The Efficiency Impact of Open Access Competition in Rail Markets

The Case of Domestic Passenger Services in Europe

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Abstract

On-track competition in passenger services has traditionally been limited in European railways, with private operators offering marginal services in selected corridors in the UK, Sweden and Germany only. In recent years, a larger scale and more stable wave of open access market entry has occurred in Austria, the Czech Republic and Italy, where open access operators have gained market shares of 20-30% in long-distance corridors.

Economic theory suggests that competition can result in productive efficiencies, although theories of competition are potentially outweighed by market characteristics which make monopoly a more efficient market structure when applied to the rail sector. The contestability of rail markets is further hampered by the presence of several barriers to entry as well as expansion.

The literature on the efficiency effect of rail policy changes is vast, but the focus to date has been on industry structure and competitive tendering, with non-conclusive results highlighting the importance of tailoring rail policies to the specific characteristics of each network. Studies have not yet attempted to measure the industry efficiency impact of passenger open access operations, neither specifically nor systematically – which is the goal of this paper.

Using a difference-in-difference estimator, we find that on-track competition has not, to date, led to major efficiency improvements across the rail systems affected – despite claims that new entrants have lower unit costs compared to incumbents. In the early days of market opening when guarantees of non-discriminatory access have not yet been fully established, on-track competition may be resulting in higher costs than in countries with monopoly passenger services.

These results are based on a short timeframe and will need to be tested over a longer period, recognising that competition is a process with no instantaneous effects. An early assessment of market opening policies is crucial to inform future regulatory decisions, at a time of budgetary constraints, forthcoming European reforms under the Fourth Railway Package and growing interest in market entry by new operators.

Competition in European rail markets

The contestability of rail markets

Railways fulfil multiple societal and economic objectives, including the provision of connectivity between key economic centres, regions and countries, and offer a relatively fast and reliable alternative to road and air modes. But railways are expensive to build, maintain and operate, leaving policy-makers with the conundrum on how best to structure and regulate them.

From a regulatory point of view, the railway sector should be treated as a multi-product natural monopoly with different levels of production and a variety of outputs. The first level of production is rail infrastructure, whereby the network provides outputs such as tracks, signalling systems, stations and depots used by rail operators. Operators on the rail network represent the second level of production, providing either passenger or freight services. Further segmentation leads to different markets for rail services. For instance, passenger services can either cater for high-capacity commuter networks, high-frequency intercity routes or high-speed national and international connections.

Railways share a number of characteristics with other network industries. Rail infrastructure networks are characterised by the presence of high infrastructure costs, economies of scale and economies of density in production. Economies of scale arise when a single firm can meet market demand more efficiently than any combination of two or more firms. Economies of density arise when large volumes of people and/or goods need to be transported between locations; the higher the loading density, the more efficient is rail transport compared to other modes.

These features make the introduction of competition in the railways problematic. Although some parts of the industry cannot sustain competition and are best structured as regulated monopolies, it is possible to have some degree of competition in train operations. Competition can be in the form of competition for the market or competition in the market – the latter is also known as the 'open access model'.

Research question and hypotheses

The open access model assumes that "competition in the market, or at least the threat of competition, results in a creative product offering, technological innovation, and downward pressure on costs and prices" (Beckers et al 2009). In theory, on-track rail competition can reduce the costs of operations, provided that some conditions are met. These include the identification of separate lines on which commercial services can be run profitably, and the provision non-discriminatory access to the network as well as rail-related services.

Open access operators (OAOs) with free access to commercially-viable routes are able to tailor their services with a focus on profit-maximising objectives (rather than public service goals) and to maximise asset productivity, including by employing better performing trains, and by avoiding stations that disproportionately add costs. OAOs can also achieve staff efficiencies, being free from historical industrial relations and making greater use of outsourcing. Technology can further contribute to reducing the cost of ancillary services such as ticket sales and customer support.

Additional savings can come from the indirect impact of OAOs. First, competition can stimulate efficiencies in the incumbent operators through incentives by comparison and the adoption of innovation.

These savings depend on whether the incumbent is commercially managed or relies on state funding. Secondly, competition in the market gives incentives for train operators to put pressure on the infrastructure manager to reduce costs in order to reduce access charges, and to use existing capacity more efficiently (Competition and Markets Authority, 2015).

On the other hand, competition can also lead to higher costs. Simply put, the addition of new operators adds costs to the system. The need for large upfront investment in rolling stock, staff and new technology means that a large proportion of costs are added during the first years of operations. The fragmentation of services following entry can result in a loss of economies of scale and density in operations, limiting the efficiency of both new entrants and incumbents. These arguments have been first put forward by Preston et al. (1999) and echoed thereafter.

Similarly network effects such as interconnection possibilities and integrated vehicle scheduling may be lost. Negative impacts upstream are also likely, as the infrastructure manager needs to consult and negotiate with multiple agents with respect to capacity allocation, maintenance works and timetables. In addition, higher transaction costs will emerge in relation to regulatory reviews, potential disputes and appeals.

This study assesses which of the competition dynamics described above appear to be dominating, shortly after market opening, based on a quantitative assessment. The following section provides the necessary background to European rail sector reforms and portrays the current competitive landscape.

Rail reforms at the EU and national level

Historically, European railways have been vertically integrated public monopolies. However the decline in rail market shares, and the growing public funding requirements witnessed in the post-War era called for change. Therefore from the 1980s onwards a process of restructuring has been taking place, with a view to reverse the industry’s negative traffic trends and decline in efficiency.

Reforms have taken place both at the vertical and horizontal level, fuelled by successive rounds of European legislation led by the Commission’s view that a new framework was necessary to promote gradual market opening through non-discriminatory access and interoperability standards (Finger and Messulam, 2015)

Building on the principles introduced by Directive 91/440/EEC in 1991 (managerial independence from the State, accounting separation, financial sustainability), the 2001 First Railway Package introduced requirements for horizontal separation between the passenger and freight operations, a system for access charges, independent capacity allocation and licensing processes, and Technical Specifications for Interoperability (TSIs). The Package was recently recast by Directive 2012/34/EU, with a view to clarifying the existing provisions on the funding and management of infrastructure, access to rail-related facilities (depots, maintenance, etc.) and the role and independence of regulatory bodies.

In practice, the implementation of these proposed structural reforms has differed across Member States (Steer Davies Gleave, 2012): some countries have opted for a separation of both functions and ownership between the infrastructure manager and the operator (e.g. Sweden, the UK, the Netherlands), whereas others have maintained integrated structures and regulated infrastructure access in order to comply with EU accounting and non-discrimination rules (e.g. Germany, Italy).

In 2003-2004, the Second Railway Package focused on reducing barriers to entry and promoted the harmonisation of technical and safety standards, and liberalised freight services. In particular, Directive 2004/51/EC removed all access barriers to domestic markets for freight operators holding an EU license.

The European Railway Agency was created with the role of EU-wide technical and safety regulator. The Third Railway Package, introduced in 2007, gave passenger railway companies the opportunity to compete on international routes. New international operators also began to compete on short sections of national networks with the incumbents.

The missing bit of the market opening jigsaw is domestic passenger services, for which a comprehensive framework has been proposed by the Commission in 2013 (part of the Fourth Railway Package). The ‘market pillar’ of this Package aims to introduce a common framework, including measures to promote competition for the market by making competitive tendering of public service contracts mandatory, and competition in the market by ensuring non-discriminatory access conditions, as well as removing legal barriers to open access in passenger services.

Some Member States have already opened their rail markets to competition. As a result of different governance arrangements, coupled with different competition models, the institutional landscape of railways across the EU is extremely diversified – as summarised in Table 1 below.

