corollary 2. *Within an established railway network with every track being profitable, competition on just some tracks can result in a collapse of the entire network.*

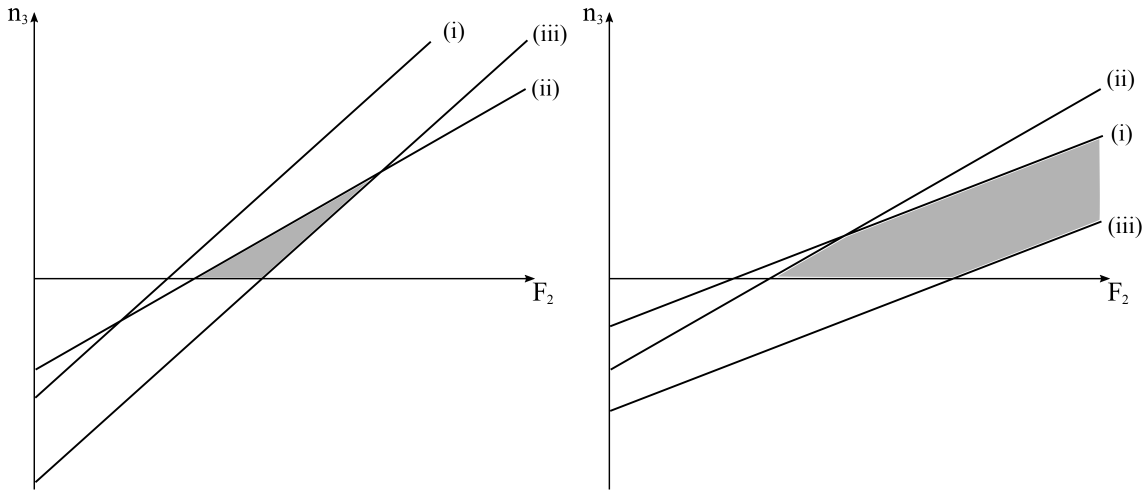

Figure 2: Possible equilibrium conditions for the rail company exiting the market after achieving the most profitable outcome of bargaining game. The right figure illustrates a higher margin $A_3 - c_3$ on route 3.

In conclusion, introducing intermodal competition to existing railway service on just a few routes can lead not only to decreasing profitability of the respecting train connection but of other routes as well. This is caused by existing network effects. These positive external effects of individual routes or partial networks on other routes, parts of or the entire railway network are important for the profitability of the entire network. Combinations of connections are seen as complements to each other by groups of customers. Some connections might be feeder lines for others. Thus, when some connections are becoming less attractive for customers the entire railway network does. All routes are important to other routes and with decreasing numbers of customers on some routes external effects diminish. As a consequence, all routes become less profitable when one route does. Depending on the strength of this effect, fewer customers on one connection can trigger a domino effect on the entire network leading in an extreme case to a breakdown of profitability such that the network has to be abandoned.

3 Implications for Further Research and Policy

As stated before, the purpose of the developed model is to show the possible existence of external network effects when competition comes partially up to an already existing network industry with substantial fixed costs. In particular, the effect can become relevant when bus competition is introduced, while a railway network already serves the routes where bus operators enter the market. This development is currently imminent in Germany and other European countries, where interurban bus service is going to be deregulated.

A core objective of our research is to discern implications for policy makers, regarding particularly the case of bus liberalization. In practical use, our research shows the difficulty of deriving welfare effects of such a competition scenario. Our findings show that a forecast of liberalization effects is not an isolated competition game between transport modes on the affected route. Instead external network effects have to be taken into account. The consequences are depending on the strength of the external network effects and the resulting welfare effects in a specific case. Note that the mere existence of those network effects are not a general argument against intermodal competition. Negative welfare effects might be more or less an edge case, unlikely to occur, so that further research is necessary.

According to our findings, the external network effect is triggered by quality deteriorations on the railway connection which is directly threatened by bus competition. Caused by bus entry, the reallocation of fixed costs on this route can lead to unprofitability of the old rail service level. Subsequently the railway company is forced to change its quality level, which is represented by abandoning this route in our model.[8] Out of this, it is possible to derive some easy indicators for the probability of the external network effect by using a two-step approach: At first, there are determinants for the risk of quality deteriorations, directly caused by bus competition on a specific route. Based hereon, there are further determinants for the "infection" of other routes.

