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Vertical integration, separation in the rail industry: a survey of empirical studies on efficiency

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Whether vertical separation of the rail industry creates demonstrable performance and efficiency gains is an issue of ongoing economic analysis and public policy debate. To assist in consideration of the merits and disbenefits of vertical separation this paper provides a summary of the different studies that have been undertaken to gauge the effects of vertical separation on the rail industry, and analyses and codifies the main findings of this research. The evidence indicates that whether separation will improve efficiency of a jurisdiction's rail industry, and the extent to which this will occur, depends upon a number of specific conditions including what range of services are being provided – that is, passenger and/or bulk or general freight –the intensity of track use, and the extent to which inter-modal competition exists. The research highlights the merits of undertaking preliminary analysis of the characteristics of a jurisdiction's rail sector before initiating structural reform of this nature.

Keywords: *Vertical integration; separation; competition, rail industry; public ownership, private ownership, efficiency.*

1. Introduction

Productivity in the rail industry has been the subject of considerable investigation over an extended period; key studies including those by Klein (1947), Borts (1952, 1960), Meyer (1958), Griliches (1972), Keeler (1974); Caves and Christensen (1980); Harris (1977); Caves, Christensen and Swanson (1980); and Braeutigam, Daughety, and Turnquist (1984). Dodgson (1985), Hooper (1987) and (Oum, Waters & Yu 1998) provide detailed summaries of this work. An important policy purpose underlying much of this research was to investigate the relative efficiency of private versus government ownership and the relative efficiency of firms in regulated and unregulated environments. In addition, some European based studies looked at the efficiency effects of management autonomy. In more recent years, however, attention has turned to the effects on performance and productivity of the vertical disaggregation of the industry; that is the separation of the ownership and maintenance of the rail and associated infrastructure (signal equipment, marshalling yards and stations) on the one hand from the running of the trains on the other.

It is possible for the rail industry to be vertically integrated – that is, infrastructure services (track, signals and stations) and the operation of trains incorporated into a single firm – or vertically disaggregated, with the infrastructure services and train operations separated. Such separation enables those components of the industry with natural monopoly characteristics, the track

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services, to be detached, thereby allowing above train operators to compete against each other in the delivery of freight and/or passenger services (if there is sufficient traffic density). The track, signals and stations are considered more of a natural monopoly because they are durable and immobile and generally uneconomic to duplicate (unless density of traffic is very high). Train operations do not share these characteristics, although do possess some economies of scale and density (Wheat & Smith 2015, 35). Separation may take a variety of forms ranging from complete detachment of the provision of track infrastructure from the operation of passenger and/or freight trains, to putting in place third-party access arrangements so that track services may also be provided by an incumbent train operator. In some cases, the latter takes place with a holding company owing separate entities that provide the track infrastructure and train operations.

By creating competition amongst train operators it is hoped that higher levels of efficiency will be achieved; however, whether vertical separation creates demonstrable performance and efficiency gains is still an issue of debate. To shed further light on the merits of vertical separation, the focus of this brief paper is twofold – first to provide an overview of the different studies that have been conducted on the effect of vertical separation on the rail industry, and secondly, and more importantly, to analyse and codify the key structural findings of this research in order to determine how important vertical separation is to improving the performance of the industry. In providing this analysis the paper will provide assist policy makers on the issues surrounding rail industry separation.

The rest of this paper is structured as follows. Sections 2 and 3 set out the context in which the issue of vertical disaggregation is to be considered. This is done by first briefly detailing the theoretical bases underpinning reforms of this nature, and secondly by outlining some of the more recent regulatory and structural changes that have occurred in the rail industry, particularly those that have taken place across Europe and Australia. The following section then examines the research assessing these and related reforms – first focusing on the studies undertaken, and then summarising the research findings. Section 5 concludes by considering the policy implications of this analysis and highlighting issues that may be a focus of future research and examination.

2. Theoretical drivers of vertical separation

The primary theoretical driver for vertical separation in the rail industry is that it will enable on track competition. In turn it is argued that by enabling on track competition, vertical separation will:

- create incentives to reduce costs and promote innovation from increased competitive pressures amongst train operators;
- lead to greater specialisation of operators and their expansion into other markets;
- create competitive neutrality between train operators so that the most efficient survives and grows; and
- create a greater degree of transparency for policy makes in the form of information on access pricing, track usage, etc.

The extent of the potential benefits of vertical separation will, however, depend on the specific nature of the rail industry in question. This is because the benefits of vertical separation appear to be higher:

- the greater the proportion of the industry with potentially competitive elements (train operation). However, rail has high fixed and sunk costs which mean the potentially competitive element is relatively small;
- the greater the potential for productivity improvements;

- the denser the market and greater the scope for competitors to operate. Rail has significant economies of density.[3] The share of costs in the industry in the potentially competitive activities is higher in rail freight (sixty to eighty per cent freight based on the United States experience, but lower for passenger fifty per cent based on the United Kingdom experience: Gomez-Ibanez, 2003); and
- the greater institutional capacity of the industry for regulation (Drew, 2009, p. 235).

Moreover, while vertical separation and the introduction of competition might lead to higher levels of efficiency, there are also added costs associated with separation which may outweigh any benefits flowing from improved efficiency driven by competition. In particular, separating infrastructure provision from the operation of train services results in increased costs associated with the need to create new mechanisms to resolve conflicts in the allocation of train paths, for ensuring standards are met in the rail-wheel interface and for identifying who is responsible for delays (Organisation of Economic Cooperation and Development, 2005, p. 33; Merkert, 2012, p. 13). An operator of trains, for example, cannot provide a reliable, high speed passenger service if the infrastructure provider does not maintain the track to a high enough standard, and/or makes the track infrastructure available when the services are scheduled. As such, it is generally argued that for railways to operate efficiency there must be a close coordination between train operation and infrastructure track maintenance activities. Maintaining or upgrading track and other facilities directly affects operating schedules and vice versa. Similarly, there is often a technological interdependence between infrastructure and vehicle technologies (Pittman, 2005, p. 185). For example, investment, efficiency and safety depend to a degree on the intersection point between rails of the track and the wheels of the rolling stock. Railways are often tailored to particular users (or with multiple users optimised for a specific user), and can vary according to whether they are being used for passenger, general freight or bulk freight trains. Where there is vertical separation, a track infrastructure owner would be reluctant to bear the risks of specialised investments without long term contracts for a specific user. By contrast a vertically integrated railway can coordinate operating decisions with infrastructure maintenance and investment decisions and can realise the full benefits of efficiency enhancing investments. Such actions can be costly or impossible in open or forced access regimes (Ivaldi & McCullough, 2001, p. 162). Costs are also likely to be greater where there are network capacity constraints and other technical constraints (Drew, 2009, p. 235).

