ISSN 2281-4299

Dipartimento di Ingegneria informatica automatica e gestionale Antonio Ruberti

Sapienza
Università di Roma

How disruptive business models with limited capacity impact on long-haul transport markets: social welfare implications

Alessandro Avenali
Martina Gregori
Pierfrancesco Reverberi

Technical Report n. 2, 2021

How disruptive business models with limited capacity impact on long-haul transport markets: social welfare implications

Alessandro Avenali[1], Martina Gregori[2], Pierfrancesco Reverberi[3]

Abstract:

For long in Europe the policy makers tend to foster railways services on road services in the long-haul passenger transport market. In recent years, numerous European countries started processes for coach markets liberalisation (UK, Germany, Italy, etc.), pushed by EC directives, with the aim of enhancing the service quality through competition.

Even if competition led to important improvements on railways services quality, it was observed that made it difficult, especially for niche open-access rail operators, to survive (e.g. in Germany). Recently new entrants characterised by bus-based disruptive business models (e-Platform Bus Service Retailers, e.g. Flixbus, BlaBlaBus) are challenging the incumbents rail operators, applying judo economic strategies. The new market structure can be theoretically modelled, and its attributes studied to verify the potential in jeopardising the overall social welfare optimisation. The new competitive relationship is analysed in two steps. It is proposed a theoretical model à la Hotelling to perform social welfare analysis; it is then run a series of numerical simulations calibrated on a real case study (to validate the results while relaxing part of the first step assumptions; through R). Results(from both steps) confirm that PBSRs could threaten the (incumbents) rail operators economic profitability, ultimately forcing them to leave the market, thus jeopardising overall demand satisfaction. Policies applying compensating treatment between the competitors are proven to be effective in improving social welfare.

Keywords:
intermodal competition, long distance, e-Platforms, coach transport, judo economics.

Corresponding author:
Martina Gregori, PhD student

[1] DIAG, Sapienza University of Rome (*avenali@diag.uniroma1.it)*
[2]DIMA, Sapienza University of Rome and DIAG, Sapienza University of Rome (*martina.gregori@uniroma1.it)*
[3] DIAG, Sapienza University of Rome (*reverberi@diag.uniroma1.it)*

1 Introduction

The European long-haul passenger mobility markets are currently facing substantial changes. New entrants characterised by disruptive business models are challenging the incumbents, applying judo economic strategies. The new market structure can be theoretically modelled, and its attributes studied to verify the potential in jeopardising the overall social welfare optimisation.

Traditionally, European policy makers tended to favour railways services over road services, recognising subsidies to rail operators and/or applying restrictions on intercity bus services activation. As a result, intercity bus services' role used to be mainly complementary (qualitatively and/or quantitatively) rather than competitive, and the markets often presented railways operators in monopolistic-alike positions. Recently, several European countries deregulated their national intercity bus markets, gradually introducing intermodal competition in the sector. Early cases of national liberalisation are in the UK, Sweden and Norway, with bus companies free to choose routes, frequencies and fares (Beria *et al.*, 2014). More recent are, for example, the cases of Germany and France (Beria and Bertolin, 2019), where long-haul bus transports passed from an unknown niche to cover a meaningful role in the intermodal competition (e.g. not more than 5% of the overall German long distance market share, and virtually not existent coach alternative in the French market).

Italy started the liberalisation process as far as 2005 reaching a full implementation only by 2014; even before the deregulation, the coach services in the country had a meaningful role in assuring connections to areas scarcely populated and/or with poorly infrastructures. A significant issue related to the Italian long-haul passenger market is the uncertainty in regulation that lead in some cases to a not clear distinction between market services and public service obligations[4]. This could result in undesirable situations for which the coach liberalisation could introduce competition on subsidised rail services (Beria *et al.*, 2014).

van de Velde (2009) presents a review of the main regulatory systems active in European countries before the intense deregulations process, which was actively promoted by EU directives (Regulation EC no. 1073/2009).

Most of the European countries currently adopt a competition in the market for the coach services, with way fewer constraints in the service activations (*see Table 3.1*). Spain, Belgium, The Netherlands and Austria still present mechanisms of competition for the market (Bergantino *et al.*, 2019).

The coach market liberalisation was followed in all the countries by traffic growth (Aarhaug & Fearnley, 2016), an increase in the number of routes served, number of operators and frequencies (Knorr & Lueg-Arndt, 2016; Blayac & Bougette, 2017), reduction in prices, improved on-board services (e.g. wi-fi connection).

The introduced intermodal competition also led to relevant improvements in railways service quality, but it also negatively impacted rail operators' profitability. Several studies verified that in

[4] The Legislative Decree 285/2005 states that long-distance coach services are "passenger services […] operated on paths linking more than two regions" (corresponding to NUTS 2; Beria *et al.*, 2018). This definition create for example situation in which geographically longer path are defined as local transport, whereas shorted routes crossing more than two regions are included in the long distance market.

Germany, even though the number of passengers has been increasing in most recent years, railways are facing a revenue decline associated with the parallel competition with coaches (de Haas & Schäfer, 2017). Indeed, it was also observed that the new competition made it especially difficult for niche open-access rail operators[5] to survive (van de Velde & Karl, 2018). Regarding the bus market concentration and the level of intramodal competition, in some European areas (e.g. Germany, France Italy), intercity bus markets could be considered quasi-monopoly, held by companies with strategic advantages[6]. Bus companies historically active in an area, even before liberalisation, present such advantages; the progressive market concentration direction is also due to frequent merges (or take overs) among the operators. However, the companies able to apply a new disruptive business model are the ones that reached the most effective position.

The new business model, disruptive for the traditional transport context, is based on online ticketing multi-platforms that consolidate the offer, making easier the interaction between the two sides of the market: production and demand (Willing *et al.*, 2017). Companies with this business model could be defined as e-Platform based Bus Service Retailer (PBSR). A PBSR does not own any buses and does not hire any drivers. Instead of owning mobility resources, the PBSR holds revenues shared bi-later contracts with (usually) small independent coach companies. The independent coach companies are operating the transport services, while the PBSR is coordinating their offer and presenting to the clients an integrated and seamless system, through unified sales and marketing operations (which also mainly constitute the part of costs internalised by PBSR). The PBSR business model has used internet technology innovations to create more customer-oriented services and has been very successful where adopted (Guihéry, 2019).

Examples of PBSRs companies are Flixbus and BlaBlaBus, which are actually becoming competitors in the European markets.

Flixbus started to operate in 2013, and is currently covering in total more than 2500 destinations in 31 different countries[7] (mainly Europe, but with investments also in the US market). In Germany, the country in which was founded, Flixbus is the leader with a market share of 95%.

On the other hand, BlaBlaBus started operate in 2019 when the company BlaBlaBus took control of the French bus operator Ouibus (previously controlled by the national railways company SNCF). BlaBlaBus recently teamed up with Alsa in Spain and Portugal, National Express in the UK and Marino Bus in Italy (Guihéry, 2019), creating the Europe's largest coach network (300 destinations in 10 countries).

[5] Open-access rail operator stand for rail operators that can freely have access to the infrastructure use to serve specific path, in a situation in which the competition in on the market rather than for the market.

[6] One of the main important aspect correlated to the coach market concentration is the fact that the level of the overall demand could be actually be too low to allow intermodal competition. However, even if the coach market is not contestable, intermodal competition should ensure efficiency (Preston & van de Velde, 2016).

[7] Flixbus official website [www.global.flixbus.com/company/about-flixbus. Accessed on: 09 June 2020]. Since March 2017, FlixMobility also offers a Flixtrain service connecting a selection of routes in Germany (e.g. Hamburg, Cologne, Stuttgart), this introduce for the first time in Germany also a competition on the tracks. (Burgdorf, *et al.*, 2019).

Table 3. 1 Regulation main characteristics of a selection of European countries.

Country	*Years of the deregulation process*	*Competition*	*Rules for opening new routes services and fare restrictions*
UK	1980 *Transport Act*	In the market	New routes allowed with no restrictions *(with the exception of London and Northern Ireland)*
Sweden	1993-1999	In the market	New routes allowed, but PA can still block the establishment. Operators and regional authorities cooperate regarding time-schedules and ticket sales.
Norway	1997-2003	In the market	New routes allowed, PA may impose open routes in underserved regions
Germany	2009-2013	In the market	New routes allowed as long as stops are above 50 km and no (subsidised) regional rail service with one hour journey time exists.
Italy	2005-2014	In the market	New routes allowed if connecting three or more regions, otherwise subject to concession (exclusive or not).
France	2012-2015 *Law Macron (2015)*	In the market	New routes allowed as long as stops are above 100 km *(previously not allowed to operate services on routes covered by the national railway company SNCF; applied public service delegation contracts)*
Spain	1990	For the market *(from 8 to 20 years of concession)*	Fares adapted to a price-cap regulation

Sources: Alexandersson (2010); ART (2017); Grimaldi *et al.* (2017); Fageda and Sansano (2018), Bergantino *et al.* (2019).

The PBSR strategic advantages over traditional transportation companies can be naturally described by the theory of judo economics. Judo economics was initially introduced by Gelman and Salop (1983) to describe a strategy that allows a company to use an opponent's strength to its advantage. An example is the use of credible capacity limitations against large dominant incumbents, which would then find retaliation more expensive than accommodate the entrant. Currently, any advantage generated with a combination of movement (small dimension and agility to anticipate market changes, or act quickly on them), balance (capacity to absorb and contain competitors moves) and leverage (using competitors' strengths against them) can be considered a judo strategy (Yoffie & Kwak, 2002). The application of judo strategies is particularly effective in mature markets against "slow-moving giants", and it is often linked to technological transitions. These two characteristics well adapt to the European long-distance transport market.

The incumbents in the market are railways companies that operated for a long time in the absence of competition, which is also related a tendency to present large dimensions. The railway operators are usually rigid, and their profitability (and sustainability) is sensitive to demand behaviour changes. Railways transport production is characterised by high indivisibility (e.g. high vehicles capacity) and high investments (e.g. fleet acquisition, infrastructure access or construction), which make the offer difficult to readjust in a short time and the activation/survival of service justified only in the presence of a sufficiently high level of demand.

The new entrants in the market are the PBSR companies, for which the investment required to be operative is low, especially in comparison with the competitors (traditional bus companies or railways), while the service characteristics (e.g. small vehicles) and the production costs structure (e.g. not owned fleet), allow for high flexibility (Blayac & Bougette, 2017). PBSRs are also able to apply lower prices compared to rail operators. In general, any significant investment can become a barrier to change, and un-flexible large companies have trouble in matching the same profitability of smaller, cheaper and more flexible competitors (Yoffie & Kwak, 2002).

The liberalisation, which introduced competition in the market, combined with the PBSRs' judo strategies-alike, could make the rail services production less profitable and force the rail operators into reducing their production, or even exit the market (e.g. for different level of initial investments). This effect on the incumbent is more likely under specific circumstances, as it could be an extensive demand diversion towards the new entrants' services.

In this context, we aim to analyse the intercity intermodal competition between traditional rail systems and PBSRs. In particular, our objective is to verify how much and how the rail-PBSR competition impacts operators market shares, demand satisfaction, and social welfare. Concerning demand satisfaction, an important element to consider is the limited overall capacity that bus operators can offer in the market. The limit in capacity could threaten the transport system's ability to fulfil the overall mobility rights (especially if the rail incumbent is forced to reduce/stop the production).

The limitations are related to both technical feasibilities (e.g. minimum headway[8]) and the need to limit road congestion to preserve the service quality for clients.

[8] A minimum headway between two subsequent rides is associated with safety reasons and, most of all, coach stations management and timetable’s reliability control. Bus lines characterised by high frequency have often to face phenomena such as bus bunching and headway instability, which lead to low efficiency,

Indeed, for a bus-based operator could sometimes be difficult to cover with its capacity a high volume of demand, such as the daily demand of a rail-served route. On average, to substitute a train ride could take from 6 to 10 bus rides (depending on the number of wagons), thus requiring a significantly higher frequency, which could sometimes not be feasible (e.g. minimum headway, safety), or convenient (e.g. complicate service and stations management). Moreover, any adjunctive ride does impact congestion on the used shared road infrastructure, potentially reducing the offered level of service (e.g. increasing the users' travel time).

In outline, the main issues we attempt to tackle are: (1) identify the conditions for which the rail incumbent is still able to operate in the market after the PBSR's entrance; (2) analyse the effects generated by rail incumbent loss of profitability and/or exit from the market on-demand satisfaction and social welfare; (3) test possible public policies interventions to mitigate the previous negative effects (if occurred), ultimately verifying the effects of the bus long-haul market deregulation.

The intermodal competition between intercity bus and railway services is being explored by scientific research under multiple points of view; nevertheless, not much attention has been dedicated to the impacts of the PBSR disruptive business model.

