Comparing the Costs of Vertical Separation, Integration, and Intermediate Organisational Structures in European and East Asian Railways

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Abstract

There is a major policy debate within Europe and more widely on how to structure railway systems to enhance competition, whilst minimising costs. This is the first study in the academic literature to examine, using econometric methods, the cost impacts of three different approaches to structuring railway systems: vertical separation, vertical integration and the intermediate holding company model. Our analysis is based on a panel of European and East Asian railways (1994-2010). We find that the optimal railway structure depends on the intensity and type of traffic running on the network. Our research suggests that, at least on cost grounds, countries should be free to choose between vertical integration, the holding company model or vertical separation.

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1.0 Introduction

Since 1991 (European Commission Directive 91/440), European Commission policy has been to reform Europe's railway systems by progressively opening up rail markets to competition. Via successive legislation (see Nash, 2013 for a review), Europe's rail systems have been required to separate train operations and infrastructure (at least into separate divisions with their own accounts). Based on this separated model, competition "in the market" has been allowed to develop via third-party open-access to the infrastructure (mainly for freight traffic), whilst competitive tendering has been the chosen means of introducing competition in passenger services, though in the period covered by this study competition in passenger was concentrated mainly in Britain, Sweden and Germany. The proposals contained in the European Commission's Fourth Railway package (European Commission, 2013) for further reforms of Europe's railways, mean that, once enacted, it will be compulsory to introduce competitive tendering for passenger services run under public service contracts and open access for commercial services across the whole of Europe.

Importantly, the requirement to separate train operations and infrastructure – seen as a pre-requisite to obtaining a level playing field so that competition can develop – has been achieved in different ways in different European countries. Some countries, such as Sweden and the UK, have implemented full institutional separation; others have re-organised infrastructure and operations into separate subsidiaries within a holding company structure (the German “holding” model); finally, a number of countries have chosen separation of the key functions of train slot allocation and infrastructure charging together with other functions such as investment planning into a separate body (the French “separation of key functions” model, although France is now proposing to move to a holding company model).

Outside Europe, most railways are vertically integrated (for example the US and Japan), with operators accessing the infrastructure of other companies, if at all, mainly on the basis of negotiation rather than as of right. Only the Australian inter-state system has followed the European model.

In the aforementioned Fourth Railway Package the European Commission has articulated its preference for the Swedish, full legal separation model as the only means of guaranteeing fair access to the network for new entrants. However, under pressure from some European countries, it has stopped short of requiring all railways to implement this model; though if legal separation is not implemented, strict safeguards are proposed to ensure fair access.

An important empirical and policy question then is whether full, legal separation will raise total industry costs relative to the alternatives. On this question the previous literature with respect to European railways is unclear (see Nash, 2013, for a full review of the literature). To summarise, some papers find that vertical separation raises costs (Growitsch and Wetzel, 2009; Merkert et al., 2012; Jensen and Stelling, 2007), whilst others find either no significant change (Wetzel, 2008; Asmild et al., 2008; Cantos et. al., 2011), or a reduction, at least when combined with other reforms (Friebel et al., 2010 and Cantos et al., 2010). The literature covering US railroads suggests that vertical separation would raise costs (see, for example, Bitzan, 2003). A key contribution to this literature is the paper by Mizutani and Uranishi (2013) which argued, based on a dataset of OECD railways, that whether vertical separation reduces or increases costs depends on the intensity with which the network is used.

However, one key limitation of the Mizutani and Uranishi (2013) model in the context of the European rail policy debate, as with the rest of the previous literature, is that it only considers the comparison between vertical separation and vertical integration. As noted, of much greater importance in the European policy debate is whether the form of separation - and in particular, whether separation is implemented within a holding model or through full institutional separation - matters in terms of its impact on whole industry costs. It is also the case that the Mizutani and Uranishi dataset (in common with all other papers in the previous literature) excludes Britain, which is seen within Europe as a key case study (Britain implemented the most radical rail reforms anywhere in the world). Its exclusion thus weakens the power of any findings on the impact of rail industry structure. Finally, as structural changes are happening all the time in Europe, with markets being progressively opened up to competition, it is important to have as up-to-date a picture as possible. In this regard most previous papers have not extended beyond 2005, with the exception of Mizutani and Uranishi (2013) and Cantos et al. (2011), which extend as far as 2007 and 2008 respectively; our paper is thus the most up-to-date study of its kind in the literature.