The table shows where competition in the market exists either de jure (i.e. where the law allows open access operations) and/or de facto (i.e. where new entrants have come into the market following regulatory changes) as of 2014. Fifteen countries allow open access operations, but only in six are multiple operators active. The next two columns indicate where competitive tenders for the main market segments take place, and the final column shows that that in all markets but the UK, incumbent operators are wholly controlled by the relevant state.

Concessions granting exclusive rights to operate rail services are subject to public tenders only in some member states. Even where public tenders have been held, direct awards have often been necessary due to a lack of participation by non-incumbent operators, who have been discouraged by unclear access rules as well as the size of the necessary investment in rolling stock and staff ahead of each tender.

Table 1. **Market opening for domestic services in the EU (2014)**

Country	Open access		Competitive tenders		State ownership
	De jure	*De facto*	*Long-distance*	*Regional / Suburban*	*% share of largest operator*
Austria	✓	✓	X	X	100%
Belgium	X	X	X	X	100%
Bulgaria	✓	X	X	X	100%
Czech Rep.	✓	✓	X	Mix	100%
Denmark	✓	X	Mix	Mix	100%
Estonia	✓	X	Mix	X	100%
Finland	X	X	X	X	100%
France	X	X	X	X	100%
Germany	✓	✓	X	Mix	100%
Greece	X	X	X	X	100%
Hungary	X	X	X	X	100%
Ireland	X	X	X	X	100%
Italy	✓	✓	X	Mix	100%
Latvia	✓	X	X	X	100%
Lithuania	✓	X	X	X	100%
Luxembourg	X	X	X	X	100%
Netherlands	X	X	X	Mix	100%
Poland	✓	X	X	Mix	100%
Portugal	X	X	X	Mix	100%
Romania	✓	X	X	X	100%
Slovakia	✓	X	X	Mix	100%
Slovenia	✓	X	X	X	100%
Spain	X	X	X	X	100%
Sweden	✓	✓	✓	✓	100%
Great Britain	✓	✓	✓	✓	0%

Source: Adapted and updated based on Steer Davies Gleave (2012) and European Commission (2013).

Open access competition in domestic passenger markets

According to Finger and Messulam (2015), "European-style deregulation has created antagonistic interests between all the actors involved [… in the rail industry]". However in proposing further market opening as part of the Fourth Railway Package, the European Commission's view is that "increased competition should enhance the attractiveness of rail and make the sector more responsive to customers' needs, allowing rail operators to compete with other modes … and contributing to achieving climate change targets" (COM/2013/025).

Actual experiences of on-track competition in domestic passenger services are limited. In Germany, open access services by Veolia Interconnex running between Leipzig and Berlin has likewise achieved a domestic market share of less than 1%, and the service was discontinued in 2014. New services such as the Cologne-Bonn Express started operations in Germany very recently. In Sweden, market entry has led to unstable outcomes. For instance, the arrival of OAO Veolia led to the withdrawal of competing services between Malmö and Göteborg by the Swedish incumbent SJ (SDG 2012), thus direct competition in the market was short-lived.

A notable exception is represented by OAOs First Hull Trains and Grand Central, which have been active since 2000 and 2007 respectively, competing with the incumbent on the East Coast Main Line in Great Britain. The British case has been analysed by the Competition and Markets Authority (CMA), which has found overwhelming evidence of downward pressure on fares and upward pressure on service and innovation arising from open access competition. The evidence on the industry-wide efficiency impacts of OAOs is more mixed, as detailed below. However the national market share of OAOs in Great Britain is under 1% as their access rights have been subject to restrictions to limit traffic abstraction from franchise operators[1].

Finally there are examples of cross-border operators competing with domestic operators on selected parts of the network. These include ÖBB services running between Austria and Venice, competing with Trenitalia, and Eurostar services between Paris and London, overlapping with British franchises in Kent. However international services have much lower frequencies and have not, to date, targeted domestic passenger markets specifically. Rather, international joint ventures have provided a way to soften competition, as in the case of the Railteam Alliance (Bergantino, 2015).

A more recent, large-scale and stable wave of market entry has been witnessed in the Austrian, Czech, and, Italian markets which is described in the following paragraphs.

Austria

In Austria, private rail operator WESTbahn was founded in 2008 with capital from both Austrian investors and the French incumbent operator, SNCF (which initially had a 26% share in the company). WESTbahn applied for track access rights on the main rail corridor connecting Vienna to Salzburg. The incumbent operator ÖBB held a monopoly on the line, which was deemed to be 'commercially viable' and therefore was operated by ÖBB without any state subsidies.

WESTbahn's market access and growth were delayed by a number of events. The operator made several complaints to the Austrian regulator and competition authority, including in relation to

1 This includes the so-called non-primarily abstractive (NPA) test, which obliges the British rail regulator ORR to limit new entry if more than one-third of the new passengers are forecast to come from existing operations.

discriminatory access to essential facilities by the integrated infrastructure manager (ÖBB Holding), and to unfair competition involving predatory pricing by the incumbent operator.

Despite these initial difficulties, WESTbahn commenced operations in December 2011 and operated more than 3 billion train-km in 2013, equal to a market share of 20-25% on the Vienna-Salzburg route (CMA, 2015) and an overall 3% share nationally (own calculations). Since the arrival of competition, rail passenger numbers have grown both in absolute and relative terms in Austria.

Czech Republic

In the Czech Republic, RegioJet – an established coach and bus provider – entered the long-distance rail passenger market in 2011, after founding a rail subsidiary in 2008 and procuring its first rolling stock second-hand. RegioJet started competing with the incumbent ĈD on the Prague-Ostrava route, the busiest domestic rail corridor, and on which ĈD was previously the only operator.

In November 2012, a second new entrant arrived – Leo Express, founded by a private equity fund. The company acquired a new fleet of trains that were significantly lighter than its competitors, and started competing with the other two operators along the same route.

Following complaints by the new entrants, administrative procedures against ĈD were launched by the regulatory authority, accusing the incumbent of undercutting competition by abusing its dominant position. These accusations notwithstanding, new entrants operated a combined 4.5 billion train-km in 2013, equivalent to a market share of 40-50% on the Prague-Ostrava route (CMA 2015) and an overall 3.5% share nationally (own calculations). Since the arrival of competition, rail passenger numbers have grown both in absolute and relative terms in the Czech Republic.

Italy

In Italy, the monopoly held by Trenitalia was interrupted in April 2012 with the entry of NTV on the high-speed rail network connecting Italy’s largest urban areas. NTV is a private company, albeit with a 20% participation by SNCF. Founded in 2006, it began a tortuous application process for safety certification in 2008, and in the same year new rolling stock was ordered; approvals to operate were obtained in 2011.

NTV has complained about entry barriers, partly due to the behaviour of FS Holding (controlling both the incumbent operator Trenitalia and the infrastructure manager RFI) and slowing down the process of de facto market opening. Alleged barriers included delays in processing path applications, limited access to essential facilities (e.g. Rome Termini and Milan Centrale stations), and cross-subsidisation in order to sustain Trenitalia’s predatory pricing policies.

Both the competition authority and the new transport regulator (ART) set up in 2013 have intervened with structural and behavioural remedies to ensure non-discriminatory conditions. Additionally in October 2014, track access charges for the high-speed rail network were reduced by around 30% in order to support competition and reduce the costs of operations.

NTV operated 12.5 billion train-km in 2013, equivalent to a market share of 20-25% on the high-speed network (Bergantino et al. 2013) and an overall 2.5% share nationally (own calculations). The introduction of competition has not contributed to reversing the decline in passenger-km in Italy, partly due to the economic crisis and the associated fall in demand for transport services, but the market share of rail has grown vis-à-vis road and air, highlighting the commercial success of high-speed rail (HSR) operators.