Indeed, there are reasons to believe that in the rail industry there exist significant economies of vertical integration. Further, vertical separation may actually reduce incentives to the infrastructure provider to maintain investment in the network. Moreover, it may also be difficult to create adequate incentives with separation for investment to occur in both maintenance and new capacity (Australia, Bureau of Transport and Research Economics, 2003, pp. 17-18; Vickerman, 2004, p. 318; Buehler, Scmutzler & Benz, 2004, pp. 265-6). There is some evidence internationally that vertical separation creates additional costs (Bitzan, 2003, p. 222; Ivaldi & McCullough, 2001, p. 180; 2004, pp. 17-18; 2008, pp. 168-9; Wetzel & Growitsch, 2006; Growitsch & Wetzel, 2007, pp. 20-1; 2009, p. 22; Merkert, Smith & Nash 2012, p. 363; Merkert & Nash 2013, pp. 23-24). If this is so separation could only be economically justified if it was expected that separation would create considerable amounts of competition, which in turn would lead to substantial efficiency gains.

3. Rail reform since the 1990s

Much reform of the rail industry has been undertaken around the world since the early 1990s. Rail assets have been corporatized, privatised, independent train operators allowed to provide

[3] Van der Velde, et.al. (2012), do however point out that at high levels of freight density the average cost of vertical separation can be high.

services over existing track infrastructure, and in a few countries separation of the track from train services has been mandated. A key driver for reform has been the view that the state-run, monopoly railways were inefficiently run as a consequence of poor incentive properties that derived from soft budget constraints, political demands for the delivery of uneconomic services and over-manning (Lalive & Schmultzler, 2007; Pittman, 2007). The private railways that replaced them, however, often experienced difficulties.

In Britain, where the widest reaching change occurred (and largest scale vertical disaggregation), when the rail system in that country was privatised in 1994 a vertically separated company, Railtrack was established to manage the track and associated infrastructure. After a fatal accident occurred (at Hatfield) which disrupted the entire system, and after extensive criticism of the company's underinvestment in physical assets, in 2002 Railtrack was bought back into quasi-public ownership as a standalone track infrastructure owner and operator and renamed Network Rail (Bagwell, 2004; Pollitt & Smith, 2002; Glass, 2011; Whitehorse, 2003). In addition, a number of the original on track operators of passenger franchises in Britain failed, arguably due to strategic or irrational bidding on the part of the operators, leading to the need to re-negotiate many contracts or to the temporary management of operators by government.

Despite these problems in Britain, reform of the rail industry has been extended to the rest of Europe.[4] The EU Directive 91/440 is the legislative instrument which provided the framework for the operation of the government-owned railways in the European Union. This Directive required that open access to track be granted to train companies other than those that own the track infrastructure. These regulatory arrangements include the cross border transit of freight. EU Directive 2001/14 sets out the framework for the creation of agencies that control and regulate the allocation of capacity to companies, and the charges for using the track. As of January 2016 the fourth railway package was agreed upon by European transport ministers and been adopted by the European Commission but not yet been approved by the European Parliament. The Package covers standards and authorisation for rolling stock; workforce skills; independent management of infrastructure; and the liberalisation of domestic passenger services (European Commission, 2013).

Subsequently nearly all European countries have separated the management of track and associated infrastructure from the operations of trains. Some like Denmark, Sweden, the Netherlands and Finland, have created fully separated train and infrastructure companies from their state run enterprises. Others countries, such as Germany, have created separate subsidiaries for infrastructure and track operations (DB Netz) while keeping ownership under a single holding company. In some other cases, separated accounting between the two organizational sections has occurred.

Outside of Europe, and on a smaller scale, the Australian Rail Track Corporation was created in 1998 to operate the Australian Government's inter-state rail track, when the on track freight operator, National Rail was first separated, and then privatised. Amongst the State and Territory jurisdictions in Australia, the process of reform has varied markedly. In the State of Western Australia, for instance, while some commuter services are vertically integrated (i.e. in the city of Perth - the capital city and largest city of the State), there is mandated access to new entrants to the intra-state regional network (i.e. in the country regions of south-east Western Australia) and vertical separation on the standard gauge, inter-state network (i.e. between Perth and the eastern states of Australia). In addition, there are vertically integrated, privately owned, rail lines in the northern parts of the state, which transport mineral ores to seaports for shipping overseas for

[4] Sweden was the first country in Europe to separate track from train operations, when in 1988 two separate companies were formed (Hansson & Nilsson, 1991).

which in the past access has not been provided.[5] By contrast, in the State of Victoria there are some commuter rail services which are vertically integrated (i.e. in the city of Melbourne - the capital city and largest city of the State), while others such as the country passenger services are vertically separated. In addition, access to track has been provided for the intra-state regional network (i.e. in the country regions) whereas there has been vertical separation of the standard gauge, inter-state network (i.e. between Melbourne and the other states of Australia). Similarly, in New South Wales from 2004 until 2013, the state government owned company, RailCorp provided metropolitan passenger rail services via CityRail and long distance services via CountryLink, while providing access to freight operators. In 2013 the company's operation and maintenance functions were transferred to Sydney Trains and NSW Trains, leaving RailCorp as an asset owner (see Merkert & Hensher, 2014, pp. 4-9).

4. Vertical separation – research methodologies and findings

While considerable reform of the rail industry has occurred over the last two decades, the empirical bases upon which these changes have occurred is less clear. The purpose of this section is to summarise the methodologies used to assess the efficacy of reform to vertically separate the rail industry, and to codify the key findings of this research.

4.1 Methodologies

Since the early 1990s, a disparate body of research has been undertaken to assess the merits rail vertical integration/separation. As illustrated in Table A1 and A2 provided in the Appendix, the research to date has ranged from interviews/surveys (see for instance: Merkert & Hensher, 2006; Merkert & Nash, 2013) and case study based analysis (see for instance: Dionori, Dunmore, Ellis, & Crovato, 2011; Drew, 2009; Nash, Nilsson & Link 2011) to more empirically based analysis of productivity improvement. In this latter cohort of studies, methodologies utilised include data envelopment analysis (DEA) (see for instance: Cantos, Pastor & Serrano, 2008, 2010; Driessen, Lijesen & Mulder, 2006; Growitsch & Wetzel, 2007, 2009; Wetzel & Growitsch, 2006), multi-directional efficiency analysis (MEA) (see for instance: Asmild, Holvad, Hougaard & Kronborg, 2009); cost functions (see for instance: Bitzan, 2003; Ivaldi & McCullough, 2001, 2004, 2008; Jensen, & Stelling, 2007; Mizutani & Uranishi, 2012; Mizutani, Smith, Nash & Uranishi, 2015; Nash, Smith, van de Velde, Mizutani & Uranishi, 2011), stochastic production frontier (see for instance: Friebel, Ivaldi & Vibes, 2003, 2004, 2010; Wetzel, 2008). Most of these studies involve an estimation of relative efficiency across companies/countries. For a comparison of approaches, see Mulder, Lijesen & Driessen (2005, pp. 16-18); Driessen, Lijesen & Mulder (2006, pp. 15-18), Friebel, Ivaldi & Vibes (2010, pp. 78-79) and Van de Velde et. al. (2012, pp. 12-13).