To conduct the analysis, we describe the market's competitive relations theoretically. Our formulation is based on *à la* Hotelling horizontal differentiation model. It also includes as distinctive elements the presence of fixed costs for the rail operators (i.e. associated with service activation, while investments are considered sunk) and a constraint on the PBSR operators' production capacity.

In the second step, we run a numerical simulation (coded using the software R, calibrated on a real case study), which allow us to relax some of the previous assumptions and verify if we still obtain similar results.

Notice that the high-speed rail services are excluded from the analysis, as well as connection longer than 300km (or that present a relevant difference with bus services in travel time; Gremm, 2017). These restrictions make sure the considered rail and bus services are sufficiently comparable, and could genuinely represent realistic alternatives.

Results confirm that indeed, under specific circumstances (i.e. parameters' ranges), the bus-market liberalisation, given the activation of PBSRs' services, results have negatively impacted the overall social welfare. Secondly, we tested the efficacy of a compensation treatments policy[9]. The compensation allows the rail operators to operate in the market even in a not economically profitable way (potentially mitigating adverse effects associated with PBSRs' monopolistic behaviour and/or the presence of unsatisfied demand). Results show that there are circumstances for which the application of the policy (enabling the existence of duopoly market settings) is socially preferable to no public intervention (and, thus, a PBSR monopoly setting).

---

low service quality (poor on-time performance and excessive waiting time; Chen *et al.*, 2016) and, in the most severe cases, could even result in the collapse of the service. These phenomena are more likely to happen in a urban context, but they could still have a role also on long-haul distances, on service lines with high demand and dense rides.

[9] The introduction of subsidies to support railways production, financed by taxation of PBSRs' profits.

Applying the numerical simulations, the compensation treatments are confirmed to be able to improve the overall social welfare if the delta between the perceived quality of rail service and the perceived quality of bus service is not too evident. Again, all other things being equal, the compensation policy appears to be more effective as the maximum capacity activated by the PBSR company increase.

Paragraph 3.2 describes previous works carried out in the literature. Paragraph 3.3 and Paragraph 3.4 depicts the proposed theoretical model *à la Hotelling* and presents the results on market composition and profit analysis. Paragraph 3.5 reports the social welfare analysis, detailing how it was run and which results were obtained. Paragraph 3.6 describes how we run the numerical simulations, with which results. Finally, in Paragraph 3.7 we summarise our main findings, discuss limitations and gives indications on possible future research steps.

2. Literature review

According to Beria & Bertolin (2019), despite its importance, the analysis of long-distance transport dynamics and policies has not reached the same understanding of local transport services. In particular, the nature of the coach market liberalisation's effects is still unclear, with relatively few studies showing the associated advantages (van de Velde, 2014). Previous research works dedicated to the interaction between the bus and rail modes on long-distance paths mainly focus on pricing processes (Gremm, 2018; Beria *et al.*, 2018), the evolution of the intramodal long-haul bus market (e.g. network dimension and density on the territory, market concentration, market composition – de Haas and Shäfer, 2017; Blayac & Bougette, 2017; Fageda & Sansano, 2018) and evaluation of the users' willingness to pay for different characteristics of the offered transport services (i.e. surveys, applications of discrete choice modelling; Hasiak *et al.*, 2016; Burgdorf *et al.*, 2018).

The coach markets first expanded with the coverage of the most profitable connections (e.g. between main cities). Indeed, Fageda & Sansano (2018) found that a regressive fare-setting scheme still can be observed, for which low-income cities experience higher prices and lower quality of service (e.g. lower frequencies).

After the liberalisation and the introduction of PBSRs companies business model, there have been found evidence of an initial aggressive pricing strategy, adopted to induce demand for the new services, followed by a progressive increase in fares once the service becomes popular (Blayac & Bougette, 2017; Bertolin & Tolentino, 2019). In Germany and France, there have been observed lower frequencies of bus rides following the market takeover by a single company (de Haas *et al.*, 2017; Blayac and Bougette, 2020).

In general, the intramodal competition inside the coach market seems to be based more on frequencies settings, while the intermodal competition with rail operators is more based on prices (Fageda & Sansano, 2018). Greem (2018) and Beria & Bertolin. (2019) showed how bus fares decrease where train alternative is available (including routes served by high-speed trains). This confirms a reciprocal relationship of influence in pricing between the bus operators and the rail operators.

However, the continuous interaction with the railways systems will lead to a complementary role for the coach market or to service cannibalisation?

Aarhaug & Fearnley (2016) showed that in Norway, a relatively more mature market compared to other European countries ones, express coaches were able to expand without damaging the railways services patronage, thanks to an overall increase in passenger demand. Nevertheless, the central government has gradually increased railways subsidies at a national level (Aarhaug *et al.*, 2018)[10].

On the French market, the presence of strong intermodal competition by comparably cheap high-speed train services, low-cost airlines and carpooling were the main causes for a systematic lack of profitability for the coach operators (Crozet & Guihéry, 2018). On the other hand, in Germany, Gremm (2017) found that railway services seem not to be cannibalised in general by the new competition; however, some connections with distances between 200 and 300 km (for which the two transport services are perceived as a close substitute by the users) do show to suffer from sale losses. In general, the more damaging effects were produced on niche railway operators, for which some market exit had happened (van de Velde & Karl, 2018).

Clearly, the literature does not offer a unanimous position regarding the liberalisation effects; neither drawn clear conclusions on the PBSRs roles on overall social welfare effects. Indeed, the new long-haul European markets layout are still much under development and need to be tackled.

There a few notable works in literature that explicitly modelled the rail versus bus competition. In 2013, Betaille & Steinmetz (2013) developed a IO model finding a significant network effect of liberalisation on rail profitability. They showed as the introduction of intermodal competition on single routes may affect other rail services not directly facing competition by buses, leading to unprofitability that may cause the collapse of the entire network. However, they do not examine possible policy interventions and, due to the earliness of the research, do not consider the PBSRs business model explicitly.

Gremm *et al.* (2019) discuss the entry factors for intercity bus companies and the incumbent railway company's price reactions, considering the German context. The proposed model accounts for horizontal product differentiation (variety) for bus companies' intramodal competition, and vertical differentiation (quality) for intermodal competition, with two-stage equilibrium. The main findings are the tendency for bus companies to operate in niches in which the quality advantage of railways is comparatively slow. Fixed costs or constraints on bus operators' capacity production seem not to be haven taken into account explicitly.

Burgdorf *et al.* (2018, 2019) proposed a system dynamic simulation model[11] to describe the German liberalised long-distance transport market. Interestingly, they tested the effects of two possible policies interventions: a reduction of infrastructure charge paid by the rail operators, and/or an additional road-toll for intercity buses. Both the interventions aim to balance the different infrastructure costs sustained by the competitors, which represent one of the main argument for describing the bus competition as unfair to rail operators. Results show that if reducing the tracks infrastructure charge has a significant positive effect on the rail operators

[10] At the same time, the regional governments have introduced subsidies also for the coach services production. This recognize the relevant role of bus transports in Norway, where geographical conditions make difficult in some areas the implementation of railways infrastructures.

[11] Their system dynamic simulation model integrate three different steps that take into account respectively aggregated demand behaviour, market share distribution and supply process.

market share, the additional toll paid by the bus operators only marginally incentive the use of rail, but it is also associated with a strong negative effect on the demand for road services and may then worse the overall social welfare.

3. The model

We deal with intermodal competition between rail and bus services through a spatial competition model *à la* Hotelling. We consider a single long-distance route as a linear market of unit length, represented by the interval $[0, 1]$. There are two firms in the market, a rail operator (firm r) and a bus company (firm b). We assume that each firm is located at one extreme of the interval, respectively, firm r at point 0 and firm b at point 1 (*see Figure 1*).

There is a continuum of consumers of mass 1 who are uniformly distributed on $[0, 1]$ with unit density. Consumers have unit demand. They receive a gross benefit u^* from using the transport service, whereas their benefit from not travelling is normalised to zero. When purchasing from firm i ($i = r, b$), a consumer x ($x \in [0, 1]$) has to pay the price p_i charged by the firm. Moreover, the consumer incurs a disutility from buying a service that is not the ideal version, namely, does not exactly match her preferences (given by her location on the line segment). Thus, the consumer has a 'mismatch cost' $t_i d_i$ ($i = r, b$), where t_i ($t_i > 0$) is the utility loss per unit of 'distance' from firm i, and d_i ($d_i \geq 0$) is the distance from firm i.

We assume that $t_b = t$, with $t > 0$, and (for simplicity) $t_r = 1$. In doing so, we adjust the traditional horizontal differentiation model by inserting a quality factor that reflects differences between the two transport modes in terms of comfort, on-board services, and travel times. If $t > 1$ (respectively, $t < 1$), then the perceived quality is higher (lower) for the rail service than for the bus service (when $t = 1$, the perceived quality is the same).

Consumers purchase from the firm that provides them with the highest net utility. Let $\hat{x}$ ($\hat{x} \in [0, 1]$) be the indifferent consumer (i.e. the one who gains the same net benefit from buying from either firm). Thus, given that firms have fixed locations, the following condition holds:

$$u^* - p_r - \hat{x} = u^* - p_b - t(1 - \hat{x}) \tag{1}$$

where the LHS in (1) is the net utility of $\hat{x}$ when choosing the rail service, while the RHS in (1) is the net utility of $\hat{x}$ when choosing the bus service.

From (1), we obtain that $\hat{x} = \frac{p_b - p_r + t}{t+1}$. We assume that the market is fully covered. This means that the gross benefit from travelling u^* is high enough that all consumers would prefer to purchase than not. Hence, all consumers x for which $x < \hat{x}$ (respectively, $x > \hat{x}$) prefer to buy from firm r (firm b).[12]

We assume that the two companies have a different cost structure. Thus, the bus company has variable costs (including online platform management, sales operation, marketing and activities for network planning), but negligible fixed costs[13]. On the other hand, the railway company incurs

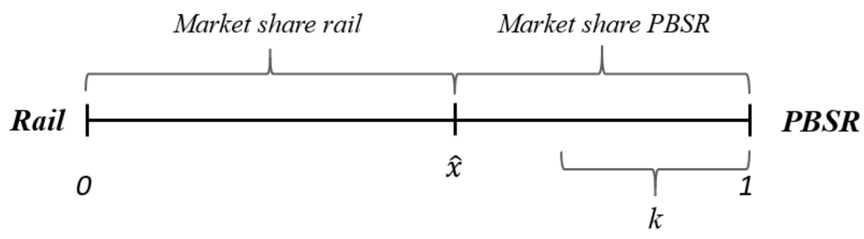
[12] In what follows, we will assume that the gross benefit from travelling is so high that there is full market coverage even in the case of a monopoly of either the railway or the bus company.

[13] The PBSR companies' fixed costs are mainly due to their business development phase. First of all, there are expenses related to the software system first creation. Furthermore, also the marketing costs do include

significant fixed costs independent of the number of rides, which include staff, fleet acquisition and infrastructure costs such as maintenance of rail tracks and stations (network deployment costs are considered sunk). For simplicity, operation costs are assumed to be negligible[14].

Consistent with the cost structure of firms, let c_i be firm i's marginal (per passenger) cost, where $c_b = c > 0$, while c_r is normalised to zero. Moreover, let F_i be firm i's fixed cost, where $F_r = F > 0$, while F_b is normalised to zero. To be profitable, the rail operator must have revenues from sales at least equal to F. Fixed costs are avoidable, so that they are not incurred if the firm ceases production.

Figure 3. 1 Representation of the constrained duopoly linear market



Note: PBSR would serve $(1 - \hat{x})$ *people having enough capacity, otherwise it fix its market share at* k *representing its maximum capacity expressed as percentage of the overall demand.*

Thus, the profit functions of the rail operator and the bus company respectively are:

$$\pi_r = p_r * \hat{x} - F \qquad (2)$$

$$\pi_b = (p_b - c) * (1 - \hat{x}) \qquad (3)$$

We also assume that the two companies have different production capacities. On the one hand, the railway company has no capacity constraints, so that it covers the whole market in case of monopoly. On the other hand, the bus company has a limited capacity k. We assume that $k < 1$, so that, in case of monopoly, some consumers are necessarily left unserved. Depending on the value of k, some consumers may be left unserved by the bus even under duopoly. Indeed, due to the capacity limit, the bus company may not be able to serve the number of users derived from profit maximisation. In such a case, the excess demand for the bus service is covered by the rail operator. When the capacity constraint is binding, under either monopoly or competition, the bus company is said to be *capacity constrained* (see Figure 1).

a (consistent) initial investment. The starting market operations are necessary to support the company entrance on the transportation national markets and, most of all, to assure enough visibility to the platform-services. The brands' image and trust are indeed among the most important assets offered by the PBSRs companies to the bus operators, in the subscribed bi-lateral partnership contracts. However, the described development costs are extensive but limited – if compared with the railways counterpart ones – and affect the running services on the single new-activated route only partially.