The efficiency impact of open access competition

The emerging evidence on competition impacts

The structural reforms of European railways have been analysed by a large literature. Econometric studies have in particular assessed the impacts of both rail freight liberalisation and of competitive tendering for passenger rail services. The key findings of the econometric literature are summarised by Nash et al (2015):

- There is no consensus on the efficiency impact of vertical separation. Results vary depending on the different approaches used (data envelopment analysis (DEA) and econometrics) and on the measure of efficiency and productivity used (Cantos et al. 2013).
- However Mizutani and Uranishi (2010) find that vertical separation reduces costs at low levels of rail network density but increases them at high levels, partly due to the increase in transaction costs (Merkert et al. 2012).
- Both Van der Velde et al. (2012) and Mizutani et al. (2014) find no evidence that the degree of competition (in the form of freight liberalisation and competitive tenders respectively) has a significant effect on cost. In contrast Cantos (2013) finds positive efficiency effects from competition in the market.

Three other studies using econometric analysis to assess the impacts of competition are worth noting. The first, by Laabsch and Sanner (2012), uses fixed-effects panel data regression to assess the impact of vertical separation on modal share. Here, the competition variable used is a "Degree of liberalisation [index points]" computed by IBM in 2007 and 2011. The low explanatory power of their model, with no conclusive results on the impact of competition, confirms that fixed effects models require larger datasets than available, and that better measures of competition than a simple index should be used.

The second study, by Driessen et al. (2006), is based on a model with limited dependent variables (LDV) and is unique in that it relies on physical measures of productive efficiency to derive efficiency scores, and separate measures of competition as independent variable; a dummy for open access is created, with a value of 1 when new entrants have a market share of over 1% either in the freight or passenger sector. The regression model tests the relationship between efficiency scores for thirteen countries (obtained by way of DEA analysis) against a set of explanatory variables for the period 1990-2001. The authors find that entry reduces productive efficiency, as it may disable railway operators to reap economies of density.

Using long-term industry cost data for Sweden to test cost dynamics by way of regression models, Jensen and Stelling (2007) provide evidence on the positive efficiency impact of regulatory reforms in Sweden. By comparing the total sector costs between 1978 and 1988 with the total cost between 1989 and 1999 they identify a reduction of 16% in fixed monetary value (adjusted for output differences), of which only 9% seems to be attributable to the deregulation. Their findings highlight the long-term nature of competition benefits, unfolding over the course of a decade.

A number of national studies also give an overview of cost trends following policy changes. With respect to competitive tenders, Alexandersson and Hultén (2005) recount that the first rounds of competitive tenders for regional services in Sweden led to cost savings of more than 20%. Lodge (2013) highlights the efficiencies achieved by the rail freight sector in the UK, where freight operating companies reduced unit costs by 35% between 1999 and 2009, partly as a result of competition. Similarly the McNulty Study (2011) found that rail freight traffic doubled over that period with a less than proportionate increase in staff costs.

However the impacts of open access competition in domestic rail passenger services on overall industry efficiency have not been assessed yet. In 2014, Finger wrote that “open access in the passenger segment, for the limited experience that exists, does not necessarily implies more services” and points to the German experience being “short-lived”, the Swedish experience beginning “only very recently” and experiences in Italy, Austria and the Czech Republic being “too recent to be conclusively evaluated”.

Since 2014, some authors have assessed specific aspects of efficiency arising from the entry of OAOs. The UK CMA in its recent assessment of competition in rail passenger services commissioned a study on cost differentials between OAOs and franchisees (Wheat and Smith 2015). This finds that OAO’s input prices are 29% lower than those of franchisees operating intercity routes. Savings in input costs are modelled against cost disadvantages from the limited scale and density of OAO’s operations. Mindful of the high degree of uncertainty regarding the precise magnitude of the efficiencies, the authors find that efficiencies more than offset the cost disadvantages on two long-distance lines, but do not on a third line.

Analysis of OAOs at the national level therefore continues to yield mixed results with respect to operator’s efficiency. A recent review carried out by Arup and Oxera (2015) confirms that “there is little information on specific costs structure of other European rail operators” and reports on some of the emerging findings of market reviews.

For instance in Italy, Bergantino et al. (2013) show that competition between NTV and Trenitalia has led to passenger growth on high-speed services and a higher modal share for rail overall, while at the same time price competition has reduced the lowest fares (advance, discounts) by up to 30% (Croccolo 2013) and new managerial practices have been introduced in the sector (Capozza et al 2014).

Tomes et al (2014) analyse the situation in the Czech Republic and conclude that competition has led to lower fares and quality improvements, but all of the competitors are operating at a loss, and open-access competition has increased congestion on the main railway artery Prague-Ostrava.

Thus country reviews mainly point to the customer benefits of competition in Austria, the Czech Republic and Italy. Yield management systems have been applied for the first time, price hikes have been limited and new offers are available, online services are made easier and reservation fees have been removed, and ancillary services such as Wi-Fi on-board have been introduced. The efficiency question remains unanswered by these studies, however, and doubts are cast over the long-term financial sustainability of new entrants in the presence of low margins.

The measurement of efficiency impacts

The analysis that follows is a primer attempting to quantify the efficiency impacts of open access entry since new operators have begun large scale operations in Europe over the period 2011-2012. For the first time, a well-developed econometric technique (difference in difference – DID) is applied to an ex-post assessment of rail policy changes, borrowing the methodology recently developed by Dan Graham and colleagues to evaluate the impacts of HSR in Spain. Lastly, the dataset collated for this study covers total rail industry operating costs for nine countries over seven years, based on industry data from the International Union of Railways (UIC) and the analysis of annual reports including new entrants'. The following paragraphs provide more details on the data and the methodology used.

Selecting the appropriate metric

A critical step towards obtaining meaningful results is to select the appropriate dependent variable – that is, the cost measure which best captures fluctuations in operational efficiency.

The literature on rail efficiency makes use of various indicators, including the ability to attract more customers (measured by modal shares), the ability to cover costs by way of commercial revenues (measured by operating ratios) and technical/operational efficiency (measured by units of inputs per units of outputs). The latter is of interest in this study. Yet even when focusing on operational efficiency only, this can be measured either by physical or monetary inputs.

Monetary inputs are preferable, as discussed by the OECD (2015, p.18):

"Operating expenses per train-km is a critical indicator for railway efficiency because it measures the level of financial inputs required per train. The higher the number, the more that railway must invest for each train-km. A higher number compared to the peer group implies relative inefficiency at the railway"

It is possible to structure the analysis either around specific cost items (e.g. passenger operating costs per passenger train-km) or total system costs. On the one hand, passenger-specific measures would be useful for this study given the focus on market entry in passenger operations. On the other hand, the potential impacts of open access entry in passenger operations can extend to the whole rail system. In addition, the allocation of costs to different rail activities is a thorny issue given the multiplicity of outputs produced by the railways.

For these reasons, and following both Mizutani and Jensen, a measure of total cost for the railway system is used. The cost of train operations includes operating, maintenance, administration, and marketing costs. The cost of infrastructure includes all costs of an infrastructure service provider except costs of new investment. However depreciation costs are included. For vertically separated systems, infrastructure charges paid by operators are removed to avoid double counting.

Total costs need to be normalised, in order to ensure a like-for-like comparison between networks with different sizes and traffic flows. Instead of using total aggregate costs as the dependent variable, a more comparable measure of efficiency is therefore the ratio of costs per unit of output, as used in OECD (2015) and Civity (2012). As a denominator, two options are available: (1) passenger-km and tonne-km can be added to obtain "total transport units", or (2) total train-km, which measures the length travel by both passenger and freight trains on a network, can be used.

The former option captures the total traffic transported on the network, but poses two problems: first, passenger and freight can increase/decrease by increasing train loads but not train runs, as a result of fare/commercial policies; secondly, the units of measure for passenger and freight are not directly comparable. Instead, train-km measure the actual train traffic on the network in terms of rolling stock, multiplied by the distance run. Hence 'total costs per train-km' is the selected dependent variable in this study, capturing changes in system efficiency in a non-biased way: this variable is not related to demand fluctuations and can be controlled by companies' management.