In economics, efficiency is a reference to the extent to which waste or other undesirable features are avoided by a producer. Productivity, in turn, is an average measure of the efficiency of production. Productivity can be expressed as the ratio of output to inputs used in the production process, i.e. output per unit of input. When all outputs and inputs are included in the productivity measure it is called total productivity. Outputs and inputs are generally defined in the total productivity measure as their economic values (typical lists of outputs and inputs used for the rail industry productivity studies are shown in Column 3 of Table A2). The value of outputs minus the value of inputs is a measure of the income generated in a production process. It is a measure of total efficiency of a production process and as such the objective to be maximized in production process.

[5]After many years of contention in June 2010, the Australian Competition Tribunal ruled access to two lines would be mandated (the Robe River and Goldsworthy lines) but not to the busier Hamersley and Mount Newman lines.

One method of determining levels of productivity is to construct index numbers. Broadly speaking, these index numbers can be used to indicate the partial or total factor productivity of the industry. Partial productivity measures generally relate a firm's output to a single input factor. These types of measures are common in the rail industry but have shortcomings, in that using only a single input may be ignoring a factor that may be driving productivity growth (for a list of rail examples see Oum, Waters & Yu, 1998, p. 15). Academic studies, therefore, tend to apply a total factor index approach or methods such as DEA or econometric estimations of production or cost functions.

A total factor productivity index is the ratio of a total aggregate output quantity index to a total aggregate input quantity index. Total factor productivity growth, therefore, is the difference between the growth of the output and input quantity indices. Various different approaches can be used to measure total factor productivity, which can lead to different empirical results and interpretations. One such approach is DEA. DEA was pioneered by Charnes, Cooper and Rhodes. (1978) based on work by Farrell (1957). DEA is a linear programming technique which estimates organizational efficiency by measuring the ratio of total inputs employed to total output produced for each organization. This ratio is then compared to others in the sample group to derive an estimate of relative efficiency. DEA identifies the most efficient providers of a good or service by their ability to produce a given level of output using the least number of inputs. Other organizations in the sample group receive an efficiency score determined by the variance in their ratio of inputs employed to outputs produced relative to the most efficient producer in the sample group. DEA is therefore a measure of relative efficiency against the sample group's benchmark best practice. DEA has been used extensively to assess productivity and efficiency levels for the rail industry as well as being used to benchmark firms against one another it is possible to use DEA to estimate changes in productivity of individual firms, or the sample as a group, over time (see for instance Cantos, Pastor & Serrano, 2008, 2010, 2012; Growitsch & Wetzel, 2007, 2009; Wetzel & Growitsch, 2006).

Econometric methods choose either the estimation of a cost or production function. The estimated function can then be used to identify changes in productivity or productive efficiency. A number of studies have applied stochastic frontier methodologies to the rail industry. These have involved the estimation of both production and cost functions (in the case of the rail industry see for instance Bitzan, 2003; Cantos, 2001; Ivaldi & McCullough, 2001, 2004, 2008). Parametric techniques can be used to estimate technical efficiency by constructing first the production frontier derived from the best practice firms and then comparing the actual output of firms relative to the best practice firms (Wetzel, 2008). All of these types of studies depend upon the quality of the data included in these studies, and if data from different countries/companies is used it is important that the data is comparable.[6]

Many of the studies involve the use of methods that compare the operation of different railway companies/systems. This does create some difficulties in that railways are capital intensive multiproduct enterprises, whose outputs have a spatial dimension as well as quality attributes. These qualities make it difficult to undertaken any comparative productivity analysis with any precision. Often there is a problem of the availability of data and cross comparisons or different rail systems have problems with the essential comparability of the way in which these systems operate. Different rail systems, for instance, may have different shares in different types of traffic as well as different spatial dimensions. For these reasons making general conclusions from productivity studies of the rail industry is a difficult process. There are different fundamental conditions in rail industry (population, geography, climate, rail industry history, railway policy, etc.) and existing researches are conducted in different countries (Europe, the United States

[6] Defining output is a problematic exercise when output is defined as train kilometres produced, which is different to passengers of tonnes of freight carried. Other output effects such as congestion and emissions reduction are also often difficult to incorporate. Often the research choice of output indicators is driven by data availability rather than expected outputs.

Australia and Japan). Given the problems associated with using cross comparisons it is important that multiple company case studies be undertaken to flesh out some of the issues. A number to date have been undertaken (see for instance Dionori, Dunmore, Ellis & Crovoto, 2011; Drew, 2009; Merkert & Hensher, 2006; Nash, Nilsson & Link, 2011).

A range of different data has been used to capture the inputs and outputs of the industry, with the outputs generally being the number of freight ton and passenger kilometres and the inputs some indicator of capital and labour used (see Table A2). In some cases, the unavailability of data or the level of aggregation can make comparisons across studies problematic. The time periods observed can also be a problem, with longer term studies being better as they trend out short term fluctuations in results.

The literature uses a variety of techniques and data sources, and often reaches what seem to be contradictory conclusions (see Table A1). Nevertheless, while a difference in results can be a product of the difference in methods used, it can also at times produce consistent results across the various methods used, which in turn can help to validate the results of studies.

4.2 Key findings to date

Analysis of vertical separation has focused on the range of different tasks that exist in the rail sector. At the broadest level, there are passenger and freight tasks. For passenger traffic, there may be either an intra-urban passenger task – that is transport within a single city – or an inter-urban task – that is, a passenger task between population centres. For freight, the tasks include high and low density bulk freight, as well as long distance low volume freight (e.g. packages and containers). Table 1 provides a comprehensive list of past studies, and their results.