The purpose of this paper is therefore to adapt and develop the Mizutani and Uranishi (2013) model in a number of important ways: most importantly to expand the set of institutional possibilities to be compared, now including a comparison of the holding company model as compared to full, vertical separation or vertical integration. Our focus is on which of these forms performs better from a cost perspective and how this comparison might depend on the intensity (and also now types of) traffic running on the infrastructure. The paper is thus concerned with providing empirical evidence on an important question which is central to European rail policy. At the same time we also make several methodological and data advances as noted. A version of this model was reported in a study commissioned by the Community of European Railways and Infrastructure Companies (CER) – the EVES Rail Study (see van de Velde et. al., 2012)[1] and an overview of the policy implications given in 2013 at the Thredbo conference (Nash et. al., forthcoming).

The structure of the paper is as follows. Following this introduction, in section 2 we briefly summarise the relevant literature and our contribution to that literature. Section 3 sets

[1] The previous study was focused on policy findings and used slightly different data as we have been able to update some of the data since that report and the earlier study also did not include the full range of models as in this paper.

out the data and the method, and the results are set out and discussed in Section 4. Section 5 concludes.

2.0 Literature review

The purpose of this section is to discuss the policy background and briefly review the literature on the impact of organization structures in railways on cost, in particular to draw out the important methodological and data issues relevant for the analysis contained in this paper.

2.1 Policy context

The policy context for this paper lies in the major structural reforms implemented and proposed to be implemented in Europe's railway systems. The aims of the reforms are to improve the competitiveness of rail relative to other modes and to meet the objectives contained in the European Commission's White Paper (European Commission, 2011). Specifically as part of its policy to reduce greenhouse gases, the Commission wishes to see rail as the main mode of transport for medium distance passenger and long distance freight transport.

One of the key debates, which is common to infrastructure industries (e.g. energy networks), is whether full, legal separation is necessary to achieve a level playing field for competition, and whether such separation raises costs relative to vertical integration. Our paper is solely concerned with the second question. Further, and more precisely, in the railway sector, some countries have chosen to re-organise their railways within a holding company structure, with separate divisions within the holding for passenger and freight railways and infrastructure provision (the German “holding” model). If, through implementing strong Chinese walls between the different divisions, backed by a strong regulator, fair access to the infrastructure can be ensured, it is argued that this structure could allow lower costs than a vertically separated structure.

2.2 Previous literature

The reasons put forward for cost differences between alternative structures are that transaction costs may be lower in the holding (and vertically integrated) model than a fully separated structure, and also that costs more widely may be reduced due to the avoidance of misaligned incentives (a problem with separated structures, in that each company will seek to optimize its own operations rather than the system as a whole). Whilst appropriate track access charges and performance regimes go some way to reduce these problems, there is evidence – e.g. McNulty, 2011– that they do not completely remove them. In respect of the former, Merkert et al. (2012) show that whilst transaction costs are higher in separated systems, overall they are rather small, in the region of 2-3% of total railway costs. In respect of the latter, Mizutani and Uranishi (2013) further postulated that the extent to which costs may change between integrated and separated structures will depend on the intensity of usage of the network. The authors emphasized transaction cost theory as the explanation for this phenomenon. Further discussion of this point is contained in van de Velde et al. (2012), where it is noted that more heavily used networks will tend to imply higher transaction costs and also higher costs associated with misaligned incentives more widely.

As noted in the introduction there are no clear conclusions emerging from the previous literature on the question of whether vertical separation raises or reduces costs relative to vertical integration. Some studies found that vertical separation raised costs whilst others found that it reduced costs or had no significant effect. In some studies the success of separation depends on the interaction with other reforms and the sequencing of the reforms. Mizutani and Uranishi found that vertical separation would reduce costs for lightly used railways but increase costs for more intensively used railways. We refer the reader to Nash (2013) for a detailed review of the findings. Whilst the evidence on the cost impact of vertical separation versus vertical integration is unclear, more importantly, for the purpose of this paper, there has been no study of the cost impact of the holding model relative to vertical separation (or integration).