Data availability and selection

Obtaining railway statistics (consistent across countries and over time) is often a severe obstacle to in-depth analysis of rail policy outcomes. In the past, some authors have been able to overcome these obstacles by resorting to questionnaires coordinated by industry associations (e.g. Mizutani et al. 2014 with the Community of European Railways) whereas others have avoided using cost measures and have focused on other outputs to assess the impact of policy changes.

For this study, the starting has been the annual railway statistics published by UIC. The UIC database is not comprehensive, and some of the inconsistencies between time series have been criticised in the past (e.g. Nash and Smith 2014). However, it provides an initial set of broadly comparable financial data sourced from UIC's affiliated operators. The data was verified and complemented by further analysis of railway companies' annual accounts, including infrastructure managers, passenger and freight operators. Financial values were converted to a common price base and further adjustments were made when less than 100% of the market was covered by the available data. Units and main sources are summarised in the Table 2 below.

Table 2. **Data and main sources**

Data	Units	Data sources			
		UIC	RMMS	Annual Reports	Eurostat
GDP	€ million				✓
Population	Million				✓
Rail costs	€ million	✓		✓	
Train-km	Million	✓	✓	✓	
Passenger-km	Billion				✓
Tonne-km	Billion				✓
Rail network	000s km	✓			
Rail employees	000 FTEs		✓	✓	✓

Note: prices adjusted to common basis using CPI indices; traffic measures related to total km operated on the national network; network length is net of unused sections of the rail network.

The output of the data collection phase is a panel dataset for 9 countries for the years 2007-2013. The dataset covers the following countries: Austria, the Czech Republic, Finland, France, Hungary, Ireland, Italy, Portugal and Spain. This is a relatively rich database, especially thanks to the presence of cost data – the lack of cost metrics has limited any efficiency comparisons in this sector in the past.

Econometric technique

An identification strategy is necessary in order to establish how observational data can be used to approximate a real experiment (Angrist and Krueger 1999). Here, the analysis exploits the variation established by the following random treatment: the entry into the long-distance passenger rail market by new operators (OAOs) other than the incumbent. By 2012 only in six EU Member States OAOs were present, and only in Austria, the Czech Republic, and Italy large scale entry had occurred. The next question is then what is the best econometric technique to exploit this random experiment and assess the impacts of competition on efficiency.

A key objective of any econometric model is to be able to isolate, and observe, the impact of an independent variable on a dependent variable of interest. In this case, the impact is market opening to open access passenger services, and the independent variable is the efficiency of rail operations in a country. Different econometric techniques are available to capture the impact of open access competition on operational efficiency. Having identified linear regression as the preferred model, the specific choice of technique is discussed below.

Linear regression offers a powerful analytical framework, based on the conditional independence assumption (CIA). Also known as “selection on observables’’, this states that introducing control factors and holding them fixed allows researchers to isolate the impact on the dependent variable of randomly changing the independent variable. The CIA can however be violated when the error term of the regression is correlated with the dependent variable, as a result of omitted variable bias, simultaneous equations measurement error, missing data, or misspecification of the functional form (Angrist and Pischke 2008).

The possibility of causal links running in the opposite direction to what is assumed in this study (i.e. an improvement in efficiency leading to market entry) can be discarded based on the fact that entry is determined by regulatory changes in the first place, and only subsequently by market attractiveness. In order to avoid the omitted variable bias, theory suggests that all variables that may be correlated with the dependent variable should be included in the regression model. This avoids the error term being correlated with the dependent variable, which would undermine the validity of the analysis.

The number of variables that can potentially be related to railway industry costs is very big, and an unrealistically large dataset would be needed in order to perform standard linear regression for the purpose of this analysis. Instead, using panel data (datasets in which sets of units are observed over time), two alternatives are available: the fixed effects (FE) model and the difference in difference (DID) estimator.

The FE model enables researchers to control for all variables that vary over the cross-sectional units but are constant over time, even though we cannot measure those variables. For example, a country’s infrastructure manager may have an internal management policy of contracting out maintenance in order to reduce costs. This would need to be accounted for; but in the absence of such information, we can account for this time-invariant practice in the FE model. FE models, however, rely on stronger functional form assumptions which may be violated if panel datasets are not large enough.

Given the limitations in data availability discussed above, the DID estimator has been chosen for this work. DID is a commonly used technique to measure the difference between the average change in the dependent variable (Y) in a treatment group and in a control group[2]. The policy change / occurrence (in this case the entry of OAO) represents the ‘treatment’. The treatment group consists of countries that have received this treatment (Austria, the Czech Republic and Italy) whereas the control group contains countries that have not.

The DID technique is appealing because it controls for invariant differences between groups (embedding the properties of time fixed effects described earlier) and it compares changes between

2 The analysis leading to the selection of the appropriate control group is presented in Appendix 1.

groups over time (before and after the treatment). Specifically, as detailed by Angrist and Pischke (2011), “the heart of the DID set-up is an additive structure for potential outcomes in the no-treatment state […meaning that…] in the absence of change, [the outcome variable] is determined by the sum of the time-invariant state effect and a year effect that is common across states” (p.170).

The DID estimator can be obtained by way of regression, using dummy variables for ‘treatment’ and for ‘after’. An interaction variable between these variables is created, capturing the impact of the policy change over time. The DID model can be expressed as follows:

$$(1)\ \mathrm{Outcome\ variable}_{it} = \beta_0 + \beta_1 \mathrm{post}_{it} + \beta_2 \mathrm{treated}_{it} + \beta_3\ \mathrm{post} * \mathrm{treated}_{it} + \varepsilon_{it}$$

Therefore the data requirements necessary to perform this analysis are less onerous than under a FE model. It is only necessary to collect data on operating costs and train-km, both prior to and after the policy change, in order to construct a measure of cost efficiency that is compared before and after open access entry, and between treatment and control group. However further data is needed in order to establish that the assumptions of the DID technique are not violated, and to add explanatory variables.

This key assumption is that the treatment and control groups being compared have parallel trends. That is, irrespective of policy changes, the two groups would have developed in a very similar way. This assumption is verified in two ways: first, by carrying out a visual comparison of historical trends in operating costs, passenger and freight traffic in the two groups during the years before the policy change, in order to select a control group that is most suitable; secondly (adopting the methods employed by Graham et al 2013), by testing the null hypothesis that the selected control group has a statistically significant slope divergence from the treatment group; if the null hypothesis can be rejected with statistical confidence, than the parallel trends assumption holds.

Lastly, the DID estimator may suffer from serial correlation. The presence of serial correlation (within groups and over time periods) can adversely affect the performance of the estimator, as investigated by Bertrand et al (2004), leading to inconsistent standard errors. The model used in this research derives standard errors both with robust standard errors (which correct for heteroskedasticity) and clustered standard errors (which deal with autocorrelation in panel data). Models with both robust and clustered standard errors are compared.

Summary of results

Descriptive statistics

The dependent variable, operating cost per train-km, has been calculated for all countries in the sample and for all years 2007-2013. The mean unit cost for the sample as a whole is EUR 27.5 per train-km in 2013, and the standard deviation is just over EUR 10. Most countries' average unit costs fall within one standard deviation from the mean, except for France (highest unit costs) and Hungary (lowest unit costs).

These figures are consistent with previous research published by the OECD (2015) showing that the average cost per train-km across Europe was EUR 25.8 in 2011. In a benchmarking study of passenger operators, Civity Consultants estimated operating costs per train-km to be between £10-15, the equivalent of EUR 12-18. Adding infrastructure costs (on average 20-50% of operators' costs) leads to a similar figure. These comparisons provide external assurance with respect to the reliability of the data collected.

The following charts provide some further analysis based on the data collected for nine rail networks: Austria, the Czech Republic, Finland, France, Ireland, Italy, Portugal and Spain.