The evidence of the effects of vertical separation on efficiency in passenger activity is mixed. Vertical separation has been associated with improved productivity in the passenger task, where it has been combined with horizontal separation (Cantos, Pastor & Serrano, 2008, pp. 27-28; 2010, p. 160; 2012, p. 72). This is consistent with the related analysis incorporating both passenger and freight tasks, which did not find any significant impact of vertical separation on material or staff costs, as compared to the effect of accounting separation on both input categories (Asmild, Holvad, Hougaard & Kronborg, 2009, p. 633). Further Friebel, Ivaldi & Vibes (2003, p. 16; 2004, p. 16; 2010, p. 88) found that the sequencing with which reforms are undertaken may also affect the extent to which the overall reforms generate efficiency benefits, as compared to where reforms are undertaken contemporaneously. As might be expected the greatest gains were achieved, they argued, the faster and more comprehensive the manner in which reform is implemented.

In the case of intra-urban passenger rail this task involves intensive use of infrastructure, primarily because it involves multiple train movements over relatively short distances. In addition, high safety standards are generally required, because it involves movements of people (as compared goods), and because these movements generally occur through densely populated environments in which the rail network is integrated with a broader transport system. Together, these factors mean the cost of separation will generally be high, and as a consequence are unlikely to be offset by any potential benefits that would arise from greater competition. For this reason, introduction of competition in the intra-urban passenger market appears to have occurred primarily through the implementation of franchising arrangements in the passenger sector to improve efficiency, with franchises preferring to operate on track they control. Studies by researchers such as Dionori, Dunmore, Ellis, and Crovato (2011, p. 13), Cantos (2001, p. 83), and Wetzel (2008, p. 27) all found that separation in freight to provide far more scope for efficiency gains that urban passenger services. In addition, Mizutani, Smith, Nash and Uranshi (2015, pp. 56-57) and Nash, Smith, van de Velde,, Mizutani & Uranishi, (2014) found that the optimal structure depended on the density and type of traffic. They found that vertical separation increased costs if networks were intensely used, which supports the previous made contention that in densely populated environments the costs of separation can be high. In the case of inter-urban passenger services there are similar concerns regarding safety, management

Table 1. Summary of the results of the studies on rail vertical integration (separation)

AUTHORS	RESULTS
Affuso & Newbery 2002	Vertical separation and competition created greater incentives for companies to invest
Asmild, Holvad, Hougaard & Kronborg 2009	Accounting separation improved TE. Complete separation not significant.
Bitzan 2003	Economies associated with vertically integrated railway maintenance and transport
Cantos 2001	Costs from freight & infrastructure are complementary and for passenger & infrastructure substitutes. Investment in infrastructure needs to closely meet needs of freight.
Cantos, Pastor & Serrano 2008, 2010	Efficiency gains from horizontal & vertical separation. The former more important, both by itself and helping vertical separation
Cantos, Pastor & Serrano 2012	Efficiency gains from horizontal & vertical separation. The former more important, both by itself and helping vertical separation. vertical separation by itself did not improve efficiency
Dionori, Dunmore, Ellis, & Crovato 2011	Greatest benefits from separation of freight rather than passenger. Depends on degree of competition introduced. Full separation with competition is the best.
Drew 2009	Separation benefits freight customers more than open access does.
Drew & Nash 2011	No correlation between vertical separation and the growth in rail freight traffic or rail's share of total freight traffic
Driessen, Lijesen & Mulder 2006	Access lowers productive efficiency, tendering improves productive efficiency; ambiguous results for vertical separation,
Friebel, Ivaldi & Vibes 2003, 2004, 2010	Full implementation improves efficiency; sequencing important
Growitsch & Wetzel 2007, 2009	Integrated firms relatively more efficient (70% of companies had economies of scope)
Ivaldi & McCullough 2001	Most cost complementarities between general freight & maintenance but not between bulk & intermodal and track maintenance.
Ivaldi & McCullough 2004, 2008	Vertical & horizontal economies of scope (20-40 % loss productivity efficiency from vertical & 70 horizontal)
Jensen & Stelling 2007	Vertical separation raises costs, competition lowers cost, overall improvement in cost efficiency
Merkert 2012	Transaction costs with separated companies can be up to 10% of operating costs (less with access to vertically integrated company)
Merkert & Hensher 2014	High asset specificity tends to raise costs with access
Merkert & Nash 2013	Interactions between train operators and infrastructure managers are frequent, complex and intense, particularly in the areas of slot allocation/timetabling and day-to-day operations
Mizutani & Shoji 2004	No impact of vertical separation versus integration for cost of operating & maintaining infrastructure
Mizutani & Uranishi 2012	Separation reduces costs with low density, and raises costs with high density
Mizutani, Smith, Nash & Uranishi 2015	Optimal structure depends on the density and type of traffic. Vertical separation increases costs on intensely used networks and reduces them on lightly used ones.
Mulder, Lijesen & Driessen 2005	Success of vertical separation depends on degree of new competition introduced
Nash, Nilsson & Link 2011	No discernible difference between open access & complete separation
Nash, Smith, van de Velde,, Mizutani & Uranishi, 2014	Found that costs were higher on separated track where traffic was dense and freight proportions high.
Rivera-Trujillo 2004	Found that competition increases efficiency, but that vertical separation reduces it. However, if vertical separation is necessary for introducing competition, he concluded that its overall effect may be to increase efficiency
Van de Velde, Nash, Smith, Mizutani, Uranishi, Lijesen, Zschoche 2012	Vertical separation has little affect when density average, at high density it increases costs, at low density it reduces them
Wetzel 2008	Access increases productive efficiency for freight, but reduces it for passenger services; vertical separation results are ambiguous
Wetzel & Growitsch 2006	Integrated firms relatively more efficient (70% of companies had economies of scope)

and investment requirements. Generally, if management and scheduling costs are high, as are safety requirements, it can be difficult to make many gains from vertical separation.

On a broader level, analysis also indicates that the benefits of separation are greater in freight than in relation to the passenger task – in part because passenger operations are usually highly dependent on public funding and the opportunities for purely commercial operations tend to be more limited (Dionori, Dunmore, Ellis, & Crovato, 2011, pp. 13-14).

Generally, the freight task is associated with the greater possibility that either vertical separation or alternatively third-party track access arrangements (or holding company arrangements) will result in competition benefits and therefore greater efficiency (Dionori, Dunmore, Ellis, & Crovato, 2011, p. 13; Drew, 2009, pp. 23-5; Wetzel, 2008, p. 28). However, this finding is far from uniform.