Regarding measurement of both risks, it is clear from the derived results that a rather high demand and willingness to pay and rather low cost of operation prevent from negative consequences for the profitability of all affected routes. There are other useful indicators for quality deteriorations of train connections on routes which are directly threatened by the bus:

- While it is a reasonable presumption that the affected railway track was profitable before the bus enters the market, it's obvious that a high share of travelers who are not traveling only this route prevents quality deteriorations for the railway connection on this route. For instance that is the case when a regional railway connection has a more trans regional character.

- Furthermore our analysis shows, that high costs for transfer between bus and train at an interchange point decrease the risk for quality deteriorations on

[8] In a more complex modeling, more types of quality deteriorates are conceivable, for instance a thinning out of connections.

that track. In practice these costs depend for instance on the distance of bus stop and train station.

- Finally, when only few customers switch from rail to bus travel and most of the potential bus travelers are using different transportation modes, the effect on the railway network will be rather weak. Thus, the more a connection is characterized by certain supply and demand forms determining a relatively high attractiveness of bus travel, the higher is the probability that the route is negatively affected.

If there are quality deteriorations on one directly affected route, more connections are threatened indirectly under the following condition:

- If the route facing intermodal competition has a large share of travelers using further network connections, the resulting network effects are rather high. A connectivity ratio could be measured as the ratio of travelers who only travel the route which is affected by competition to those travelers on other routes, which are only in a relation to the first one (in the example: route 1 travelers to route 2 and 3 travelers).

In aggregation, it is possible to analyze characteristics of the market increasing the likelihood of a breakdown of the railway network after market entry of a bus company. From the set of possible equilibria in Lemma 3, we therefor consider the one where the rail company charges the highest possible price and a market exit is ex ante most unlikely. In that case equation (3) gives the relevant necessary conditions for the breakdown of the railway network. It is clear, that a high total contribution margin of connection 1 increases the likelihood of the rail company existing the market. The effect of other parameters is not obvious per se.

However, there is very limited scope to present precise advice for policy makers about the appropriate way of dealing with the demonstrated external network effect. The derived results are based on a simple framework which does not allow for further analyses like the strength of such effects or consequences on consumer surplus and welfare. More sophisticated modeling implies significant increases in complexity is left for future research. To present some outlook, the presented model can be extended to a framework of consumer behavior allowing for welfare analysis. This could be done by introducing a demand model of vertical differentiation.

Besides a theoretical extension of our model, empirical research could be used to determine the practical relevance of the shown effects. Regarding practical knowledge, the direct causality of abandoning of a railway track induced by intermodal competition is very difficult to measure. However, this case seems to be very unusual to observe. One reason might be that railway infrastructure is usually cross-financed from public funds. This cross financing might force the track operator to maintain the whole railway network. Political actors can increase the subsidies to maintain all railway tracks in the long run despite profitability losses due to intermodal competition. Thus, the elaborated network effect might also induce some kind of rent seeking behavior of the railway company. This could result in extended subsidy funding. Conclusions from an analysis of the extent of rent seeking and other suggested research could be very useful for policy advice.

4 Conclusion

In this paper we have developed a stylized model designed to capture effects of introducing intermodal competition to some routes within an established railway network. We have shown that external effects of individual routes of the network are fundamental for the profitability of the network as a whole. Thus, weakening these network effects can be crucial. As a result, efficient intermodal competition on some routes might cause the abandoning of other routes that are not facing any competition. This effect has to be taken into account by political actors when considering liberalization of inter urban bus travel as it is currently discussed in Germany and other European countries.

However, the derived results are based on a simplistic framework that does not allow for further analyzes like the strength and determinants of such effects or consequences on consumer surplus and welfare. In order to measure the relative impact of the effect in practice, moreover evidence is necessary. Building upon our framework, more sophisticated modeling and empirical research could lead to more precise policy advice, related to opening regulated interurban bus markets for competition.

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