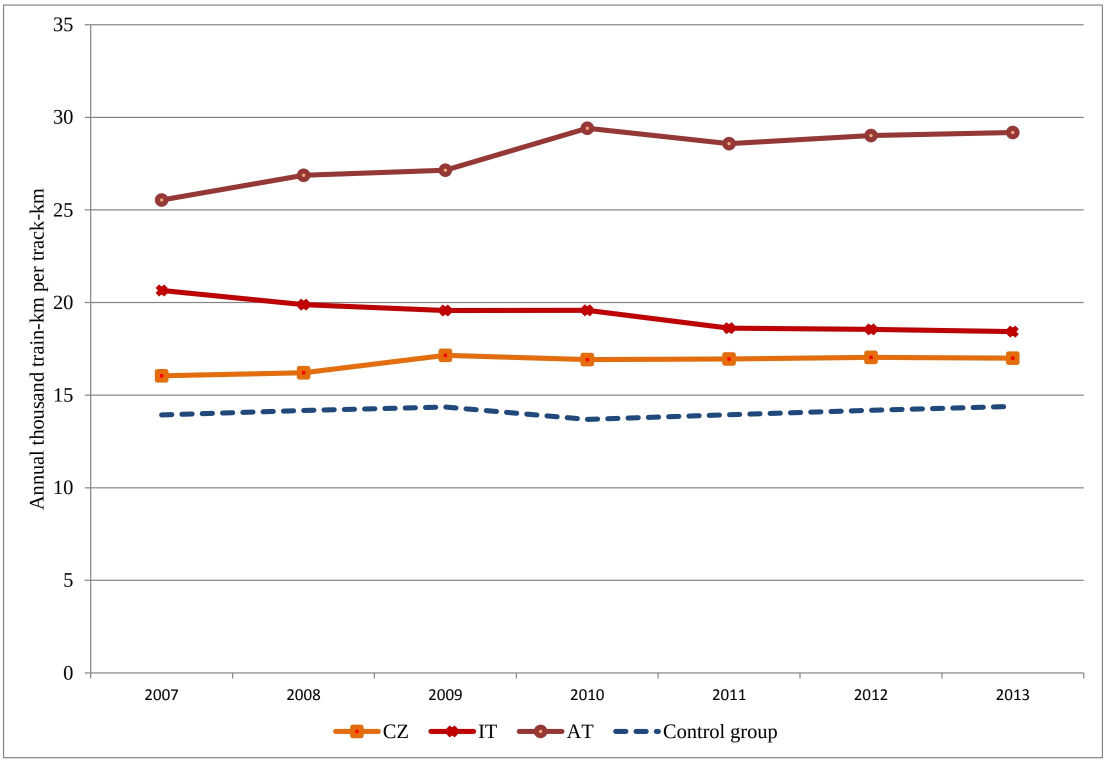
The number of train-km run on these networks has remained remarkably stable within the range of 1.500-1.600 million train-km per year. Following a decline in the aftermath of the 2009 economic crisis, moderate growth has led to traffic levels returning to pre-crisis values. When examining traffic density (total train-km per track-km) over 2007-2013, we can see density declining moderately in the Italian network, and increasing moderately on the Austrian and Czech networks (Figure 1). After 2011, the entry of new operators has not led to an apparent increase in train-km in the treated group. Rather, new entrants have eroded market shares from incumbents and total traffic density has remained fairly stable in the treated group.

Total operating costs have declined in Italy between 2007 and 2010, reflecting both restructuring activities and new commercial policies launched by Trenitalia in particular, but cost reductions have slowed down since 2011. Conversely, costs in Austria grew up to 2010, whereas costs in the Czech Republic have remained fairly stable over the period observed. Therefore, when considering the three treated countries together, operating costs decreased between 2009 and 2011, but remained stable over the period 2011-2013.

These figures suggest that an appropriate turnaround point for the analysis of 'before' and 'after' effects might be the end of 2011 for all three treated countries – not just because all OAOs were active by 2012, but also because an average of unit costs for the period 2007-2011 offers the opportunity to normalise the fluctuations seen during these years, mostly linked to the economic crisis and the subsequent decline in traffic, common to all countries in the panel, rather than any specific policy changes.

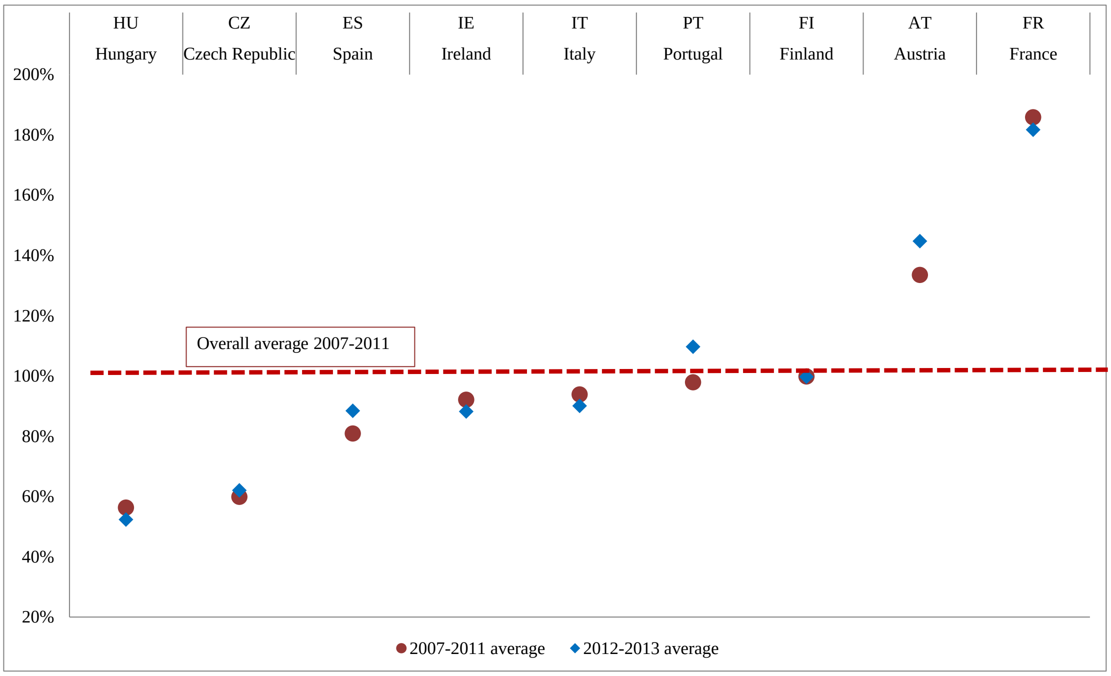
When efficiency (operating costs per train-km) for 2007-2011 is compared to the 2012-2013 period, some further trends can be observed in Figure 2 below, where costs are normalised with respect to a historical average of 100%. Two countries out of three in the treated group (Austria and the Czech Republic) saw a marginal increase in unit costs between the two periods. However costs increased in countries in the control group too, such as Spain and Portugal. A downward trend in unit costs was seen in Italy, and also in markets with limited passenger competition such as Hungary and France.

Figure 1. **Traffic density (thousand train-km per track-km) of national rail systems, 2007-2013**



Source: Own calculations based on UIC, RMMS and annual reports data.

Figure 2. **Operating cost efficiency (operating costs per train-km) in national rail systems, 2007-2013**



Source: Own calculations based on UIC, RMMS and annual reports data. Overall average 2007-2011 is equal to 100%.

An overall comparison of 'before and after' differences is presented in the table below. This is the precursor to the DID estimation which follows. It shows that the control group has initially higher unit costs; average unit costs in the treated group grow more than in the control group, and; the difference in unit costs between the control and treatment group therefore narrows after open access entry.