On the one hand, a substantive body of evidence suggests efficiency is enhanced where full separation and substantial competition is introduced (i.e. full reform) (Affuso & Newbery, 2002, p. 83; Cantos, Pastor & Serrano, 2008, pp. 27-28; 2012, p. 72; Dionori, Dunmore, Ellis & Crovato, 2011, p. 13; Friebel, Ivaldi & Vibes, 2003, p. 17; 2010, p. 89; Jensen & Stelling, 2007, p. 533; Merkert, Smith & Nash, 2012, p. 363). In part, these potential gains depend on the scope for competitive entry and size of the original inefficiency of the rail industry. In such circumstances vertical separation, if it promotes substantial enough competition, might result in improved efficiency (Mulder, Lijesen & Driessen. 2005, p. 30; Cantos, Pastor & Serrano, 2012, p. 72). By contrast, if vertical separation is not also associated with horizontal separation, the potential efficiency and productivity benefits can be far more limited (Cantos, Pastor & Serrano, 2008, p. 28).

There is also a body of literature that suggests vertical separation is either not important at improving efficiency (perhaps unless there is strong competition as well) (Asmild, Holvad, Hougaard & Kronberg, 2009, p. 633; Rivera-Trujillo, 2004) or may even have a negative effect. Bitzan (2003, p. 301), for example, found first that there are economies associated with vertically integrated, transport and maintenance, which in turn suggested that separation increases costs. He also posited that as rail is a natural monopoly that multi-firm competition would increase resource costs.

Separately, if there is strong competition between a vertically integrated railway with other railways and with other forms of transport (which results in high levels of efficiency) then separation is unlikely to bring about additional gains in efficiency. The greater this level of activity, the more likely separation costs will be greater than potential gains. This would explain the results of the studies in the United States freight industry, which envisage little to be gained from separation (Bitzan, 2003, 201; Ivaldi & McCullough, 2004, pp. 17-18; 2008, pp. 168-9).[7] In the case of a number of European studies, the reform and separation may have been able to bring about improvements in productivity, simply because so many of the national rail industries were starting from levels of low productivity.

A similar result was found by Driessen, Lijesen & Mulder (2006, pp. 35-6) in respect of third party access rights. This study also showed a negative influence of providing managers with greater independence from government on productive efficiency. It was posited that this result may relate to the predominance of state ownership amongst the industries being assessed – the suggestion being that independence in the absence of competition could result in lower productivity. More broadly, however, such results conflict with some other studies and they suggest the difference might be the result of differences in data, different variable definitions and estimation methodologies used (Drew & Nash, 2001, p. 4; Driessen, Lijesen & Mulder, 2006, pp. 35-6).

[7] It should be noted that the studies on the United States industry are on vertically integrated companies, which might affect the results by not providing a comparison of separated to integrated companies.

The extent to which freight benefits from separation, therefore, depends also on the characteristics of both the freight task and infrastructure in question. High frequency of traffic in bulk freight mean there must be a high coordination between operation and maintenance. This creates higher coordination issues if separation takes place. For major bulk carriers there might be significant savings from closely coordinating the design of track and rolling stock. Often, therefore, track is tailored to specific bulk users (Van de Velde et al., 2012, p. 27). This is particularly true if the track is not used for other purposes such as passenger or container freight traffic. A high degree of asset specificity means a higher degree of access costs (Merkert & Hensher, 2014, p. 11; Cantos, 2001, p. 83). Vertical separation can also increase costs on densely used networks because of the increased likelihood of poor decisions and increased costs of misalignment (McNulty, 2011, p. 8; Ivaldi & McCullough, 2001, p. 180; Mizutani & Uranishi, 2012, p. 57; Mizutani, Smith, Nash & Uranishi, 2014, pp. 511-512; Van de Velde et al., 2012, p. 11).

By contrast, in the case of low density, long distance freight a supplier of track access is less vulnerable and more likely to invest if the infrastructure can be designed for use by many customers rather than have to be designed to the needs of a single one (Mizutani & Uranishi, 2012, p. 57; Van de Velde et al., 2012, p. 11). In these circumstances there may be advantages from separation if it promotes competition, and in turn higher levels of efficiency. For low density bulk traffic, such as grains in transport-related isolated regions, the results might also be different from heavy freight. To date, however, little research has been undertaken on the case of low density, long distance freight (Mizutani & Uranishi, 2012, p. 42).). Further research on the impact of separation on this type of freight task could give greater clarity to the possible benefits of separation.

5. Summary and conclusions

In many countries policy makers and railway authorities have been debating the various pros and cons of vertical separation in order to determine if reform of that nature is a viable means of improving the performance of their rail sectors. Despite the various structural and ownership reforms that have occurred in the rail sector around the world, no clear model for achieving this objective of enhanced competition and efficiency has yet been found (Organisation of Economic Cooperation Development, 2005, p. 61).

This situation is driven by the often dissimilar conditions faced by the rail industries of different countries, which can change the levels of costs and benefits of vertically disaggregation. The physical conditions of the rail industry are not uniform across all regions. Further, rail services of different type and location face dissimilar levels of competition from other transport modes. The extent of this competition to rail is driven by a range of factors, including the geographic, demographic and economic aspects of the different regions and countries in which the rail industry is situated. Further, these factors may impact differently depending on the type of services being provided by the rail industry.

Given this variety of circumstances it is possible for different structural arrangements to apply to different parts of the infrastructure and for different services, and for reform to these arrangements to have differing economic effects. For policy makers, a key insight is that separation is likely to be more successful in some parts of the industry compared to others (Pittman, 2005, p. 181). This helps to explain why the studies on the impact of separation can appear conflicting. Often the studies compare different systems, with different densities, operating conditions and different levels of efficiency before reform and so can be the source of the different results.

The circumstances in urban passenger services, with high safety standards, often dense traffic with high coordination costs, a high specificity of assets, substantial management and coordination costs and often government subsidy means that separation can be potentially very costly. This situation might also be true with inter-urban traffic, although more research on this type of traffic would be useful.

Circumstances in rail freight appear somewhat different. On the one hand, the circumstances in some freight markets, such as low density, long distance freight, generally appear to be quite different from those operating in the passenger market. In this section of the rail industry, separation, and the introduction of competition, could generally be expected to lead to efficiency gains without too much increase in the costs of coordination (although the research suggests that this will depend upon how much inter-modal competition has been separately driving higher levels of efficiency). On the other hand, in the case of high density, bulk freight the results of studies are generally mixed, with some finding that separation can improve levels of competition and efficiency, and others that it leads to substantial increased costs. One possible reason for these mixed results is the original conditions that exist in the jurisdictions that have been studied. For instance, if there is a high degree of competition (both inter-modal and inter-rail) before separation takes place then it is unlikely that separation will result in much gain in terms of efficiency. In the United States, for instance, most freight markets are very competitive with competition between railways and with road transport being especially strong. Separation in these circumstances would be unlikely to gain much in terms of improved efficiency. If the industry on the other hand is characterised before separation by the existence of large, inefficient, possibly government-owned, companies, then the introduction of a combination of competition and separation can lead to substantial efficiency gains. This perhaps explains why studies that include a number of European railways show efficiency gains from the reform process. Nevertheless, the evidence to date of reform in this area is not conclusive. Additional research that focuses on the costs and benefits of separation in this segment of the market is needed, particularly case studies of individual companies or systems, which have been through a process of reform and separation. For policy makers, this also suggests that there is considerable merit in undertaking preliminary analysis of the characteristics of a jurisdiction's rail sector before initiating structural reform of this nature.