The previous literature is dominated by studies that utilise physical measures that may not adequately capture the inputs used by railways (in particular, the use of track or route length to measure the capital input neglects any attempt to measure infrastructure quality). Moreover, physical measures are subject to input substitution problems, particularly in terms of staff numbers, given the very different degrees of subcontracting found in different railway companies. A cost based study, such as that carried out by Mizutani and Uranishi (2013), whilst not immune from data challenges (see section 3 below), at least employs an overall measure of the inputs used by railways, therefore overcomes a number of the above weaknesses.

2.3 Contribution of this study

As a starting point we take the approach set out in Mizutani and Uranishi (2013) and adopt a cost function approach. However, we develop the Mizutani and Uranishi (2013) study in a number of important ways. First, we enhance the modeling of industry structure on costs. The previous literature, including Mizutani and Uranishi (2013), only considered two forms, namely vertical separation or vertical integration. In our analysis we consider also an intermediate form, namely the holding company model.

Second, we add British data to the sample; the exclusion of Britain from previous studies has been a major disadvantage of earlier work, particularly as Britain undertook the most radical reforms of any railway in the world and, whilst there have been successes, costs have increased considerably. We were able to add Britain by combining published data with new data obtained directly from railway companies in Britain. We also update the analysis beyond 2007, up to 2010 where possible[2]. Most previous papers have not extended beyond 2005, with the exception of Mizutani and Uranishi (2013) and Cantos et al. (2011), which extend as far as 2007 and 2008 respectively. Our paper thus allows us to include additional

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[2] For some companies it was only possible to update the data to 2007. We also added data for three companies, as compared to Mizutani and Uranishi (Britain, Bulgaria and Latvia). See section 3.

years of data post important reforms; for example, domestic freight markets were not required to be fully opened up to competition until 2007.

Third, we enhance the modeling of market opening. Previously, Mizutani and Uranishi (2013) only looked at the impact of vertical integration / separation, and did not consider the separate impact of competition. Whilst Cantos et al. (2011) included competition effects, these were based (for freight) on potential rather than actual entry, and for passenger were based on actual entry (tendering only), but did not distinguish between degrees of entry (i.e. that in some countries the proportion of services tendered is small, whereas in others a much higher proportion of services is subject to tendering such as in Germany; with all services tendered in Britain). Our model therefore includes freight competition dummy variables that reflect whether actual entry (rather than potential entry) has occurred. We also develop a passenger competition index that reflects the extent of entry (tendering and open access). We also used additional data, collected via questionnaire from Community of European Railways and Infrastructure Companies (CER) members on the timing of vertical and horizontal separation and on the dates for and extent of opening up of passenger and freight competition (thus correcting inaccuracies in the data for these variables in the previous literature).

Finally we develop the modeling of the relationship between industry structure and train density to distinguish between passenger and freight traffic (which have different characteristics). We consider that by focusing on data and methodological developments, our paper represents an important contribution to the literature, where there is currently much uncertainty on the impact of rail reforms on costs.

3.0 Data and methodology

3.1 The data and estimation method

The majority of the data used in this study comes from the International Union of Railways (UIC). The reader is referred to Mizutani and Uranishi (2013) for further details. In terms of country coverage, we add Britain, Bulgaria and Latvia to the sample. As noted, via a questionnaire, we also obtained new data from CER members, which was updated as far as possible from 2007 to 2010. The dataset was also checked and improved by CER members, though it was not possible for members to verify whether all definitions were totally consistent. Nevertheless, the process of having the UIC checked, improved and updated by CER members is a major step forward compared to the previous literature which has largely relied on the raw, published UIC data. The railway networks included in this study are shown in Table 1.

[Table 1 here]

In terms of the cost measure, ideally we aim to have a measure of total costs (*TC*) for the railway system in each country. Specifically in this paper, total costs means the total infrastructure costs of the main infrastructure manager[3] plus the costs of all passenger and freight operators running on that main system. For separated systems, infrastructure charges included in the operating company accounts are netted out to avoid double counting. One issue then is that, as in the Mizutani and Uranishi (2013) study, our dataset is based on a sample of companies, not countries, and does not typically include small, new train operators.