Table 3. **Unit costs before/after open access entry**

Groups	Measures	Opex per train-km Before OA entry (€)	Opex per train-km After OA entry (€)	Change (€)
Treated group	Mean	26.1	26.9	0.81
Control group	Mean	27.6	28.1	0.46
Difference	Treated - Control	-1.5	-1.2	-0.35

Difference in difference (DID) estimator

The following DID model set up for this study builds on Equation 1 and reflects the framework of two periods (pre and post treatment) and two groups (treated and control):

$$(3)\ \mathrm{Ln\_Opexpertrainkm}_{it} = \beta_0 + \beta_1 \mathrm{post2011}_{it} + \beta_2 \mathrm{treated}_{it} + \beta_3\ \mathrm{post2011} * \mathrm{treated}_{it} + \varepsilon_{it}$$

The outcome variable (logarithmic measure of operating cost per train-km) is regressed against a dummy for observations after 2011, and a dummy for the treated group. The coefficient of interest is β3, the interaction variable between post and treated (PT). Full results are in Appendix 2.

The coefficients for treated and post are not statistically significant at the 90% confidence level. This means that it is not possible to draw any conclusions as to whether: the rail systems in the treatment group are in any way more or less efficient than the ones in the control group, and; there is any significant difference in the operating costs over the period 2012-2013 compared to 2007-2011.

However in equation (3) the coefficient for the interaction variable PT (post * treated) is large and significant at the 90% confidence level. The coefficient 0.201 would suggest the presence of a 20% gap in unit costs (operating cost per train-km) between the two groups, with unit costs being considerably higher in Austria, the Czech Republic and Italy following the policy change. Two issues with this regression model suggest that further research is needed, however: first, the coefficient of interest is only marginally significant and the null hypothesis (no difference between the groups) can only be rejected with a 10% probability level; second, the overall explanatory power of the model is very weak, with an R2 of 2%.

It is possible to exploit the properties of the DID estimator by adding further covariates to the model in order to both improve its explanatory power and to assess the strengths of the coefficients estimated in Equation 3 in the presence of other variables. Following on from the test in Equation 2.A (see Appendix 1), measures of passenger and freight traffic can be added to the model. When these covariates are added (Equation 4), the coefficients of the variables included are not statistically significant and hence do not explain the variation in unit costs. There seems to be however a potentially positive impact of more passenger traffic on unit costs and a potentially negative impact of freight traffic. The R^2 of this model is higher at 22%.

An alternative model can be specified with the inclusion of state-specific time trends as regressors. As discussed by Angrist and Pischke (2008) with reference to Besley and Burgess (2004), the addition of state-specific time trends can act as a robustness check. This check allows us to understand whether the estimated impacts of interest change once the underlying trends are controlled for. On the one hand, the inclusion of state-specific trends may be appropriate to net out the impacts of interest in the econometric model; on the other hand, it may lead to an over-specified model, affecting the validity of standard errors.

When state-specific trends are introduced (Equation 5), two main effects unfold. The explanatory power of the model increases greatly, leading to a high R^2 value. However the size of the coefficient of interest decreases and the standard errors lie outside the confidence interval. The inclusion of state-specific trends therefore kills the effect of competition on unit costs.

If we accept these results, two main interpretations are possible. The first is that the introduction of open access competition correlates with other long-term trends at the state level, whose causal effects cannot be disentangled from the policy change. The alternative explanation is that open access competition takes place where costs are following an upward trend. This might not be a coincidence, but rather an indication of strategic behaviour by new entrants entering the less efficient markets.

Equation 6 tests the model with the inclusion of both traffic covariates and state-specific trends. This model confirms the absence of any statistically significant relationships once all covariates are included. Lastly a model with differently-specified standard errors (i.e. robust errors) is tested. A potential limitation related to the use of clustered standard errors is the low number of clusters included in the analysis. Instead of correcting for within-state correlation, robust standard errors only correct for heteroskedasticity. Comparing Equation 6 and Equation 7, robust standard errors are smaller than clustered standard errors for the coefficient of interest (0.36 instead of 0.42), but they still lie outside the 90% confidence interval.

The results of an alternative model are shown in Appendix 2. This model follows an different time specification which shifts the before and after periods. Here, the potential impacts of open access competition are assumed to take place shortly after the date in which open access operations are announced by the new entrant. For the countries in the treatment group, the announcement year is considered to be 2008, when new entrants announced their intention to entry the market either by public statements (Austria and Czech Republic) or by application for track access rights (Italy).

Hence the alternative model is specified as follows:

$$(8)\ \mathrm{Ln\_Opexpertrainkm_{it}} = \beta_0 + \beta_1 \mathrm{post2008_{it}} + \beta_2 \mathrm{treated_{it}} + \beta_3\ \mathrm{post2008} * \mathrm{treated_{it}} + \varepsilon_{\mathrm{it}}$$

The results of Equation 8 point to a statistically significant effect of open access competition on unit costs, when the announcement date is considered as the market entry point. Specifically, the coefficient of the PT variable is positive and significant at the 95% confidence level, in contrast with Equation (3). The size of the coefficient is smaller, indicating that unit costs in the treatment group are some 14% higher than in the treated group. When control variables on passenger and freight traffic are added, the coefficient remains significant but decreases to 13%, while the R2 of the model increases to 22% (Equation 9).

However, even when announcement dates (rather than market entry) are taken into account, the inclusion of state-specific trends likewise kills any competition effect. This can be seen in the results of Equation (10), where the inclusion of a control variable for each state-specific trend results in all other variables becoming insignificant. As discussed above, this may in itself provide some indications around changes in the competitive landscape as growing costs might be one of the reasons for entry.

Discussion

Interpretation of results

The difference-in-difference estimator developed for this study provides some preliminary, yet not conclusive, indications on the impact of open access competition on the efficiency of railway systems. The simplest DID model tested (with no covariates and no state-specific trends) suggests that the introduction of open access competition in the passenger sector leads to higher operating costs for railway systems. This finding is consistent with the view that additional costs linked to the entry of new operators can outweigh the potential positive effects of competition, and thus increase total costs by way of a duplication of functions and an increase in coordination costs.

The second set of DID models tested, whereby the before and after comparison is brought forward to reflect announcement dates, suggests that the introduction of open access competition raises system costs soon after new entrants announce their intention to enter. Models which compare unit costs after new entrants have expressed their intention to operate services show a smaller increase in costs, carrying however greater statistical confidence. A possible explanation is that higher coordination costs (borne especially by the infrastructure manager) arise during the process of track access applications, capacity allocation, and timetabling.

Adding explanatory variables that account for potentially large cost drivers (the amount of passengers and freight transported), and state-specific trends, does not yield the expected results. Traffic loads do not appear to have a causal effect on operational costs over the observed period. Instead, the inclusion of state-specific trends explains the variation in costs over time and across observations. This result may, as detailed above, be interpreted in different ways. Of particular interest is the possibility that new entrants may have been targeting those markets where operating costs were either higher than average, or were on an upward trajectory.

The existence of such strategic behaviour can be validated using some of the auxiliary information gathered earlier. By the end of the first decade of the 2000s, Austrian railways indeed had higher unit costs across Western Europe, and unit costs in the Czech railways were higher than most Central-Eastern European systems. Moreover cost trends did not suggest that these countries were on a path of efficiency improvements. In Italy, savings were being made by the incumbent operator, though against a background of historical financial losses which signalled the presence of large inefficiencies.

Can the combination of relatively inefficient incumbents and de jure open access explain why costs have not decreased in the presence of competition? Perhaps, if one considers the hypothesis that further inefficiencies are introduced in rail systems through the introduction of on-track competition. There is also evidence that incumbent operators have accelerated planned investment, such as in rolling stock, in order to match the new entrant's quality improvements, thereby raising short-term costs in anticipation of market entry.