Appendix

Table A1. Summary of studies on rail vertical integration – methodologies and data used (separation)

AUTHORS	DATA USED	METHOD
Affuso & Newbery 2002	UK; 1995-97 to 2000; passenger; 25 companies	Investment function
Asmild, Holvad, Hougaard & Kronborg 2009	Europe; 1995-2001; passenger & freight; 25 countries	MEA & 2nd stage regression
Bitzan 2003	US; 1983-97; freight; 30 companies	Translog quasi-cost function
Cantos 2001	Europe; 1973-90; passenger & freight; 12 companies	Translog cost function
Cantos, Pastor & Serrano 2008, 2010	Europe; 1985-2000, passenger & freight; 16 countries	DEA & 2nd stage regression
Cantos, Pastor & Serrano 2012	Europe; 2001-2008, passenger & freight; 23 countries	DEA & 2nd stage regression
Dionori, Dunmore, Ellis, & Crovato 2011	Europe; passenger & freight. 5 countries	Case study
Drew 2009	Germany/Sweden/UK; 1997-2005; freight; 3 countries	Case study
Drew & Nash 2011	Europe; 1998-2008; passenger & freight; 16 countries	Index comparison of markets
Driessen, Lijesen & Mulder 2006	World; 1990-2001; passenger and freight; 52 countries	DEA & 2nd stage regression
Friebel, Ivaldi & Vibes 2003, 2004, 2010	Europe; 1980-2003; passenger & freight; 11 countries	Stochastic production frontier
Growitsch & Wetzel 2007, 2009	Europe; 2000-2004; passenger & freight; 54 firms	DEA
Ivaldi & McCullough 2001	US ; 1978-1997; freight; 25 companies	Estimate multiproduct cost function
Ivaldi & McCullough 2004, 2008	US; 1978-2001; freight	Generalized McFadden cost function
Jensen & Stelling 2007	Sweden; 1970-1999; passenger & freight	Estimate cost function
Merkert 2012	Germany/Sweden/UK; 46 companies	Estimation of transaction costs
Merkert & Hensher 2006	Australia; freight; 45 managers	Survey
Merkert & Nash 2013	Germany/Sweden/UK; 2008, 2012/13; passenger & freight ;81 managers	Interviews
Merkert, Smith & Nash 2012	Germany/Sweden/UK; 3 countries	a bottom-up approach to compute transaction costs between train operation and infrastructure
Mizutani & Shoji 2004	Japan; 1 company	Case study
Mizutani & Uranishi 2012	Europe & East Asia; 1994-2007; passenger & freight; 30 companies	Cost function
Mizutani, Smith, Nash & Uranishi 2015	Europe & East Asia; 1994-2010 Passenger & freight: 33 companies	Cost function
Mulder, Lijesen & Driessen 2005	Netherlands; 1998-2004; passenger & freight	Cost benefit case study
Nash, Nilsson & Link 2011	Germany/Sweden/UK; passenger & freight; 3 countries	Case study
Nash, Smith, van de Velde,, Mizutani & Uranishi, 2014	Europe, 1997-2010; passenger & freight	Cost function
Rivera-Trujillo 2004	Europe; passenger & freight	
Van der Velde, Nash, Smith, Mizutani, Uranishi, Lijesen, Zschoche 2012	Europe & Japan; passenger & freight. 27 countries	Cost function
Wetzel 2008	Europe; 1994-2005; passenger & freight; 31 companies/22 countries	Stochastic production frontier
Wetzel & Growitsch 2006	Europe; 2000-2004; passenger & freight; 54 firms	DEA

Table A2. Summary of studies on rail vertical integration – variables used (separation)

AUTHORS	INDEPENDENT/OUTPUT VARIABLE	DEPENDENT VARIABLES
Affuso & Newbery 2002	Investment in new rolling stock	Contract characteristics (length of the contract, request of renegotiation, award of extension, asset specificity); Proxy market conditions (demand, variance of demand; future state of competition); Firm characteristics (initial state of rolling stock, level of profits; vertical and horizontal structure; merger or intra-industry contract
Asmild, Holvad, Hougaard & Kronborg 2009	Passenger train kilometres Freight train kilometres	Staff costs Material purchases and external charges Network length Reform characteristics (accounting separation; complete separation; independent management; competitive tendering for passenger services; market opening freight transport)
Bitzan 2003	Cost excluding way and structure costs	Prices of labour; materials and supplies; fuel; equipment Adjusted unit train gross ton-miles; way train gross ton-miles; through train gross ton-miles Route miles Average length of haul Miles of track per mile of road Net investment in way and structures per mile of track
Cantos 2001	Number of passenger kilometres Tonnes-kilometres transported	Value of ways and fixed installations Track length Labour costs Energy and fuel costs Materials and external services
Cantos, Pastor & Serrano 2008, 2010	Number of passenger kilometres Tonnes-kilometres transported	Number of employees in all the railway systems A representative measure of the passenger train supply calculated as the number of coaches, railcars and multiple unit trailers available for passenger transport A representative measure of freight train supply calculated as the annual fleet wagons strength for freight transport Number of kilometre of railway infrastructure Reform characteristics (e.g. vertical separation, horizontal separation and combined reforms) Derived variables using original variables above
Cantos, Pastor & Serrano 2012	As per Cantos, Pastor & Serrano 2008, 2010	As per Cantos, Pastor & Serrano 2008, 2010 save that reform characteristics include specific variables for introduction of new freight operators and for introduction of passenger franchising)
Driessen, Lijesen & Mulder 2006	Passenger kilometres Freight kilometres	Input of labour Tracks Input of capital Control variables (Total area; GDP per capita; Population density; Traffic structure; Traffic Density)
Friebel, Ivaldi & Vibes 2003, 2004, 2010	Passenger kilometres Freight ton kilometres	Labour Capital Reform characteristics (vertical separation; third party access; independent regulatory entity)
Growitsch & Wetzel 2007, 2009	Passenger kilometres Freight ton kilometres	Employees Rolling stock Track length Operating expenditure Organisation type (integrated firms; infrastructure managers; passenger operators; freight operators)
Ivaldi & McCullough 2001	Car miles of bulk traffic Car miles of high value traffic Car miles of general traffic	Replacement ties installed in a given year Indices of labour prices; equipment prices; fuel prices; material prices and other input prices Miles of road operated