[14] The variable costs of the rail operator are considered negligible if compared to the extent of their fixed costs, and in relation to the different influence exercised on PBSRs' structure costs. This assumption allows for a simplification in the social welfare analysis and can be relaxed modifying the model.

For given locations, firms simultaneously choose prices. Thus, the rail operator solves: $\underset{p_r}{max}\ \pi_r$ subject to (s.t.) $\pi_r \geq 0$, where π_r is given by (2); while the bus company solves: $\underset{p_b}{max}\ \pi_b$ s.t. $(1-\hat{x}) \leq k$ and $\pi_b \geq 0$, where π_b is given by (3). In what follows, we determine the equilibrium market structure, depending on model parameters.

3.1 Unconstrained duopoly case

We start examining the unconstrained duopoly market setting as first possible equilibrium. In this case, the capacity constraint on firm b is not binding, meaning that the k threshold is higher than the quantity of demand optimising firm b's profits.

The first-order conditions on (2) and (3) yield the optimal prices:

$$p_{r_{uncons}} = \frac{2t+c+1}{3} \quad ; \quad p_{b_{uncons}} = \frac{t+2c+2}{3} \tag{4}$$

Inserting for (4), the equilibrium market shares for rail and PBSR respectively are:

$$q_{r\ uncons} = \frac{2t+c+1}{3(t+1)} \quad ; \quad q_{b_{uncons}} = \frac{t-c+2}{3(t+1)} \tag{5}$$

where $q_{b_{uncons}} < k$. Therefore, equilibrium profits respectively are:

$$\pi_{r_{uncons}} = \frac{(2t+c+1)^2}{9(t+1)} - F \quad ; \quad \pi_{b_{uncons}} = \frac{(t-c+2)^2}{9(t+1)} \tag{6}$$

The unconstrained duopoly is feasible if a series of conditions on parameters are verified. First of all, to respect the model assumption, the gross benefit of travelling u^* needs to be high enough to allow all consumers to buy a unit of transport:

$$u^* \geq \frac{(2t+c+1)(t+2)}{3(t+1)} \tag{7}$$

Secondarily, we need to assure that all constraints on the formulation are not binding in equilibrium, so that there is an interior solution. Then, in an unconstrained duopoly, both firms make positive profits and the bus has excess capacity. There are a number of conditions for this equilibrium to exist.

First, for the bus company to be active in the market, marginal costs must be sufficiently low. More formally, the following condition must hold (see (7) and (8) below, and the related discussion):

$$c < t + 2 \tag{8}$$

Note that the constraint is tighter (respectively, looser) as long as the unit disutility from taking the bus decreases (increases).

Second, the rail operator is profitable as long as fixed costs are low enough, that is:

$$F \leq \frac{(2t + c + 1)^2}{9(t + 1)} \tag{9}$$

As expected, this constraint is tighter (respectively, looser) as long as the unit disutility from taking the bus decreases (increases), and/or when firm b's marginal cost decreases (increases).

Moreover, an interior solution exists if firm b has sufficient capacity (see 5), that is:

$$q_{b_{uncons}} = \frac{t - c + 2}{3(t + 1)} < k \tag{10}$$

We are now ready to perform some comparative statics on the equilibrium. For this purpose, it is convenient to proceed one step at a time, and begin by considering the benchmark case where firms have symmetric marginal costs.

3.1.1 Benchmark case: Symmetric marginal costs

Assume that firm b's marginal cost is normalised to zero. In such a case, equilibrium prices, market shares, and profits depend solely on t, that is, the unit disutility for taking the bus (recall that, for simplicity, $t_r = 1$).

From (4), we obtain that both prices are increasing in t. However, market shares and profits are decreasing (respectively, increasing) in t for the bus (rail) company. Indeed, $|t - 1|$ measures the quality differential between transport modes. If $t = 1$ then the perceived quality of transport modes is the same, and so are equilibrium prices, market shares, and profits (gross of the fixed costs for the rail operator). Instead, if $t > 1$ then we have that $p_r > p_b$, $q_r > q_b$, and $\pi_r + F > \pi_b$, whereas, if $0 < t < 1$ then we have that $p_r < p_b$, $q_r < q_b$, and $\pi_r + F < \pi_b$. As expected, the company (either the rail or the bus) who provides the 'superior' product charges a higher price, has a higher market share and makes a higher profit (gross of the fixed costs for the rail). Note, however, that both firms are active independent of the value of t.

3.1.2 Comparative statics analysis

Let us now return to the case where $c_b = c > 0$. In such a case, the effects of t on equilibrium prices, quantities, and profits can no longer be evaluated in isolation, since they may interact with the effects of c. First, as to prices, it directly follows from (4) that they increase in both t and c, with $p_{r_{uncons}}$ ($p_{b_{uncons}}$) increasing faster in t (c) compared to $p_{b_{uncons}}$ ($p_{r_{uncons}}$).

Moreover, we have that:

$$p_{r_{uncons}} > p_{b_{uncons}} \quad if \quad t > c + 1 \tag{11}$$

As to market shares, results are more intricate. First, we should note that, when the bus company is less efficient (i.e. $c > 0$), the rail operator may have a higher market share than the bus even if the (perceived) quality of the bus service is higher (i.e. $t < 1$). If firm b's marginal cost is sufficiently high (i.e. $c > 1/2$), then $q_{t_{uncons}} > q_{b_{uncons}}$ holds independent of the value of t.

Moreover, we obtain that:

$$\frac{\partial q_{r_{uncons}}}{\partial t} = \frac{1-c}{3(t+1)^2} \qquad ; \qquad \frac{\partial q_{b_{uncons}}}{\partial t} = \frac{c-1}{3(t+1)^2} \tag{12}$$

$$\frac{\partial q_{r_{uncons}}}{\partial c} = \frac{1}{3(t+1)} \qquad ; \qquad \frac{\partial q_{b_{uncons}}}{\partial c} = \frac{-1}{3(t+1)} \tag{13}$$

Generally, from (12) and (13), we find that equilibrium market shares are more stable as the value of t increases. Intuitively, for any given t, the rail operator takes advantage of a higher marginal cost for the bus service, to the detriment of the bus company. On the other hand, the impact of t on equilibrium market shares is ruled by the value of c. If c is sufficiently low (i.e. $c < 1$), then the impact of t is the same as when firms have symmetric marginal costs. Nonetheless, when c is high enough (i.e. $c > 1$), the impact of t is reversed, so that the equilibrium market share of the rail (respectively, bus) company decreases (increases) in t.

Although this may seem counterintuitive at first sight, a higher value of t reflects in a higher price for the bus, but in an even higher price for the train service (see (4)). This, in turn, softens competition and leaves room for the bus service. In other words, when the bus company is significantly less efficient, the rail operator accommodates the rival as long as the (perceived) quality of the bus service declines. Indeed, firm r raises the price for the train service to the extent that more users prefer to suffer the disutility from taking the bus.

Finally, in terms of profits, a higher disutility for taking the bus benefits both firms, whereas a higher marginal cost for the bus service benefits the rail operator, but harms the bus company.

$$\frac{\partial \pi_{r_{uncons}}}{\partial t} > 0 \qquad ; \qquad \frac{\partial \pi_{b_{uncons}}}{\partial t} > 0 \tag{14}$$

$$\frac{\partial \pi_{r_{uncons}}}{\partial c} > 0 \qquad ; \qquad \frac{\partial \pi_{b_{uncons}}}{\partial c} < 0 \tag{15}$$

3.2 Constrained duopoly case

Let us now assume that the capacity constraint for the bus company is binding in equilibrium (where the rail operator makes a positive profit). This means that firm b serves a fraction k of the market. It directly follows from (5) that this occurs as long as:

$$k < (1-\hat{x}) = \frac{(t-c+2)}{3(t+1)} \tag{16}$$

where the capacity limit is tighter or looser depending on the values of t and c (with the same effects as on firm b's equilibrium market share: see the discussion above).

In broad terms, everything else being equal, the capacity limit gets tighter as the variable cost of production c increases. Furthermore, it gets tighter (looser) as t increases if $c < 1$ ($c > 1$), while is constant for any t if $c = 1$[15].

Under (16) condition, in equilibrium the market assumes the form of a constrained duopoly. Thus, respecting the constrained market share, the quantities of demand served by rail and PBSR respectively are:

$$q_{r_{cons}} = (1-k) \qquad ; \qquad q_{b_{cons}} = k \tag{17}$$

Profit maximisation with constrained market share, applying the first-order conditions on (2) and (3), and considering the (17), yields the optimal prices:

$$p_{r_{cons}} = (t+1)(1-k) \qquad ; \quad p_{b_{cons}} = (t+2) - 2k(t+1) \tag{18}$$

Therefore, equilibrium profits respectively are:

$$\pi_{r_{cons}} = (t+1)(1-k)^2 - F \qquad ; \quad \pi_{b_{cons}} = \big(t+2-c-2k(t+1)\big)k \tag{19}$$

Thus, the equilibrium price, market share, and profit for the rail operator decline in k, that is the rival firm's market share. The price charged by the bus company also declines in k. For small values of k (i.e. $k < \frac{t-c+2}{4(t+1)}$), the effect of an increase in k (i.e. firm b's market share) is stronger than the decline in price, and thereby firm b's equilibrium profit is increasing in k. Instead, for higher values of k, firm b's profit declines in k.

There are a number of conditions for this equilibrium to exist. First, for the bus company to be active in the market, marginal costs must be sufficiently low (i.e. (8) must hold).

Second, the rail operator is profitable as long as fixed costs are low enough, that is:

$$F \leq (t+1)(1-k)^2 \tag{20}$$

As expected, this constraint is tighter (respectively, looser) as long as the unit disutility from taking the bus decreases (increases), and/or when firm b gains (loses) market share in equilibrium.

[15] Specifically, if $t \to \infty$ then $k < \frac{1}{3}$ must hold, whereas if $t \to 0$ then $k < \frac{2}{3}$ must hold, given that from (3.8) will be verified that $c < 2$ and the maximum possible value for k will correspond to the point in which $c = 0$.

Finally, the market is fully covered in equilibrium as long as the gross benefit of travelling u^* is high enough:

$$u^* \geq (t+2)(1-k) \tag{21}$$

While the price and profit for the rail operator increase in t, the price and profit for the bus company increase in t only if $k < 1/2$.

3.2 Rail or Bus based monopoly

Depending on parameter values, we can find an equilibrium where either the bus company or the rail operator gains a monopoly.

Assume, first, that (8) holds, so that firm b is active in a duopoly market. Then, depending on k, there is a critical value of the fixed cost such that, for higher values of F, the rail operator is not profitable.

First, if $k > \frac{t-c+2}{3(t+1)}$ (see (5)) then the capacity constraint for the bus company is not binding in duopoly, and thereby the equilibrium profit for firm r is given by (6). Therefore, if $F > \frac{(2t+c+1)^2}{9(t+1)}$ then the rail operator decides to leave the market.

On the other hand, if $k < \frac{t-c+2}{3(t+1)}$ then the capacity constraint for the bus company is binding in duopoly, and the equilibrium profit for firm r is given by (19).

Therefore, if $F > (1-k)^2(t+1)$ then the rail operator decides to leave the market.

In either case, if F is higher than the relevant critical value, then there is a monopoly of the bus company. Let us assume that:

$$u^* \geq c + 2t \tag{22}$$

that is, the gross benefit of travelling u^* is sufficiently high that all consumers would in principle be ready to use the bus service. However, given that $k < 1$, firm b is capacity-constrained and the market is not fully covered. Then, profit maximisation with constrained market share (where $\hat{x}_{b_{mono}} = 1-k$) yields:

$$p_{b_{mono}} = u^* - tk \tag{23}$$

$$\pi_{b_{mono}} = (u^* - c)k - tk^2 \tag{24}$$

Now, assume that (8) does not hold, so that firm b is no longer active in the market. If F is sufficiently low (i.e. $F \leq u^* - 1$: see (25)) then firm r is a monopolist. In such a case, if we assume that u^* is high enough (i.e. $u^* \geq 2$; condition for which the monopoly rail market share is positive, when it is not fixed to cover the all demand) then the market is fully covered. It follows that the equilibrium price and profit respectively are:

$$p_{r_{mono}} = u^* - 1 \tag{25}$$

$$\pi_{r_{mono}} = (u^* - 1) - F \tag{26}$$

3.3 Equilibrium analysis

In this section, we illustrate results on the market settings. For this purpose, we derive the equilibrium outcomes depending on the values of parameters t and k (which are the most critical competitive characteristics) for given values of the other parameters (see Figure 2). In the figure, the red curve (see (9), (20)) separates the areas where firm r is profitable under duopoly (that is, to the right of the curve) or not (to the left of the curve). On the other hand, the yellow curve (see (16)) separates the areas where the capacity constraint for firm b is active under duopoly (that is, below the curve) or not (above the curve).