In addition, other aspects of the incumbents' behaviour may have changed strategically to deter entry. For instance, it may have been the case that operators have delayed the implementation of cost efficiency measures in order to send negative signals to potential new entrants about the size of industry margins, or may have changed accounting practices (e.g. the allocation of internal costs) to reduce the ability of new entrants to assess industry costs, profitability of specific operations, and/or benchmark their planned financial results with those of existing operators.

Relatively inefficient incumbents are clearly not the sole reason for entry, and the above discussion does not exhaust all the possible mechanisms through which efficiencies are slowed down. The presence of regulatory barriers to both market access and market growth, only briefly discussed in this paper, is a key confounding factor that has affected the efficiency of operations by new entrants. While it is impossible to isolate this effect as part of our empirical analysis, the role played by barriers surrounding the licensing, certification, capacity allocation, timetabling and other rail-related processes must be recognised.

The concomitant presence of market entry and rising unit system costs can also be explained by growing capacity constraints on the Czech network, the difficult co-existence of expanding freight and passenger services on the Austrian network, and the end-tail of the HSR deployment programme in Italy, including new station openings and more complex timetables; the potentially negative effects of all of the above factors may have been exacerbated by the introduction of competition.

Contribution to the existing literature

The key conclusion that on-track competition has not led to a decrease in operating costs in the rail systems affected is in line with previous findings across what is a relatively small literature. In particular similar conclusions have been reached by Driessen et al. (2006), who found that competitive entry lowers system efficiency, and Mizutani et al. (2014), who found that competition does not reduce system costs. However Driessen's analysis covers the impact of both passenger and freight entry, and Mizutani's work covers both for the market and in the market competition – as such these studies are not directly comparable.

A number of other studies reviewed above (McNulty 2011, Cantos et al. 2013, Wheat and Smith 2015) have instead identified some positive efficiency impacts from open access in freight services following the Second Railway Package reforms. However two key differences exist between passenger and freight rail: first, market opening in the freight sector has not often led to direct on-track competition between operators – rather, market segmentation has resulted in different operators specialising in different flows of goods; secondly, freight liberalisation has often coincided with the privatisation of national incumbents – conversely incumbent passenger operators are all entirely state-owned, with the exception of Great Britain.

Limitations and potential further research

The analysis carried out for this paper needs to be further refined, as it suffers from a number of shortcomings. These are highlighted in the following paragraphs, together with some ideas for future research.

Theories of competition often struggle to define the appropriate timeframe after which the impacts of competitive dynamics can be assessed. This study is looking at a relatively short period (2-3 years) of activity by new entrants which may be deemed too short to yield any sizeable efficiency gains. This is particularly true in the rail industry, given the slow pace at which changes in timetable and rolling stock can be made. Work by Jensen in Sweden has identified efficiencies over a 10-year period.

Experience from other sectors such as the aviation industry can also provide a useful benchmark. Competition responded sluggishly to liberalisation reforms, and the main gains only began to take place as a result of competition between incumbents and new entrants, once new entrants had reached a critical size, and national airlines had been privatised (Ng and Seabright 2001). Even stronger efficiency gains have been achieved from combined privatisation and competition in the telecom sector; however has seen a large reduction in economies of scale and scope as a result of technological innovation (Li and Xu 2004), not yet seen in the rail sector. Hence a key concern with the present study is that competition has been too short-lived to yield any impacts on costs – it is therefore recommended that this analysis should be repeated in the coming years to allow for competitive dynamics to unfold fully.

In addition, two of the pre-conditions for competition to take place as discussed above (that the presence of commercially-viable routes, and a guarantee of non-discriminatory access) have not been fully met in the countries surveyed, with episodes or at least allegations of loss-making services to undercut competitors and potential discrimination in access conditions that may have damaged new entrants.

The application of DID techniques to the rail policy arena is a useful step forward, but the lack of statistically significant results once state-specific trends are included raises more questions than DID can answer. The specific impact of different covariates could only be appropriately tested using a fixed-effects model with panel data. This would require both a longer timeframe and more country observations. Rail systems, and especially those open to competition, are limited and it is unlikely that a critical size could be achieved in the near future.

The DID set-up nonetheless allows us to isolate the impact of the policy change of interest, since the outcome variable is determined by the sum of the time-invariant state effect and a year effect that is common across states. However such set-up holds only in the presence of a very similar control group. My analysis has shown that there is no statistically significant divergence between the treated and control group, however in the future this assumption could be further validated. For instance, propensity score matching (PSM) could be used to sort countries along a spectrum and assign a control market for each treated market, thereby further controlling for exogenous differences.

As far as data quality is concerned, the dataset used in this study is likely to suffer from the shortcomings classified as ‘standardisation’ and ‘normalisation’ (Makovsek et al., 2015). Some of the key issues with non-standardised data include year-on-year changes in organisational structures and accounting policies. Companies may also been given different functions and perform different activities (e.g. station management), which affects their efficiency. When operators are State-owned, external government policies also play a role in affecting companies’ behaviour. Issues with normalisation arise because size and density are important determinants of efficiency and should be controlled for. In the sample used for this study the largest outliers have been excluded, nevertheless the introduction of further controls on these characteristics is recommended in the future.

Finally the analysis of impact of competition in the market for passenger services could be widened, beyond operational efficiency. Other measures of efficiency, namely physical measures looking at train load factors and infrastructure utilisation, could be explored. While other aspects such as service quality and impacts on rail fares have already begun to be observed, it will be important to assess the wider impacts of competition such as technological innovation (both on-board, and in rail-related services), labour market effects , the implications for public finances and any evidence around intermodal competition effects.

A difficult, yet necessary assessment

While this paper is based on data up to 2013, the rail market developments which have taken place over the following years point to the importance of gaining a better understanding of open access competition impacts. The following paragraph summarise these key developments. Although a separate paper would be needed to discuss the implications of each, these developments highlight the importance of assessing the industry impacts of greater rail competition in the coming years.

The vast majority of EU Member States is implementing macroeconomic adjustment policies which involve public deficit reductions, de-leveraging and a renewed focus on public spending that leads to jobs and GDP growth. As part of this adjustment process, rail subsidies are coming under increased scrutiny, since the EU rail sector absorbs EUR 36 billion of public funds annually, an average of EUR 80 for each EU citizen (European Commission, 2014). Benchmarking studies (McNulty Review 2011, Steer Davies Gleave 2015) show that the potential for cost savings in the industry is high. Competition, including open access, is seen as one of the possible solutions to stimulate efficiency.

The view that competition can spur efficiencies in rail markets has been voiced during the recent negotiations over the Fourth Railway Package, whose market pillar contains legislative measures in relation to the opening of the market for domestic passenger transport services by rail, as part of the drive towards a Single European Railway Area. The Commission's proposal, if approved, is likely to be moderated by rules around the economic impacts of open access, and subject to a delayed implementation timeline. Nonetheless, if non-discriminatory access conditions are enforced, this could lead to greater market opening across the EU; potentially efficiency-distorting barriers such as those faced by new entrants in the countries sampled could be removed and the efficiency gains associated with competition may be more pervasive.

Such legislative prospects, together with the emerging evidence that competition can be durable in some rail markets, have contributed to attracting the interest of existing and new train companies. Since 2014, on-track competition has consolidated in Sweden and Germany. At the time of publication (March 2016) the OAOs mentioned in this paper continue to operate and have made new rolling stock orders throughout 2014-15, signalling their intention to expand; established operators have been planning new cross-border operations (e.g. Trenitalia between Paris and Brussels, Arriva between Prague and Trenčín); competition will extend to the West Coast Main Line in the UK from 2018 with new services between London and Blackpool; and German new entrant Locomore has successfully reached its crowd-funding target with a view to launch services between Berlin and Stuttgart in 2016.