Ivaldi & McCullough 2004, 2008	Car miles of bulk traffic Car miles of high value traffic Car miles of general traffic	Replacement ties installed in a given year Indices of labour prices; equipment prices; fuel prices; material prices and other input prices Miles of road operated Per cent of car-miles moving in unit trains
Jensen & Stelling 2007	Passenger kilometres Freight ton kilometres	Total cost Reform characteristics (vertical separation; competition) Environmental characteristics (technological development; intermodal competition; political pressure)
Mizutani & Uranishi 2012	Passenger kilometres Freight ton kilometres	Labour cost per employee Energy price per 1000 TOE Material costs per rolling stock Capital cost per route length Total route kilometres Percentage of electrified line Share of passenger revenue to total revenue Passenger per train to capacity Revenue passenger kilometre per passenger Number of freight car per train Train kilometre per route length per day Reform characteristics (vertical separation; horizontal separation)
Mizutani, Smith, Nash & Uranishi 2015	Passenger kilometres Freight to kilometres	Labour cost per employee Energy price per 1000 TOE Material costs per rolling stock Capital cost per route length Total route kilometres Percentage of electrified line Share of passenger revenue to total revenue Passenger per train to capacity Revenue passenger kilometre per passenger Number of freight car per train Train kilometre per route length per day Reform characteristics (vertical separation; holding company, horizontal separation)
Van de Velde, Nash, Smith, Mizutani, Uranishi, Lijesen, Zschoche 2012	Passenger kilometres Freight ton kilometres	Route length Technology index (percentage of electrified lines) Wage rate Energy price Materials price Capital price Reform characteristics (vertical separation; holding company; passenger competition; freight competition)
Wetzel 2008	Passenger kilometres Freight ton kilometres	Number of employees Number of rolling stock Network length Reform characteristics (vertical separation; third party access rights; independent regulation)
Wetzel & Growitsch 2007, 2009	Passenger kilometres Freight ton kilometres	Employees Rolling stock Track length Operating expenditure Organisation type (integrated firms; infrastructure managers; passenger operators; freight operators)

References

Affuso, L. and Newbery, D. (2002). The impact of structural and contractual arrangements on a vertically separated railway. *Economic and Social Review*, 33(1), 83-92.

Asmild, M., Holvad, T., Hougaard, J.L., and Kronborg, D. (2009). Railway reforms: do they influence operating efficiency? *Transportation*, 36, 617–638.

Australia, Bureau of Transport and Regional Economics (2003). *Rail Infrastructure Pricing: Principles and Practice.* Report No. 109, BTRE, Canberra.

Bagwell, P. (2004). The sad state of British railways: the rise and fall of Railtrack, 1992-2002'. *Journal of Transport History,* 25(2), 111-124.

Bitzan, J.D. (2003) Railroad costs and competition: the implications of introducing competition to railroad networks. *Journal of Transport Economics and Policy,* 37(2), 201-225.

Borts, G. (1952). Production relations in the railway industry. *Econometrica*, 20, 71-79.

Borts, G. (1960). The estimation of rail cost functions. *Econometria,* 28, 108-31.

Braeutigam, R.R., Daughety, A.F., and Turnquist, M. A. (1984). A firm specific analysis of economies of density in the railroad industry. *Journal of Industrial Economics*, 33, 3-20.

Buehler, S., Schmutzler, A., and Benz, M-A. (2004). Infrastructure quality in deregulated industries: is there an underinvestment problem? *International Journal of Industrial Organization,* 22, 253-67.

Cantos, P. (2001). Vertical relationships for the European railway industry. *Transport Policy*, 8(2), 77-83.

Cantos, P., Pastor, J.M., and Serrano, L. (2010). Vertical and horizontal separation in the European railway sector and its effects on productivity. *Journal of Transport Economics and Policy,* 44(2), 139–160.

Cantos, P., Pastor, J. M., and Serrano, L. (2012). Evaluating European railway deregulation using different approaches. *Transport Policy*, 24, 67-72.

Caves, D.W., Christensen, L. R., and Swanson, J.A. (1980). Productivity growth, scale economies and capacity utilization in U.S. railroads, 1951-1974. Discussion paper 8002, Social Systems Research Institute, Madison.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Researc*h, 2(6), 429-444.

Dionori, F., Dunmore, D., Ellis, S. and Crovato, P. (2011). *The Impact of Separation between Infrastructure Management and Transport Operations on the EU Railway Network.* European Parliament, Directorate General for Internal Policies, Strasbourg.

Drew, J. (2009). The benefits for rail freight customers of vertical separation and open access. *Transport Reviews*, 29(2), 223-237.

Drew, J. and Nash, C.A. (2011). Vertical separation of railway infrastructure – does it always make sense? Institute for Transport Studies, University of Leeds, Working Paper 594.

Driessen, G., Lijesen M. and Mulder, M. (2006). The impact of competition on productive efficiency in European Railways, CPB Discussion Paper #71.

European Commission (2013). *Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions on The Fourth Railway Package-Completing the Single European Railway Area to Foster European Competiveness and Growth.* European Commission, Brussels.

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society,* Ser. A, III, 253–290.

Friebel, G., Ivaldi, M. & Vibes, C. (2003). Railway (De) regulation: a European efficiency comparison. *IDEI Report 3, University of Toulouse, Toulouse.*

Friebel, G., Ivaldi, M. and Vibes, C. (2004). Railway (De) regulation: a European efficiency comparison. CEPR Discussion Paper No. 4319, Centre for Economic Policy Research, London.

Friebel, G., Ivaldi, M., and Vibes, C. (2010). Railway (De) regulation: a European efficiency comparison. *Economica,* 77 (305), 77–91.

Glass, A. (2011). The rise and fall of Railtrack PLC: an event study. *Applied Economics*, 43, 3143-3153.

Gomez-Ibanez, J. A. (2003). *Regulating Infrastructure: Monopoly, Contracts and Discretion*. Harvard University Press, Cambridge, Mass.

Griliches, Z. (1972). Cost allocation in railroad regulation. *Bell Journal of Economics and Management Science*, 3, 26-41.

Growitisch, C., and Wetzel, H. (2007). Testing for Economies of scope in European railways: an efficiency analysis, University of Luneberg, Working Paper Series in Economics, No. 72.