Finally, the green curve (see (8)) separates the areas where firm b is active in the market (that is, to the right of the curve) or not (to the left of the curve)[16].

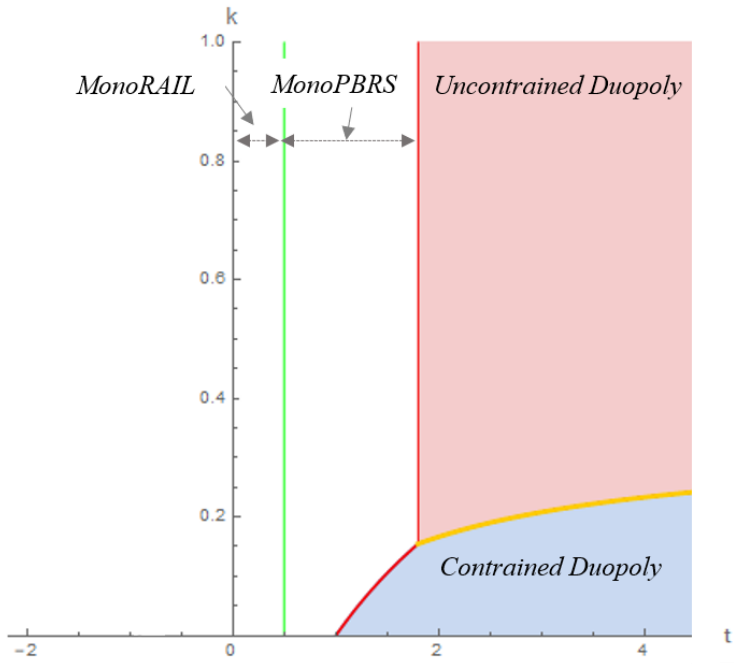
Thus, *ceteris paribus,* as t increases (i.e., moving to the right in Figure 2) first there is the monopoly of firm r (to the left of the green curve), then there is the monopoly of firm b (between the green and the red curves), and finally there is the duopoly (to the right of the red curve), either constrained (below the yellow curve) or unconstrained (above the yellow curve).

It follows from the results obtained that introducing intermodal competition from the bus company may in some cases force the rail operator to leave the market, given that it is no longer able to recover fixed costs. In such cases, the rail monopoly in the pre-liberalisation period turns into the bus monopoly after market liberalisation.

[16] We restrict the analysis to the case where the market is fully covered in duopoly equilibrium (see $(7), (21)$ *and* (22)). Given the value of u^*, a sufficient condition is that t is sufficiently low. Moreover, u^* is set so high that all consumers are willing to buy even under monopoly, so that all of them are served if firm r is a monopolist, whereas, due to the capacity constraint on the bus company, some of them cannot be served if firm b is a monopolist. In addition, the values of F and u^* are such that firm r is always profitable when it is a monopolist. Finally, parameter values are set so that, depending on t and $k,$ in Figure 2 any market structure may emerge in equilibrium, whereas, in Figure 3 for example, the monopoly of firm r is prevented. On the other hand, we exclude the case where the monopoly of firm b cannot emerge in equilibrium (which occurs when F is sufficiently low and/or c is high enough), since it is not interesting for our analysis.

Figure 2 Graphical representation of all possible market settings, when all constrained on u^* are respected.

$u^* = 6.5$



$\textit{Constraint on rail profitability}$

$\textit{Constraint on PBRS profitability}$

$\textit{Constraint on PBRS capacity}$

The rail monopoly market setting is realised if no duopoly alternative is feasible, due to violations of conditions over the gross benefit for transport assumptions.

In the figure the rail monopoly is realized for any value of $t < c - 2$.

The PBRS monopoly market setting is realised if no duopoly alternative is feasible, due to unprofitability of the rail firm.

The analysis has been restricted to the areas in which the basic conditions of existance for the duopoly are verified (all consumers are buying a unit of transport, either from the rail operator or the PBSR operator). This automatically excludes, for example, cases for which the value of t is relatively too high respect to the users' gross benefit u^*.

3.4 Welfare analysis

In this section, we assess the impact of intermodal competition between the rail operator and the bus company on social welfare.

Let the consumer surplus in an duopoly (constrained or un constrained), and in a monopoly respectively be:

$$CS_{duopoly} = \int_{0}^{\hat{x}} (u^* - p_r - x)\, dx \; + \; \int_{\hat{x}}^{1} (u^* - p_b - t(1-x))\, dx \qquad (27)$$

where $\hat{x} = (1-k)$ for the constrained duopoly, and $\hat{x}$ follows the X for the unconstrained duopoly.

$$CS_{monopoly} = \left(u^* - p_{i_{mono}}\right) * \left(q_{i_{mono}}\right) * \frac{1}{2} \qquad i = rail, bus \qquad (28)$$

Social welfare is given by the sum of both firms' profits and the consumer surplus.

For each market setting, Table 2 and Table 3 respectively display the values of consumer surplus and social welfare in equilibrium.

In what follows, we focus on two specific effects of intermodal competition from the bus company. First, we consider the case where the rail operator is forced to leave the market after liberalisation, and check whether and when the monopoly of firm b is socially desirable. Then, we consider the case where market liberalisation leads to effective competition, and check whether and when the duopoly equilibrium indeed improves welfare relative to the (pre-liberalisation) monopoly of firm r.

Table 2 Formulas for the Consumer Surplus, for each market setting.

Market setting	Consumer surplus (CS)
Unconstrained duopoly	$u^* + \frac{c^2 - 2c(4t+5) - t(11t+23) - 11}{18(t+1)}$
Constrained duopoly	$\frac{1}{2} * (2u^* + k^2(t+1) + 2k(t+1) - 2t - 3)$
Monopoly PBRS	$t * \frac{k^2}{2}$
Monopoly rail	$\frac{1}{2}$

Table 3 Formulas for the Social Welfare, for each market setting.

Market setting	Social Welfare (W)
Unconstrained duopoly	$u^* + \frac{5c^2 - 2c(2t+7) - t(t+7) - 18F(t+1) - 1}{18(t+1)}$
Constrained duopoly	$\left(u^* - \frac{k^2}{2}(t+1) - k(c-1) - \frac{1}{2}\right) - F$
Monopoly PBRS	$(2u^* - kt - 2c) * \frac{k}{2}$
Monopoly rail	$u^* - \frac{1}{2} - F$

3.4.1 Comparison between duopoly and PBSR monopoly

We have shown that intermodal competition may lead the rail operator to be unprofitable, depending on the level of fixed costs. Since the bus company is capacity-constrained, some consumers are left unserved. Hence, we argue that, from a welfare perspective, it may be preferable to restore competition by subsidising the rail service.

We consider the case where the rail operator may receive a compensation that is collected directly from the bus company (rather than from taxpayers). Specifically, we assume that firm *b* may be called upon to contribute to firm r's fixed costs by means of an *ex post* flat fee on equilibrium profit. In such a case, the burden of fixed costs is shared between firms.

Notice that, if the compensation were applied *ex-ante* on the operators, they would certainly anticipate it in their choices (market shares, pricing); thus, in terms of comparison between the realised social welfare level, results would not change.

More formally, we assume that the following conditions are fulfilled:

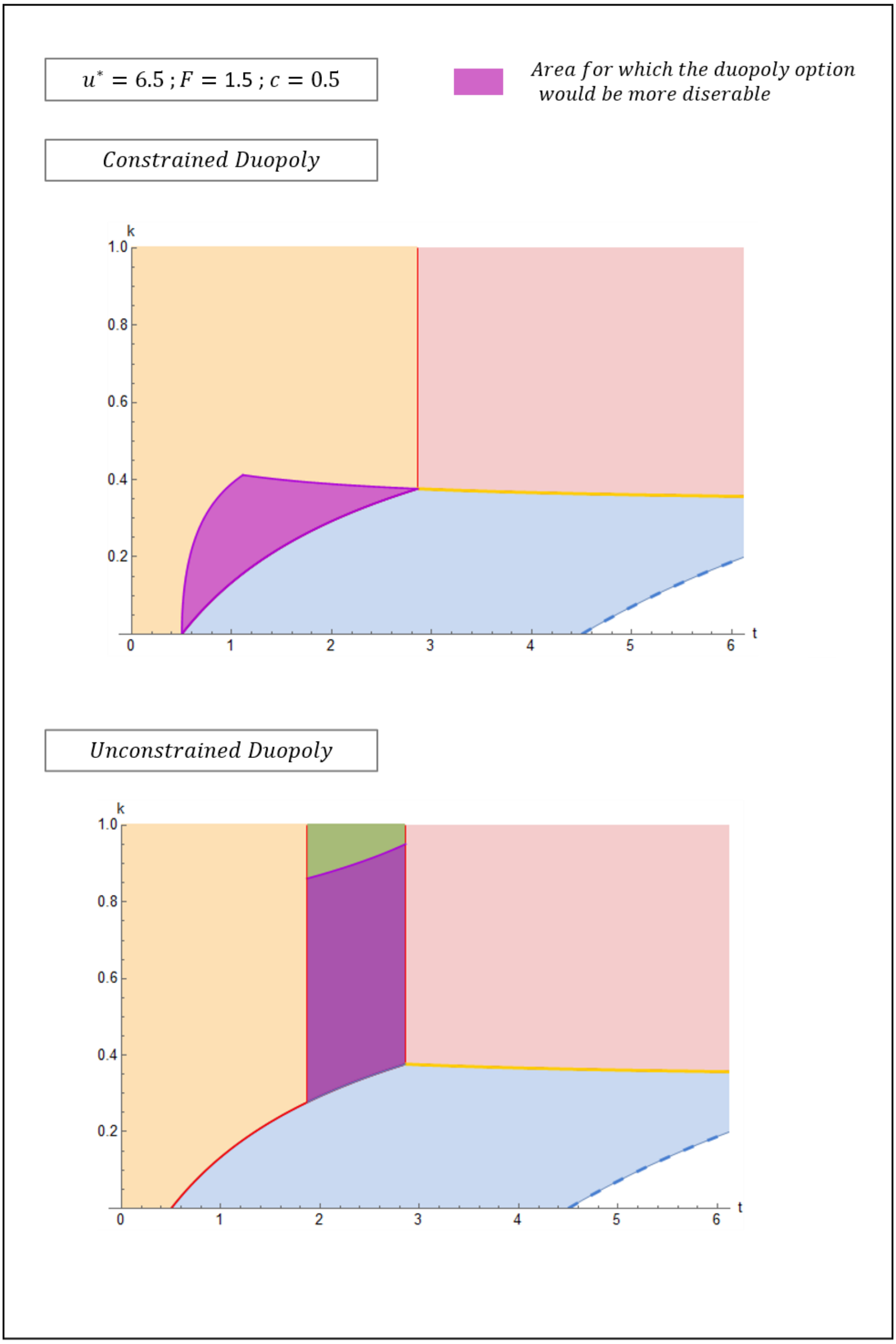
$$\begin{gathered} F \leq \pi_{r_{duopoly}} + \pi_{b_{duopoly}} \\ F > revenues\ from\ sales \end{gathered} \tag{29}$$

so that fixed costs may be recovered only in the case where they are shared between firms. Given that (31) holds, we aim at investigating whether and when collecting the flat fee from firm *b* to the benefit of firm r improves welfare by restoring competition, that is:

$$W_{duopoly} > W_{PBSR_{monopoly}} \tag{30}$$

Figure 3 shows the results obtained in a representative case (that is, for given values of u^*, F, and c). Specifically, the violet areas are those where subsidising the rail operator, and thereby restoring competition (instead of a *laissez-faire* policy allowing the bus company monopoly) improves social welfare. On the other hand, in the green area we have that, despite competition could in principle be restored, social welfare is higher under firm b's monopoly.

Figure 3 Areas in which the duopoly setting would be preferable toa PBSR monopoly from the social welfare point of view.



This occurs when bus capacity is sufficiently high, particularly as long as the (perceived) service quality of the bus option declines (i.e. as the value of t increases).

We have carried out a number of numerical simulations, which show that the higher the gross benefit u^*, the larger the area where a compensation from the bus company to the rail operator improves social welfare. Moreover, a compensation is more effective and desirable when the rail operator's fixed cost F and/or the bus company's variable cost c are not too high, otherwise it may even become impracticable.