Conclusions and way forward

Using a difference-in-difference estimator, this paper finds that two years of on-track competition following open access entry have not yielded operational efficiencies in the rail markets affected (Austria, the Czech Republic and Italy) when compared to a group of similar rail networks. On the contrary, it appears that on-track competition is to date resulting in higher unit costs than in countries with monopoly passenger services. Higher unit costs may be the result of negative efficiency impacts (loss of economies of density, duplication of large upfront investment costs, higher coordination costs) outweighing the positive efficiency impacts witnessed in other liberalised sectors.

These preliminary results are based on a short time frame and will need to be tested over the next few years. Competition is a process rather than an episode, and longer timeframes may be needed for competition dynamics to unfold in the railways, as experience from other sectors suggests. Better econometric models for studying competition impacts could also be developed further with the inclusion of more explanatory variables and a larger sample, as market entry takes place across Europe.

Improving the availability and quality of data on rail indicators, as recommended by the OECD (2015), will be critical to improve future analysis. In parallel, it is important to better understand the determinants of efficiency in rail operations and management by developing detailed narratives that account for changes in both internal and external events – of which the introduction of competition is only one.

In the context of pressures to ensure greater value for money from public expenditures (of which the railways are a large recipient), forthcoming European reforms under the Fourth Railway Package and growing interest in market entry by new operators, assessing the emerging impact of the controversial policies around rail market opening is necessary in order to inform future decisions on subsidy levels, regulatory changes and institutional reforms in the railway sector.

Appendices

Appendix 1 – Selection of the control group for the DID model

The identification of a suitable control group follows both qualitative and quantitative principles, in order to ensure that the parallel trend assumption between the treated and the control group holds.

The starting point to identify a control group is the entire set of EU Member States, excluding those with active and significantly large OAO. However, smaller or more recent OAO are active in Germany, Sweden and the UK. In order to avoid any confounding effect potentially emerging from on-track competition in these countries, they are excluded from the control group. Secondly, countries with long-standing competition for the market may also be unsuitable for comparison. For this reason, Denmark and the Netherlands are excluded. Thirdly, very small networks (i.e. with less than 10 billion train-km of annual traffic) such as Estonia, Greece and Luxembourg are not included in order to minimise size variation between samples. Fourthly, data limitations, particularly on the cost side, determine to the exclusion of five other countries.

Based on these qualitative and data-related considerations, a sub-sample of eight European rail networks is put forward as a candidate to be part of the control group: Belgium, Ireland, Spain, France, Hungary, Portugal, Romania and Finland. The next step consists in the assessment that the treatment group and the control group follow parallel trends before the treatment takes place. This is best done in visual format, following similar assessment by Card and Krueger (2000) and Pischke (2007).

Focusing on the years prior to market opening (2006/7-2011), it is possible to observe a common underlying trend for both treatment and control countries in the key variable of interest (operating cost per train-km). Belgium and Romania are excluded from the analysis due to an unstable ratio over the observed period.

In order to further assess the commonality of trends between the two groups, the following chart plots the average GDP per capita over the period 2006-2011. This shows that that both groups experience a plateau over the period 2007-2008 and a sharp decline thereafter, only to return to moderate growth in personal incomes between 2010 and 2011. Since transport demand is derived demand from economic activity, the choice of control group as being subject to a similar economic cycle is validated. Further checks looking at the historic record of passenger-km and tonne-km (freight) on the railways result in similar trends, except for a divergence in passenger-km in 2011 between the two groups.

Further quantitative evidence on the appropriate choice of the control group (now including only Finland, Ireland, Spain, France, Hungary and Portugal) is provided by way of OLS regression, following Graham et al (2013). In their paper, Graham and colleagues test whether the potential control group satisfies the parallel trend assumption for the period corresponding to the pre-treatment period of the analysis. This regression tests the null hypothesis that the selected control group has a statistically significant slope divergence from the treatment group; if the null hypothesis can be rejected with statistical confidence, then the parallel trends assumption holds. If the assumption holds, the outcome variable must follow the same trend over time in the treated and each of the potential control groups during the pre-treatment period.

The regression model used is the following, where YC is the variable of interest (a dummy variable for the countries in the control group) and ln_paxkm and ln_tonkm are two control variables on a logarithmic scale, representing annual passenger and freight traffic respectively.

$$(2.\text{A})\ \text{Ln\_Opexpertrainkm}_{it} = \beta_0 + \beta_1 \text{YC} \quad + \beta_2 \ln\text{\_paxkm}_{it} + \beta_2 \ln\text{\_tonkm}_{it} + +\varepsilon_{it}$$

The coefficient of the interaction variable (YC) in Equation 2 is not statistically significant. This indicates that the control group does not have a significant slope divergence from the treated group and the null hypothesis can be rejected. The assumption of parallel trends holds: the group of selected countries can be effectively regarded as an appropriate control because there is no statistically significant difference between its slope and that of the treated group.

Table A.1. **OLS regression results for the control group**

	(2)
YC	-0.0002
	(0.38)
Log of Pass-km	0.203
	(1.27)
Log of Tonne-km	-0.074
	(0.82)
Constant	3.016
	(10.05)**
R^2	0.21
N	63

The coefficient of the interaction variable (YC) in Equation 2 is not statistically significant. This indicates that the control group does not have a significant slope divergence from the treated group and the null hypothesis can be rejected. The assumption of parallel trends holds: the group of selected countries can be effectively regarded as an appropriate control because there is no statistically significant difference between its slope and that of the treated group.

Appendix 2 – DID regression results

Table A.2. **DID regression results (Equations 2-7)**

	(3)	(4)	(5)	(6)	(7)
Treated	-0.066	0.074	-74.671	-61.748	-61.748
	(0.20)	(0.20)	(2.20)	(2.08)	(1.15)
Post	0.005	0.009	-0.017	-0.014	-0.014
	(0.18)	(0.31)	(0.55)	(0.45)	(0.38)
PT	0.201	0.174	0.071	0.046	0.046
	(2.06)*	(1.73)	(0.56)	(0.42)	(0.36)
Log of Pass-km	NO	0.201	NO	0.347	0.347
		(1.23)		(1.37)	(1.64)
Log of Tonne-km	NO	-0.072	NO	-0.033	-0.033
		(0.79)		(0.28)	(0.35)
State-specific trends	NO	NO	YES	YES	YES
Constant	3.252	2.890	-9.348	-13.933	-13.933
	(24.05)***	(10.48)***	(0.30)	(0.46)	(0.71)
R^2	0.02	0.22	0.95	0.95	0.95
N	63	63	63	63	63

* p<0.10; ** p<0.05; *** p<0.01

Notes: The table reports estimates from DID regression using four different models. The dependent variable is the logarithmic scale of unit costs (operating costs per train-km) for 9 EU Member States over the period 2007-2013. The independent variables are dummy variables (treated, post), interaction term (PT) and covariates of traffic flows. State specific trends are interaction variables between a state dummy and a year dummy. Clustered standard errors are reported in parentheses for equations (3), (4), (5) and (6); robust standard errors are reported for equation (7).

Table A.3. **DID regression results (Equations 8-9)**

	(8)	(9)	(10)
Treated	-0.112	0.031	-102.242
	(0.37)	(0.09)	(0.99)
Post	0.010	0.006	-0.030
	(0.22)	(0.12)	(0.38)
PT	0.145	0.130	0.304
	(3.10)*	(3.14)*	(1.40)
Log of Pass-km	NO	0.201	-0.137
		(1.23)	(0.57)
Log of Tonne-km	NO	-0.072	-0.054
		(0.79)	(0.29)
State trends	NO	NO	YES
Constant	3.246	2.888	-13.637
	(24.77)**	(10.97)**	(0.62)
R^2	0.01	0.22	0.95
N	63	63	63

* p<0.05; ** p<0.01

Notes: The table reports estimates from DID regression using three alternative models. State specific trends are interaction variables between a state dummy and a year dummy. Clustered standard errors are reported in parentheses.

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