Growitsch, C. and Wetzel, H. (2009). Testing for economies of scope in European railways: an efficiency analysis. *Journal of Transport Economics and Policy*, 43 (1), 1–24.

Hansson, L. and Nilsson, J.E. (1991). A new Swedish railroad policy: separation of infrastructure and traffic production. *Transportation Research Part A: Policy and Practice*, 24A(4), 153-159.

Harris, R.G. (1977). Economies of density in the railroad freight industry. *Bell Journal of Economics*, 8, 556-64.

Ivaldi, M. and McCullough, G.J. (2001). Density and integration effects on Class I U.S. freight Railroads. *Journal of Regulatory Economics,* 19(2), 161-182.

Ivaldi, M. and McCullough, G.J. (2004). Subadditivity tests for network separation with an application to U.S, railroads. CEPR Discussion Paper 4392, CEPR, London.

Ivaldi, M. and McCullough, G.J. (2008). Subadditivity tests for network separation with an application to U.S. railroads. *Review of Network Economics,* 7(1), 159-171.

Jensen, A. and Stelling, P. (2007). Economic Impacts of Swedish railway deregulation: A longitudinal study. *Transportation Research E,* 43(5), 516-534.

Keeler, T. (1974). Railroad costs, returns to scale and excess capacity. *Review of Economics and Statistics,* 56, 201-8.

Klein, L. R. (1947). The use of cross section data in econometrics with application to a study of production of railroad services in the United States. National Bureau of Economic Research.

Lalive, R, and Schmutzler, A. (2008). Exploring the effects of competition for railway markets. *International Journal of Industrial Organisation*, 26(2), 443–458.

Merkert and Hensher, D. (2014). Open access for railways and transaction cost economics – Management perspectives of Australia's rail companies. Working Paper ITLS-WP-14-12.

McNulty, R. (2011). *Realising the Potential of GB Rail: Final Independent Report of the Rail value for Money Report.* Department for Transport/Office of Rail Regulator, London.

Merkert, R. and Nash C.A. (2013). Investigating European railway managers' perception of transaction costs at the train operation/infrastructure interface. *Transportation Research Part A: Policy and Practice*, 54: August, 14-25.

Merkert, R., Smith, A.S.J., and Nash, C.A. (2012). The measurement of transaction costs – evidence from European railways. *Journal of Transport, Economics and Policy* 46 (3), 349–365.

Merkert, R. (2012). An empirical study on the transaction sector within rail firms. *Transportmetrica*, 8 (1), 1–16.

Meyer, J. (1958). Some methodological aspects of statistical costing as illustrated by the determination of rail passenger costs. *American Economic Review*, 48(1), 209-22.

Mituzani, F. and Shoji, K. (2004). Rail operation–infrastructure separation: the case of Kobe rapid transit railway. *Transport Policy*, 11(3), 251-263.

Mizutani, F. & Uranishi, S. (2012). Does vertical separation reduce cost? An empirical Analysis of the rail industry in European and East Asian OECD Countries. *Journal of Regulatory Economics*, 43, 31-59.

Mizutani, F., Smith, A.S.J., Nash, C.A. and Uranishi, S. (2015). Comparing the costs of vertical separation, integration, and intermediate organisational structures in European and East Asian railways. *Journal of Transport Economics and Policy*, 49(3), 496-515.

Mulder, M., Lijesen, M. and Driessen, G. (2005). Vertical separation and competition in the Dutch rail industry: a cost-benefit analysis. Paper submitted to the Proceedings of the Third Conference on railroad industry structure, competition, and investments, Stockholm, 21 and 22 October 2005.

Nash, C., Nilsson, J. E. and Link, H. (2011). Comparing three models for introduction of competition into railways – is a big bad wolf so bad after all? CTS Working Paper 2011/19, Centre for Transport Studies, Stockholm.

Nash, C., Smith, A. S. H., van de Velde, D., Mizutani, F. and Uranishi, S. (2014). Structural reforms in the railways: incentive misalignment and cost implications. *Research in Transportation Economics*, 48, 16-23.

Organisation for Economic Cooperation and Development (2005). *Structural Reform in the Rail Industry.* OECD, Paris.

Organisation for Economic Cooperation and Development (2013). *Recent Developments in Rail Transportation Services.* OECD, Paris.

Oum, T.H., Waters, W.G. and Yu, C. (1998). A survey of productivity and efficiency measurement in rail transport. *Journal of Transport Economics and Policy*, 33(1), 9-42.

Pittman, R.W. (2005). Structural separation to create competition? The case of freight railways. *Review of Network Economics,* 4, 181-196.

Pittman, R. (2007). Options for restructuring the state-owned monopoly railroad. In Scott Dennis & Wayne K. Talley, Wayne K*., Railroad Economics*. Elsevier Science, Burlington, 179-198.

Pollitt, M.G. and Smith, A.S.J. (2002). The restructuring and privatisation of British Rail: was it really that bad? *Fiscal Studies,* 23(4), 463-502.

Rivera-Trujillo, C., (2004). Measuring the productivity and efficiency of railways (an international comparison). PhD thesis, University of Leeds, Leeds.

Tsai C, Mulley C and Merkert, R. (2015). Measuring the cost efficiency of urban rail systems: an international comparison using DEA and Tobit models. *Journal of Transport Economics and Policy*, 49(1), 17-34.

Van de Velde, D., Nash, C.A., Smith, A., Mizutani, F., Uranishi, S., Lijesen, M., and Zschoche, F. (2012). *Economic Effects of Vertical Separation in the Railway Sector*, Report for CER - Community of European Railway and Infrastructure Companies, by inno-V (Amsterdam) in cooperation with University of Leeds – ITS, Kobe University, VU Amsterdam University and civity management consultants, Amsterdam/Brussels.

Vickerman, R., (2004). Maintenance incentives under different infrastructure regimes. *Utilities Policy,* 12, 315-322.

Wetzel, H., (2008). European railway deregulation: the influence of regulatory and environmental conditions on efficiency. Working Paper Series in Economics.

Wetzel, H. and Growitsch, C. (2006). Economies of scope in European railways: an efficiency analysis. Discussion Paper No. 5. Halle, Germany: Institut fur Wirtschaftsforschung.

Wheat, P. and Smith, ASJ. (2015). Do the usual results of railway returns to scale and density hold in the case of heterogeneity in outputs? A hedonic cost function approach. *Journal of Transport Economics and Policy,* 49(1), 35-57.

Whitehorse, L. (2003). Railtrack is dead-long live Network rail? Nationalization under the third way. *Journal of Law and Society,* 30(2), 217-35.