3.4.2 Comparison between duopoly and rail monopoly

A second issue that deserves investigation is whether and when intermodal competition after market liberalisation is indeed socially preferable to the pre-liberalisation rail monopoly. Thus, we compare social welfare under (either constrained or unconstrained) duopoly and under rail monopoly, and we obtain that, under specific circumstances, the post-liberalisation market structure is welfare reducing. More formally, we find that the following conditions hold:

$$W_{duop_{cons}} > W_{PBSR_{mono}} \tag{31}$$

$$\begin{array}{lll} 0 < c \leq \frac{1}{2} & if \quad 0 < t < 1-2c & \forall\, k \\ & if \quad t > 1-2c & 0 < k \leq \dfrac{2(1-c)}{t+1} \\ \dfrac{1}{2} < c < 1 & if \quad \forall\, t & 0 < k \leq \dfrac{2(1-c)}{t+1} \end{array}$$

$$W_{duop_{uncons}} > W_{PBSR_{mono}} \tag{32}$$

$$\begin{array}{ll} 0 < c \leq \dfrac{4}{5} & \\ & if \quad t > 4-5c \\ \dfrac{4}{5} < c < 2 & if \quad \forall\, t \\ c > 0 & if \quad \forall\, t \quad (always\ respecting\ the\ (8)) \end{array}$$

Generally, the rail monopoly tends to be preferable when firm b's variable cost is sufficiently high and/or the (perceived) quality of the bus service is sufficiently low. Moreover, we find that high capacity levels for the bus company have a negative impact on the desirability of competition. Figure 4 and Figure 5 display representative examples, where the rail monopoly is the preferable option in the violet area.

It is worth noting that competition from bus companies is deemed to improve quality of services in long distance markets, not only in terms of increased service frequency and variety of transport modes, but also due to the rail operators' response to their competitors as to timeliness and comfort of travel. For simplicity, we abstract from these effects, and thereby our results tend to overestimate the benefits of the rail monopoly.

Figure 4 Results of the social welfare analysis performed to evaluate the most desirable option between the rail monopoly and a form of duopoly (a)

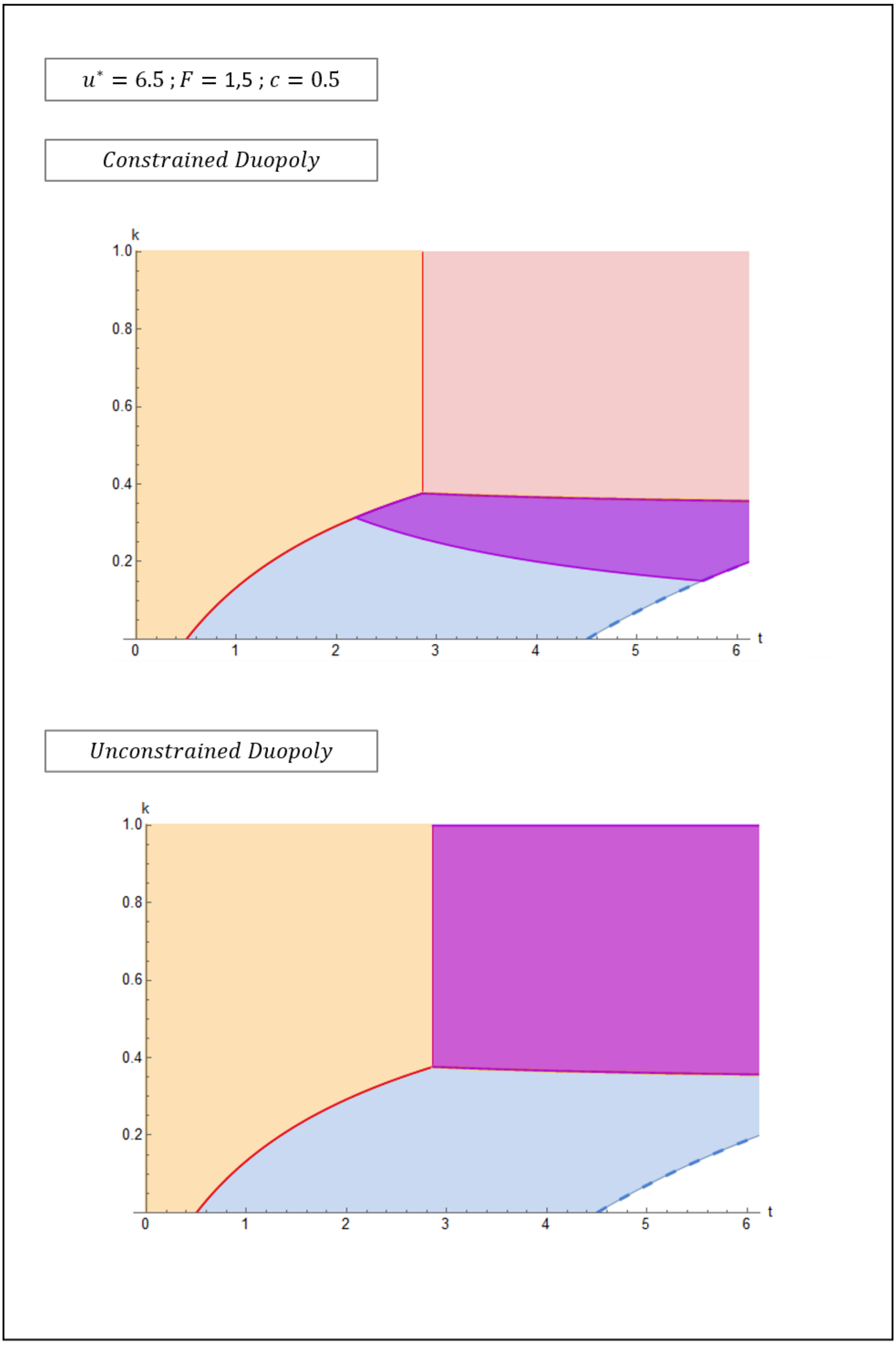
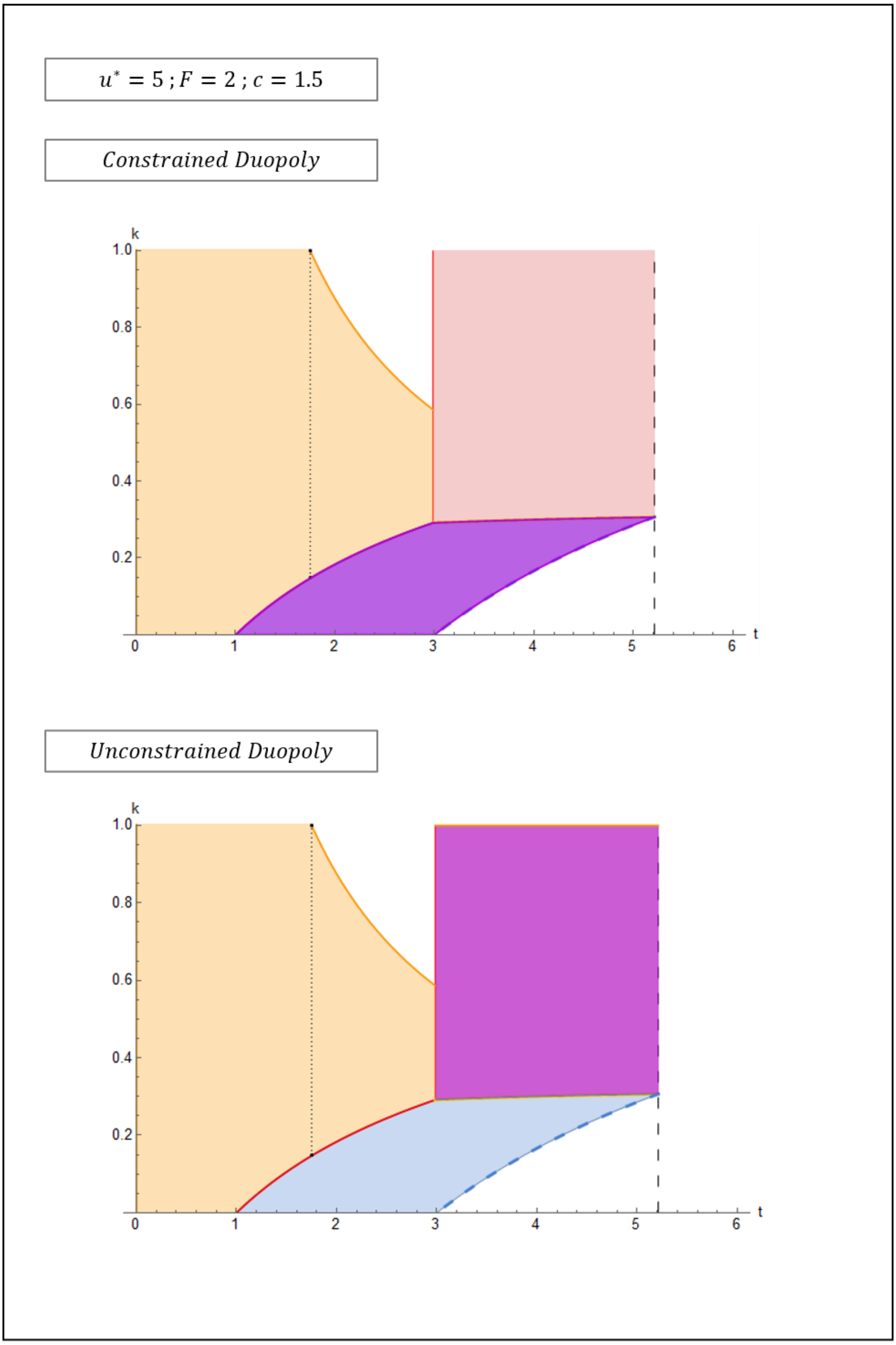


Figure 5 Results of the social welfare analysis performed to evaluate the most desirable option between the rail monopoly and a form of duopoly (b)



3.7 Numerical simulations

The results obtained in the social welfare analysis are strongly influenced by the assumptions adopted in the IO model; we are aware of potential limits in the representativeness that could follow.

First of all, a major source of concern is the assumption about how the rail operator can react to the PBSR's entrance in the market. In the IO model, we assume that the rail operator is either active in the market at its full capacity (i.e. covering its market share) or forced to leave the market as a whole. However, in a real context, a rail company would try to limit the fixed costs negative effects on profitability modulating its offer before making the decision to leave the market. Thus, there would be a much smoother process of adaptation and progressive reduction in investments. Possible ways to modulate the offer include applying reductions in frequency (equivalent to increase the load factor per ride; although this action impacts the perceived quality), along with possible reductions in fleet dimension.

Other issues could derive from the assumption of an equal gross benefit for transport towards the two transport alternatives (while there is a well-known tendency of average higher willingness to pay for rail users), and the assumption of an always no negative delta in perceived quality (t) in favour of the rail services.

The assumptions on the cost functions structures were needed for tractability and ease the interpretation of the results. We assumed negligible variable costs for the rail operator (in the limit of the activated capacity), even if the railways services production does also includes a variable component[17]. Moreover, we had simplified the PBSR cost function, not modelling explicitly the percentage of revenues recognised, by contract, to the bus operators performing the service (i.e. usually, a percentage of ticket price).

Finally, in a real context, the demand level, distribution along the day, and the two route directions could impact the firms' profitability. Indeed, these characteristics heavily influence the production costs through, for example, different needed services dimensioning.

Attempting to tackle the described issues, in the second step of our analysis, we perform numerical simulations, relaxing some of the assumptions and constraints characterising the IO model.

In outline, the numerical simulation structure integrates: the IO competition model we formulated (adjusted in were needed to the relaxation of the assumption), costs model for each transport mode, and a heuristic used for the service dimensioning. Finally, a model of strategic interaction identifies the Nash equilibrium for the market, given the scenario defined by the parameters.

The adaptation of the theoretical model introduces the possibility of deltas in gross benefits from travelling ($u_r^* \gtreqless u_b^*$), in transport costs ($t_r \gtreqless t_b$) and in variable costs per passengers ($c_r \gtreqless c_b$). Furthermore, the values for F, c_r and c_b are expressed referring to real data about rail transport

[17] The variable costs could be measured as costs per seat-km or per passenger-km. Considering, as in our analysis, the case of variable cost per passenger, in rail transport, once a certain numbers of rides have been fixed (with a certain amount of fixed costs for infrastructure activation, fleet acquisition, drivers etc.), any additional passenger is served increasing the load factor on the installed production capacity.

operators in Italy[18] and information on Flixbus costs (Gremm, 2017). Finally, we control for *daily demand* and the demand *distribution along the day* and *load factor* (LF_r, LF_b).

Simulation has been coded and run in R.

3.6.1 Simulation calibrated on a real case: definition of a market.

The numerical simulations are calibrated on a real transport system. The aim is to have the case at study represented, as far as possible, with realistic values for the relevant parameters.

We use as a base an existing route in the Italian long distance market context, on which are active both a rail operator and a PBSR company.

We select the route connecting the cities of Genoa and Milan, extracting information on route length, average speeds of service and demand volume (Table 3.4). The Genoa-Milan route is under 300km long (as required by our initial research question definition), and present travel time sufficiently comparable for the two alternative bus and train (around 1:40h for the rail option, 2:00h for the bus option). The main transport companies active on the Genoa-Milan route are Trenitalia (rail service), and Flixbus (PBSR service).

We gathered the main important information from the companies websites, while we measured the route length (in km) through Google Maps. We select the fastest path alternative for road transport (station to station, from real commercial routes), and we use the manual measurement tool to follow the railways infrastructure and calculate the length of the track.

For the sake of simplicity, we assume a simplified model for the demand behaviour description. We describe the demand through a few variables: daily demand volume, distribution along with the range of service, level of orientation on the two service directions on the path.

The volume of daily demand is made vary in the simulations between a minimum of 1,000 passengers per day (cumulative on the two directions), and a maximum of 10,000 passengers per day. Those values enclose the demand volume usually observed on the Genoa-Milan route[19], which is around 6,000 passengers per day (considering both path direction, both modes of transport).

We assume a *day of service 16 hours long*, over *365 days*, characterised by two peaks (in the morning and in the evening), each two hours long, typical for services someway involved by a commuting phenomenon.

For rail services, the presence of the peaks is modelled assuming an average load factor for the daily service for which: vehicles during peak hours run almost at full capacity, while vehicles off-peak run with a low presence of passengers. The initial value assigned to the daily average load factor is 35%, in line with data on real service provision in the Italian context. For the PBSR service, we assume a higher daily average load factor (70%), in line with offering a more flexible service, with smaller vehicles.

[18] As it will be better explained in the following paragraphs, the simulation will be calibrated on an Italian medium-distance route (Genoa-Milan) and the rail operational and infrastructure costs will be measures through standard cost functions approved by the Italian Minister of Transport (Avenali *et al.*, 2019).
[19] Notice that, this comment refer to a pre-covid route evaluation.

Lastly, we threat the demand as equally split between the two directions of service. This assumption is realistic on many paths characterised by commuting demand; however, for the same reason, it could also be strongly concentrated in peak slots for morning and evening commute. The equal split between direction is coherent with the Genoa-Milan route.

Table 2 Genoa-Milan path characteristics, vehicles capacity and load factor.

	Service by rail	*Service by coach*
Distance	140 km	150 km
Average speed	87.7 km/h	70 km/h
Average vehicle capacity	480 seats	50 seats
Average Load Factor	0.35	0.7

3.6.2 Numerical simulations' flow-chart

In outline, the each numerical simulations starts with the extraction of couples of prices (p_r, p_b) to simulate the broadest possible range of market interactions. For each extracted couple of prices, we calculate each company's market share (in a duopoly market setting) following the indifferent consumer's definition of our IO model formulation (*see* 1).

Given the initial demand share, we dimension the services (i.e. frequency, fleet) with iteratively updates that consider the competitors' limits on capacity and profitability. The capacity of the PBSR operator is fixed at the beginning of each simulation; for a given scenario, the simulation is repeated iteratively, all other things equal, updating the value of $k_b \in \{0.4, 0.5, 0.6, 0.7, 0.8, 0.9\}$. The maximum capacity for the rail operator (k_r) correspond to the technical capacity described in paragraph 3.6.1.

If the scenario leads the rail operator to an unprofitable position, its capacity is further reduced[20] until its profits become positive or until the firm is forced to live the market, leaving the PBSR acting in a monopolistic position. All the resulting acceptable observations (which could represent constrained/unconstrained duopoly, local monopolies or a PBSR monopoly) are pooled, and it is selected the record corresponding to the Nash equilibrium (or the closest possible observation).

The process is performed twice, once allowing compensation treatment and once not allowing it. We compare the social welfare associated with the obtained in the two cases to verify if the compensation policy is social welfare maximising. We especially consider the instances in which the rail firm would have been unprofitable without any intervention or capacity adjustment.

Notice that the comparison is run considering an overall 30 years period of service (with reference to an realistic average rolling stock life cycle).

We can now introduce the complete flow-chart follow to run our set of numerical simulations, graphically depicted by Figure 6 (*see also Appendix A for a complete flow-chart*).

[20] We eliminate a train from the rail operator fleet, and all the annual train*km that it could produce in 1 year of service.

Figure 6 Numerical simulation flow-chart, plain text schematic description.

1. Market definition	Extraction of couples of prices (p_r, p_b), and market share calculation *Output:* observations (p_r, p_b, x_r, x_b), respecting the IO theoretic model
2. Database creation	Check on feasibility (constraints on maximum capacities respected) Service dimensioning and economic performance *(number of rides, produced train*km and bus*km, profits, welfare measures)* Eliminate observation with $\pi_b < 0$ *Output:* database
3. Subdatabases	Select from database observations with $\pi_r < 0$ Apply capacity adjustment not allowing compensation treatments (*Without*) Apply capacity adjustment allowing compensation treatments (*With*) *Output:* subdatabases *Without* and *With*
4. Equilibrium	For each subdatabase: Observations organized in a *matrix of prices* Nash equilibrium calculation *Output:* Two sets of equilibrium to be compared

With the *extraction of couples of prices* we assign to the two companies competing in the market. In particular, we consider all the possible combination obtainable from two pool of values:

Rail operator: all the values between a minimum price of 5 € and the u_r^*, considering a step of 0.1 € between each value.

PBSR operator: all the values between a minimum price of c_b and u_b^*, considering a step of 0.1 € between each value.

The obtained couples are used to calculate the quantity corresponding to the indifferent consumer in a duopoly setting (*see* 1).

As already specified, the *rail company's cost structure* applied in the numerical simulations is based on the standard cost of production for regional railways operators running their services in the Italian context. To this end, we use the standard cost function described in Avenali *et al.* (2019), which was adopted as a reference by the Italian Ministry of Transport.

$$Cost_{train*km} = vehicles\ capacity * \left(0.02716 + \frac{0.24975}{av\_speed - 28} - 0.00349 * Turn\ over + 3.52342 * Akm\right) \quad (33)$$

where av_speed stands for average speed of service, while we also have that:

$$Turn\ over = \frac{Skm}{route\ length * 2} \quad (34)$$

$$Skm = \frac{(train * km) * vehicles\ capacity}{route\ length * 2} \qquad (35)$$

Moreover, it is also considered an access charge for the use of the railway infrastructure equal to 2.6 € per train*km of service.

As already specified, the cost structure for the *PBSR company* applied in the numerical simulations is based on the Flixbus business model. Information on Flixbus actual costs and profits are difficult to obtain even for the public authorities (Guihéry, 2019). We follow as far as possible the information gathered from the company website and the literature. We follow as far as possible the information gathered from the company website and the literature.

As responsible for the route planning, Flixbus participates in the entrepreneurial risk by paying a refund (based on the bus*km) to the bus operator running the service if the patronage is below a fixed number of passengers. If the patronage exceeds the fixed threshold, the revenues are shared with the bus operator as a percentage of the sold tickets. This percentage varies according to the specific route and the specific bus operator involved in the agreement.

We do not model explicitly in the IO formulation the presence of either the fixed fee for low patronage or the percentage of revenues for sold tickets. Although, in the numerical simulation, we do include the effects of the latter. We leave out the modelisation of the entrepreneurial risk for further research.

Flixbus indicates that the service production costs amount to around 3 € per seat over a route of 150 km; Gremm (2017), using data from the German Ministry of Transport on Flixbus cost structure, indicates 0.012 € per passenger*km for expenses due to marketing, sales and others.

We adopt two (alternative) formulations:

$$\pi_b = (p_b - c_b) * q_b \qquad with\ c_b = \{7, 10\} \qquad (36)$$

$$\pi_b = (Hp_b - c_b) * q_b \qquad with\ c_b = 0.012\ € \qquad (37)$$

The 36 adopts a fixed payment per passenger to the bus operators; the 37 consider the payment per passenger as a percentage of the price. In particular, in the simulations, we fixe H equal to 25%, which is an average value observed in the Flixbus-bus operators' agreements.

The *progressive update of capacity* is performed following:

$$k_{r_{update}} = \frac{maximum\ (train * km) per\ vehicle}{days\ of\ service} * \frac{capacity * load\ factor}{Daily\ demand * route\ length} \qquad (38)$$

The $k_{r_{update}}$ is then subtracted to the maximum service capacity that the rail operator can cover over.

Consumer surplus and social welfare are calculating following the insights of paragraph 3.4. The Nash Equilibrium is calculated through a prices matrix (*see Appendix B*).

3.6.3 Numerical simulations' results

Figure 8 and Figure 9 show how the numerical simulations substantially sustain the social welfare analysis results. Indeed, there are cases in which the rail operator is forced to leave the market due to unprofitability. If this coincides with a high enough daily demand and, relatively, high maximum capacity for the PBSR operator, then it is more likely that the application of compensation treatment policies could enhance the overall social welfare. The compensation's positive effects tend to be stronger if the transport costs towards the alternatives are low or low is the delta between the two values. In cases in which one (or both) the transport costs are particularly high, the compensation may even be not possible. In outline, the rail profits would be too negative to be balanced by the PBSR profits and/or the PBSR profits would be too low to cover the expenses of both the companies.

When the daily demand is low (e.g. below 3,500 passengers) it could happen that the rail operator loses the possibility to modulate its capacity in a smooth way and it is forced to leave the market at the first attempt to dismiss part of its fleet (i.e. the service dimensioning, in this case, would result in a small number of vehicles needed to run the service).

The figures show a case which is the closest to the theoretical model we formulated: same gross benefit from both the transport alternatives for the users ($u_r^* = u_b^*$) and a fixed amount of revenues paid to the bus operator performing the service (summed to the variable costs, we hypothesised an amount of 10 €). The numerical simulation have then be performed, making vary the values of the transport costs towards the two alternatives (T_r, T_b), the PBSR company maximum capacity k_b, and the level of daily demand.

Imposing a lower value for the amount of the variable costs (e.g. 7 €), we obtain analogous results, but the compensation treatment seems to be beneficial even for smaller values of the maximum PBSR capacity.

Imposing different values for the gross benefit from transport, in particular adopting the values $(u_r^*, u_b^*) = (26, 20)$ more in line with the usual real demand preferences, we obtain analogous results. Nevertheless, as expected, the overall level of social welfare is smaller. The deltas between the social welfare levels obtained with or without compensation treatments are lower too, compared to the previous cases. The compensation treatments are actually more difficult to apply since the PBSR profits are limited by a lower willingness to pay for the coach option.

We also tested for the influence of the load factor on our results. We started considering a realistic load factor of 35% (on average on the daily service), and we progressively increase it. Again, the results are comparable, but the need for compensation is lower since the railways can more easily profitably operate in the market.

Finally, we run the simulations also adopting the alternative formulation for the PBSR company costs (*see* 37). Again, results are analogous; nevertheless, the compensation treatments seems to the preferable even for smaller values of the PBSR maximum capacity.

Figure 8 Numerical simulation results when transport options have same gross benefit to users and the variable cost of production (including bus operator revenues) for the PBSR is 10 euro– Case (a).

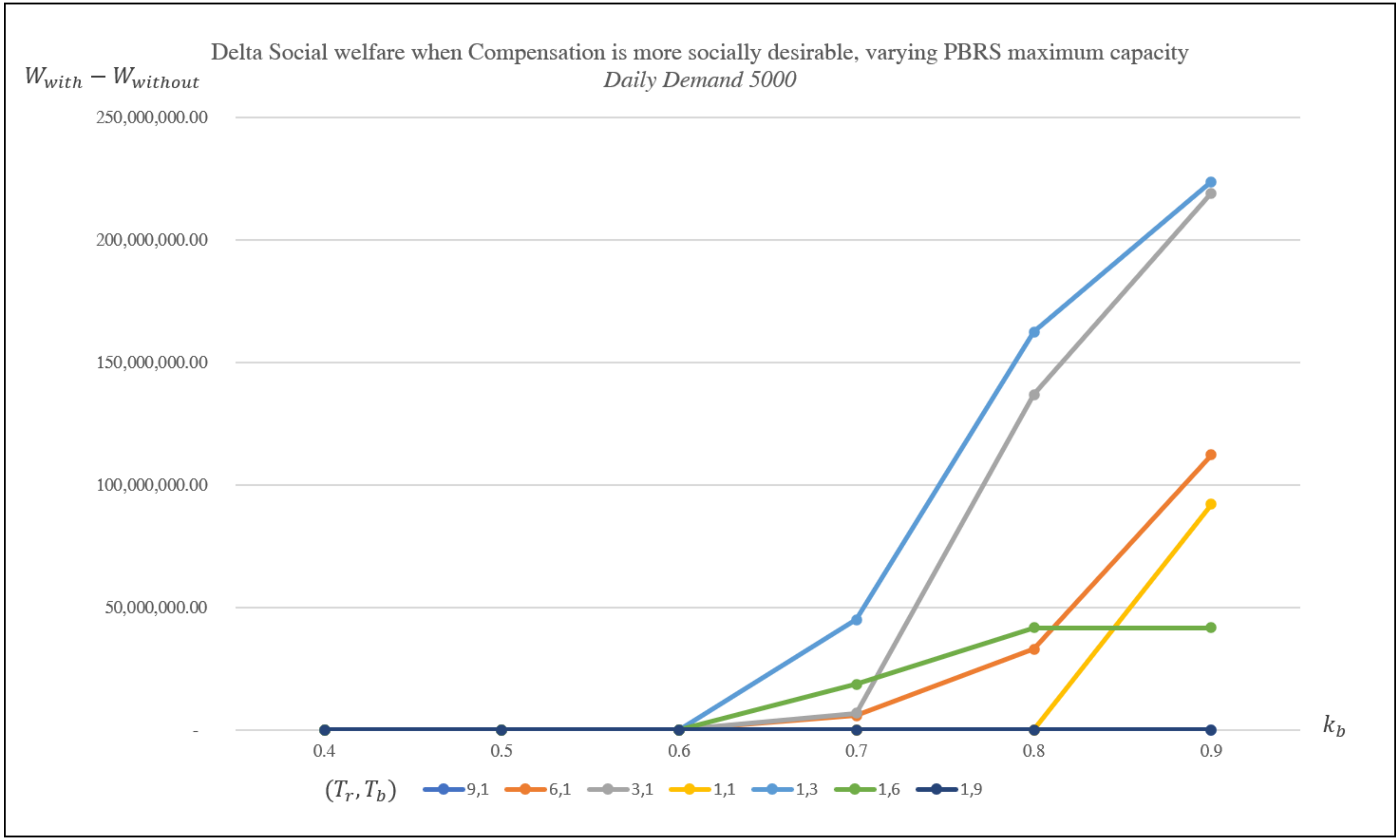
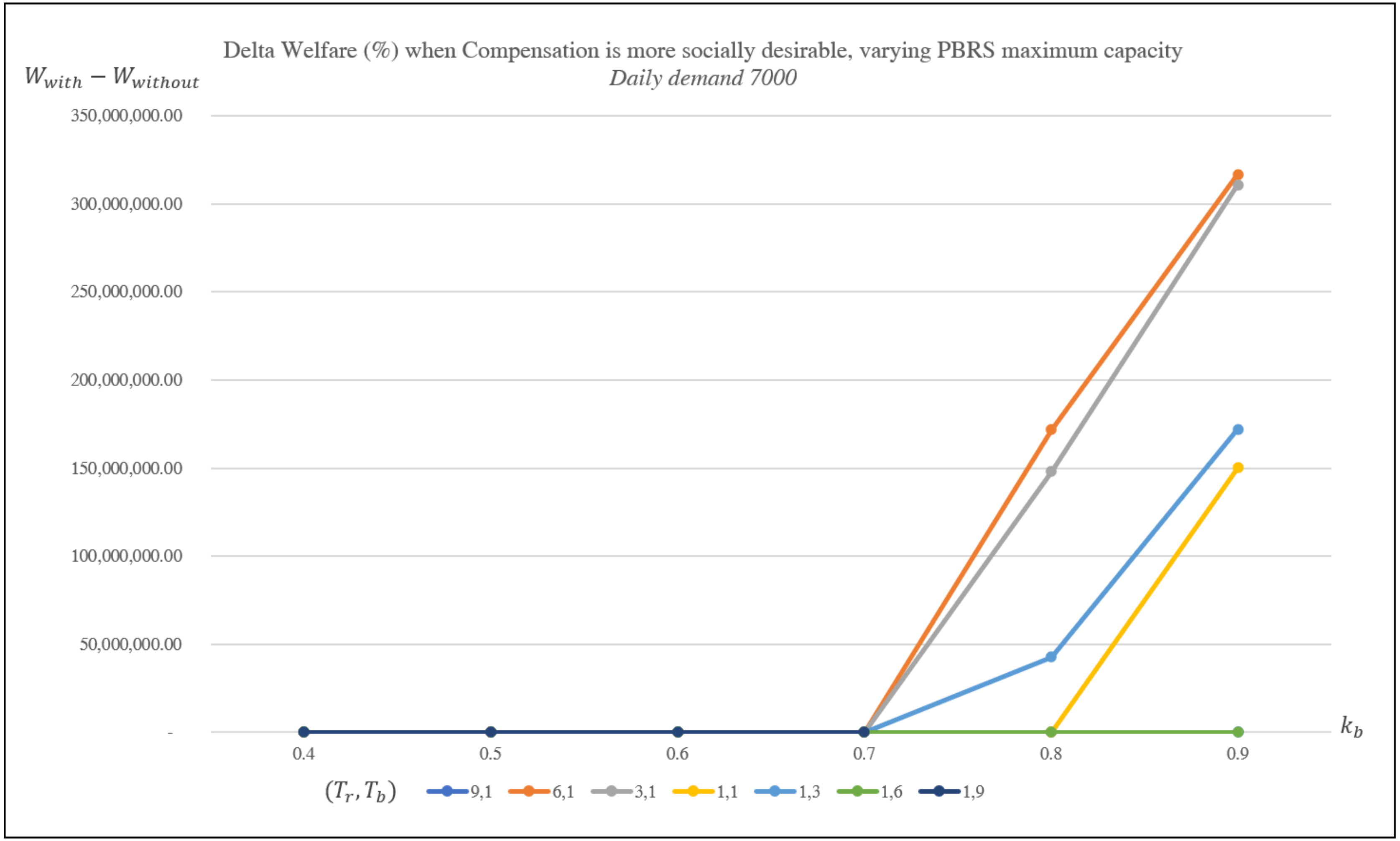


Figure 9 Numerical simulation results when transport options have same gross benefit to users and the variable cost of production (including bus operator revenues) for the PBSR is 10 euro– Case (b).



3.6 Discussion and conclusions

The deregulation of intercity bus transport introduced intermodal competition on long distance passengers markets, which were previously mainly dominated by rail operators solely. The e-Platform Bus Service Retailers, characterised by a disruptive business model, are now challenging the incumbents applying judo economics strategies. The PBSRs use their flexibility and low production costs against the rail operators, characterised instead by high indivisibility and investments, which could be pushed out of the market by a reduction in profitability and/or market share.

In a first step, we modelled the new competitive relations using game theory, including in the modelling the presence of fixed costs for rail operators and the possible PBSRs' limits in production capacity. We then study the market settings, the profits level and run social welfare analyses. Results confirm that for increasing PBSR production capacity, railway operators tend to have fewer profits or be forced to leave the market, this resulting in unsatisfied demand. From a social point of view, the rail monopoly seems to be, under specific circumstances, preferred to a duopoly. Finally, we can identify cases for which the application of compensation treatments as policy interventions could improve the overall social welfare.

We are aware that the first step results' representativeness could be limited by the theoretic model's simplifications. The main issue is the assumption of an “in-or-out” behaviour for the rail operator, that is not allowed to limit the fixed costs negative effect on profitability modulating its offer. Other issues concern the willingness to pay (equal for the two types of transport modes), how the quality of service is perceived by customers (always favouring the rail alternative), and assumptions applied on firms’ cost functions.

Thus, in the second step of the analyses, we run numerical simulations relaxing most of the constraints and assumption that we were forced to apply for the sake of treatability.

To this end, we planned a set of simulation, taking into account demand behaviour, production costs and competitive interactions and allowing a progressive reduction in investments for the rail operator. Furthermore, we attempted to increase the realism by calibrating our simulation on a real route, selected in the Italian long distance transport context (Genoa-Milan). From the simulations, we obtained results analogous to the ones obtained in the social welfare analysis. The PBSR disruptive business model could cause the rail operator to re-modulate its offer or exit the market, and in some cases, the application of compensating treatment as public policy interventions could lead to social welfare improvements. In particular, this happens in scenarios in which the PBSR service has disadvantages in perceived quality (*delta t is high*) and, especially when the productive capacity for PBSR covers a high portion of the market.

Based on our results, we can say that the public authorities should examine the routes in which PBSR intend to activate their services. Paths with a high demand level, characterised by preferences unbalanced towards the rail services, could be negatively affected by the presence of PBSR services activated with an aggressive quantity of production capacity. Possible interventions are: (i) limit the access of PBSR service to a specific route (either in total or allowing only the coverage of limited market share); (ii) apply policies of compensation between the transport modes. In the present work, we tested for a flat compensation between the firms.

Alternatively, it could be applied a variable compensation, modelled as a toll for using the road infrastructure born by the PBSR companies. This kind of toll would be linked to the produced quantity of service, and it would then change the competitive behaviour applied by the PBSR operator; we plan to verify those effects in future steps of our research.

Our work opens up also to other interesting extensions.

In long distance markets, the presence of ridesharing services (e.g. BlaBlaCar) could increase the demand diversion from rail operators. In future work, their role could then be included in the market setting. Nevertheless, it should be noted that these kinds of services are usually offered with regular scheduling and, in general, applied prices, frequencies and served demand are more difficult to detect (de Haas, *et al.* 2017).

Our style of analysis could have relevance also in urban transport systems. In this context, Uber-alike companies and sharing services could undermine the viability of established urban transit operators. In particular, Bike-sharing services and e-scooter sharing services have been rapidly growing, often supported by public interventions aiming to increase urban transport sustainability. Especially e-scooters are currently widely used in several countries (Tuncer *et al.*, 2020; Shaheen *et al.*, 2020).

It would be meaningful to analyse this phenomenon, which has been subjected in the last period to a critical acceleration. Worldwide, several public authorities are fostering micro-mobility as part of the measures to mitigate adverse effects on transport due to the Covid-19 pandemic emergency (e.g. increments in dedicated infrastructures or subsidies to final users, applied, for example, in Italy).

References

Aarhaug, J., & Fearnley, N. (2016). Deregulation of the Norwegian long distance express coach market. *Transport Policy*, vol. 46, pp. 1–6.

Aarhaug, J., Farstad, E., Fearnley, N., & Halse, A. H. (2018). Express coaches: An up-hill battle after liberalisation? *Research in Transportation Economics*, vol. *72*, pp. 82–91.

Alexandersson, G., Hultén, S., Fearnley, N., & Longva, F. (2010). Impact of regulation on the performances of long-distance transport services: A comparison of the different approaches in Sweden and Norway. *Research in Transportation Economics*, vol. 29, n. 1, pp. 212–218.

ART (2017). Indagine conoscitiva sul mercato dei servizi di trasporto via autobus a media e a lunga distanza in regime di libera concorrenza. Autorità Regolazione dei Trasporti. Torino (Italy).

Bataille, M., & Steinmetz, A. (2013). Intermodal competition on some routes in transportation networks: The case of inter urban buses and railways, *DICE Discussion Paper* (no. 84).

Bergantino, A. S., Intini, M., & Larosa, V. (2019). Quali strategie di prezzo nel mercato delle autolinee a media e lunga percorrenza? Flixbus e gli effetti della concorrenza intramodale e intermodale sull'asse Sud-Nord Itali, *Rivista di Economia e Politica dei Trasporti*, numero speciale su "Il trasporto automobilistico di lunga distanza", vol. 1.

Beria, P., Grimaldi, R., Debernardi, A., Ferrara, E., & Laurino, A. (2014). Spatial and scenario analyses of long distance coach transport in Italy, *MPRA working paper n. 54739.*

Beria, P., Nistri, D., & Laurino, A. (2018). Intercity coach liberalisation in Italy: Fares determinants in an evolving market. *Research in Transportation Economics*, vol. 69, pp. 260–269.

Beria, P., & Bertolin, A. (2019). Evolving long-distance passenger services. Market concentration, fares and specialisation patterns in Italy. *Research in Transportation Economics*, vol. 74, pp. 77–92.

Bertolin, A., & Tolentino, S. (2019). Le autolinee di media e lunga percorrenza in Italia: evoluzione del settore da prima della liberalizzazione ad oggi. Le autolinee di media e lunga percorrenza in Italia: evoluzione del settore da prima della liberalizzazione ad oggi, *Rivista Di Economia e Politica Dei Trasporti*, numero speciale su "Il trasporto automobilistico di lunga distanza", vol. 1.

Blayac, T. & Bougette, P. (2017). Should I go by bus? The liberalisation of the long-distance bus industry in France. *Transport Policy*, vol. 56, pp. 50–62.

Blayac, T., & Bougette, P. (2020). *What Can Be Expected from Mergers after Deregulation? The Case of the Long-distance Bus Industry in France*.

Burgdorf, C., Eisenkopf, A., & Knorr, A. (2018). User acceptance of long distance bus services in Germany. *Research in Transportation Economics*, vol. 69, pp. 270–283.

Burgdorf, C., Eisenkopf, A., & Knorr, A. (2019). Effects of the elimination of train path charges on the competition between bus and train–Development of travel activities and the choice of means of transport in German long-distance passenger transport. *Zeitschrift für Verkehrswissenschaft*, vol. 90, n. 2.

Crozet, Y., & Guihéry, L. (2018). Deregulation of long distance coach services in France. *Research in Transportation Economics*, vol. 69, pp. 284–289.

de Haas, S. & Schäfer J.T. (2017). Consolidations in the German interurban bus industry: Effects on prices and quantities. *MAGKS Joint Discussion Paper Series in Economics (No. 31-2017)*, Philipps-University Marburg, School of Business and Economics, Marburg.

de Haas, S., Herold, D., & Thomas Schäfer, J. (2018). *Entry deterrence due to brand proliferation: Empirical evidence from the German interurban bus industry*. Accessible at: http://www.uni-marburg.de/fb02/makro/forschung/magkspapers

Fageda, X. & Sansano, S. (2018). Factors influencing prices and frequencies in the interurban bus market: Evidence from Europe. *Transportation Research Part A: Policy and Practice*, vol. 111, pp. 266–276.

Gelman, J.R. & Salop, S.C. (1983). Judo economics: capacity limitation and coupon competition. *The Bell Journal of Economics*, pp. 315–325.

Gremm, C. (2017). Impacts of the German interurban bus market deregulation on regional railway services. In *Proceedings of the International Conference Series on Competition and Ownership in Land Passenger Transport*, Stockholm, Sweden.

Gremm, C. (2018). The effect of intermodal competition on the pricing behaviour of a railway company: Evidence from the German case. *Research in Transportation Economics*, vol. 72, pp. 49–64.

Gremm, C., Bälz, D., Corbo, C., & Mitusch, K. (2019). Intermodal competition between intercity buses and trains - a theoretical model. *KIT Working Paper Series in Economics*, 135(September 2019), Karlsruhe [ISSN 2190–9806].

Hasiak, S., Hasiak, F., & Egea, A. (2016). Coach and train: differences in individuals perception of these modes. *Transportation Research Procedia*, vol. 14, pp. 1706–1715.

Knorr, A., & Lueg-Arndt, A. (2016). Intercity bus deregulation in Germany – Intramodal and intermodal effects after two years. *Research in Transportation Economics*, vol. 59, pp. 323–329.

Preston, J., & van de Velde, D. (2016). Workshop 7 report: Market initiative: Regulatory design, implementation and performance. *Research in Transportation Economics*, vol. 59, pp. 343–348.

Shaheen, S., Cohen, A., Chan, N., and Bansal, A. (2020). Sharing strategies: carsharing, shared micromobility (bikesharing and scooter sharing), transportation network companies, microtransit, and other innovative mobility modes. In *Transportation, Land Use, and Environmental Planning* (pp. 237-262). Elsevier.

Tuncer, S., Laurier, E., Brown, B., & Licoppe, C. (2020). Notes on the practices and appearances of e-scooter users in public space. *Journal of transport geography*, vol. 85.

van de Velde (2009). Long-distance bus services in Europe: concessions or free market?. *Discussion Paper 2009-21*, OECD/ITF.

van de Velde, D., & Augustin, K. (2014). Workshop 4 Report: Governance, ownership and competition in deregulated public transport markets. *Research in Transportation Economics*, vol. 48, pp. 237–244.

van de Velde, D., & Karl, A. (2018). Workshop 3 report: Market initiative regimes in bus, coach and rail: Recent developments, threats, developing paradigms and regulatory needs. *Research in Transportation Economics*, vol. 69, pp. 254–259.

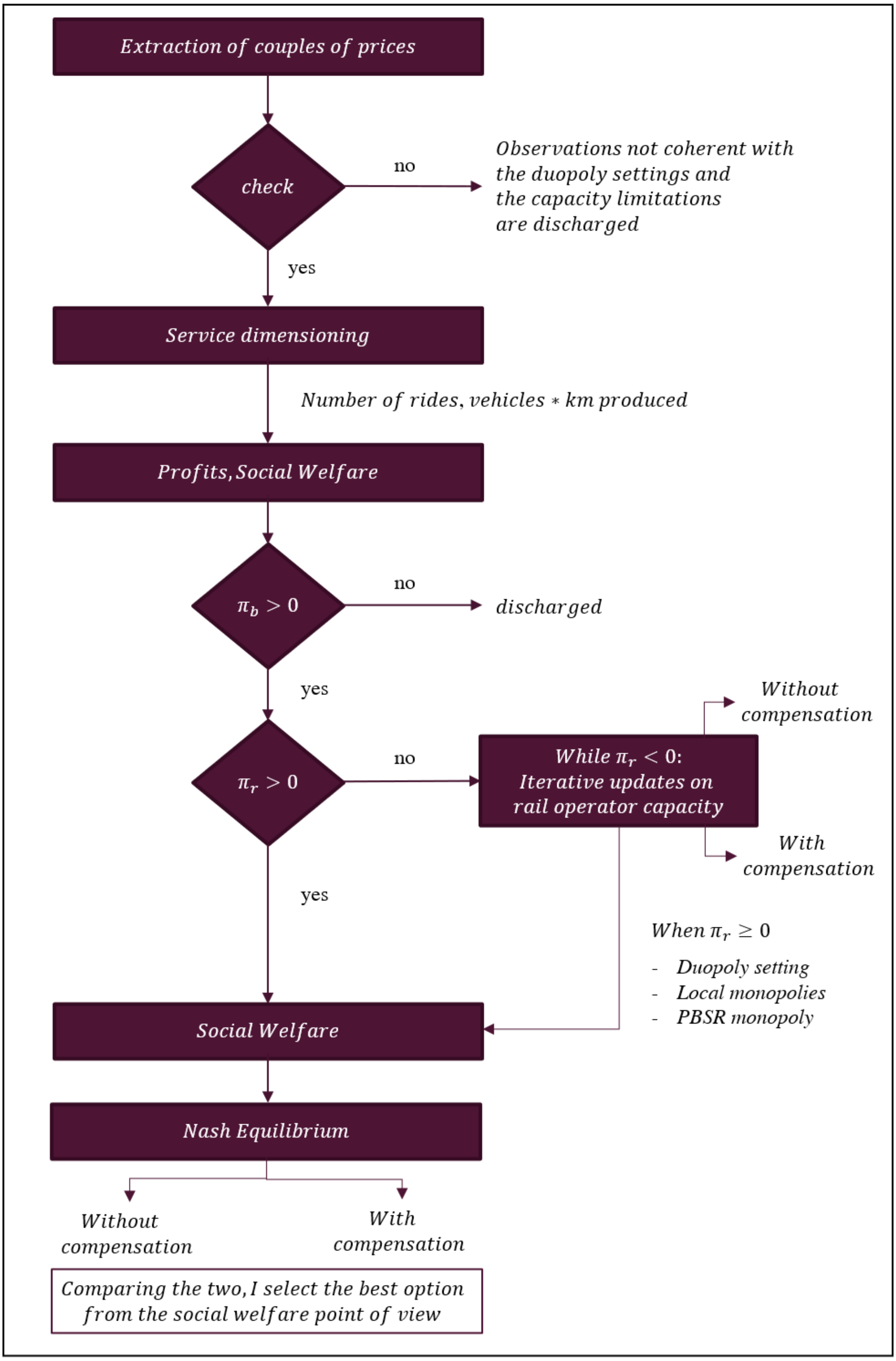
Willing, C., Brandt, T., & Neumann, D. (2017). Electronic mobility market platforms–a review of the current state and applications of business analytics. *Electronic Markets*, vol. 27(3), pp. 267–282.

Yoffie, D.B. & Kwak, M. (2002). Judo strategy: 10 techniques for beating a stronger opponent. *Business Strategy Review*, vol. 12, pp. 20–30.

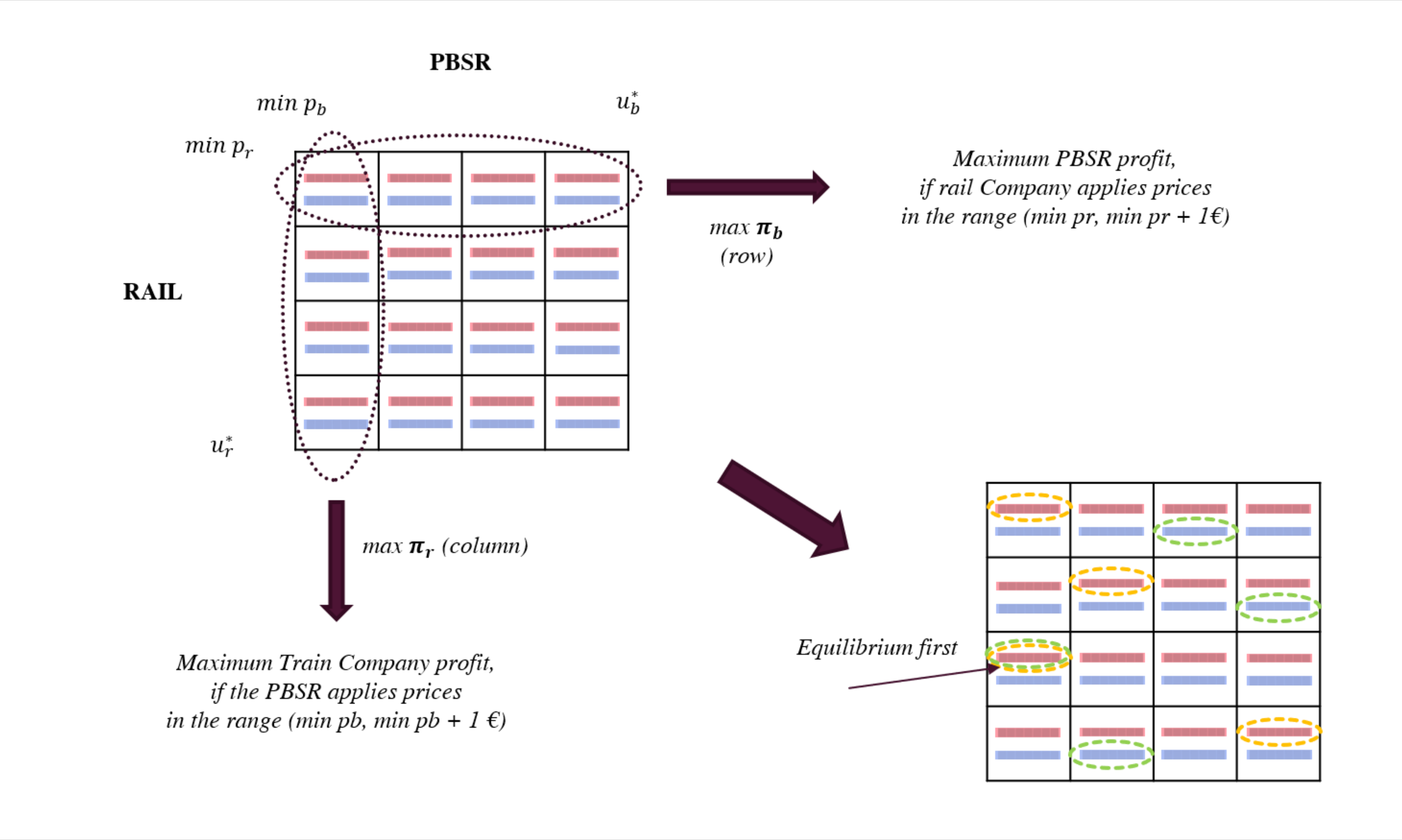
Acknowledgement

The financial support of Sapienza University of Rome (through the Sapienza Awards no. AR11916B877B0160) is gratefully acknowledged.

Appendix A


Extraction of couples of prices
check
no
Observations not coherent with the duopoly settings and the capacity limitations are discharged
yes
Service dimensioning
Number of rides, vehicles * km produced
Profits, Social Welfare
$\pi_b > 0$
no
discharged
yes
$\pi_r > 0$
no
While $\pi_r < 0$: Iterative updates on rail operator capacity
Without compensation
With compensation
yes
When $\pi_r \geq 0$
- Duopoly setting
- Local monopolies
- PBSR monopoly
Social Welfare
Nash Equilibrium
Without compensation
With compensation
Comparing the two, I select the best option from the social welfare point of view

Appendix B



PBSR
min p_b
u_b^*
min p_r
RAIL
u_r^*
max $\boldsymbol{\pi_b}$
(row)
Maximum PBSR profit,
if rail Company applies prices
in the range (min pr, min pr + 1€)
max $\boldsymbol{\pi_r}$ (column)
Maximum Train Company profit,
if the PBSR applies prices
in the range (min pb, min pb + 1 €)
Equilibrium first