To address this point, and ensure a like for like comparison, we have scaled up the cost data for train operating company costs of the incumbent based on their market share to give an estimate of total train operating company costs for the country as a whole (this is not necessary for the infrastructure, since we are concerned only with the traffic running on the main infrastructure as noted). This adjustment is only carried out for those countries which had experienced the highest degree of entry. Of course, where entry is limited or non-existent (particularly in passenger), the lack of data for smaller operators is of little concern. The problem is further mitigated by the fact that both the costs and train-km of the new entrants are excluded. One problem with our approach is that it assumes that new operators have the same cost structure as the incumbent (new entrants may be more cost efficient, implying lower costs; on the other hand they may not be able to fully exploit economies of scale or density, implying higher costs). Overall, however, for the reasons outlined above, we consider that our approach should not appreciably bias the results.

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[3] In the case of Switzerland, there are two.

In this study, following Mizutani and Uranishi (2013) we employ a translog total cost function. Whilst some studies have estimated variable cost functions[4], since our focus here is on the impact of institutional and other policy variables on system cost it is important to look at total system costs, including the cost of the infrastructure. We do, however, control for the size of the network, via the network size variable (*N*). Our approach is in line with several others in the literature, in addition to Mizutani and Uranishi (2013); see, for example, the approach adopted in Smith (2006) and the associated literature review contained in that paper.

In the model, we study the impact of three types of policy variables. First, a set of variables representing the degree of vertical separation, which now includes the holding company model (D_{HC}) as a third form lying between full vertical separation (D_{VS}) and vertical integration (the omitted dummy variable). Secondly, we study the impact of horizontal separation (D_{HS}), by which we mean that passenger services and freight services are provided by institutionally separate companies. Finally, and an addition to the Mizutani and Uranishi (2013) analysis, we study the impact of passenger (*CMP*) and freight competition (D_{CF}) on costs. These structural types and competition from 1994 to 2011 are summarized in Table 1.

The cost model is specified such that the effect of the degree of vertical separation on cost varies according to the degree of train density (as represented in the model by interactions between D_{VS} and *V* (train density), and likewise for D_{HC}). In line with the

[4] See, for example, Savage (1997), Mizutani (2004) and Mizutani and Uranishi (2007).

literature, and recognizing the different marginal costs of passenger and freight traffic, our model has two outputs (passenger and freight output)[5]. The preferred translog model specification is set out below.

$$\ln TC = \alpha_0 + \Sigma_m \alpha_m \ln Q_m + \Sigma_j \beta_j \ln w_j + \gamma_N \ln N + \tau_T T + (1/2)\, \Sigma_n \Sigma_m a_{mn} (\ln Q_m)(\ln Q_n) +$$

$$\Sigma_j \Sigma_m a_{mj} (\ln Q_m)(\ln w_j) + \Sigma_m a_{mN} (\ln Q_m)(\ln N) + \Sigma_m a_{mT} (\ln Q_m)(T) +$$

$$(1/2)\, \Sigma_k \Sigma_j \beta_{jk} (\ln w_j)(\ln w_k) + \Sigma_j b_{jN} (\ln w_j)(\ln N) + \Sigma_j b_{jT} (\ln w_j)(T) +$$

$$(1/2)\, \gamma_{NN} (\ln N)^2 + g_{NT} (\ln N)(T) + (1/2)\, \tau_{TT} (T)^2 +$$

$$f(D_i, V) + g(D_i, R) + h(D_j, CMP) \qquad (1)$$

where

$$f(D_i, V) = (d_{VS1} + d_{VS2} \ln V)\, D_{VS} + (d_{HC1} + d_{HC2} \ln V)\, D_{HC} + d_{HS} D_{HS} \qquad (2)$$

$$g(D_i, R) = d_{VS3} \ln R\, D_{VS} + d_{HC3} \ln R\, D_{HC} \qquad (3)$$

$$h(CMP, D_j) = d_{CP}\, CMP + d_{CF} D_{CF} \qquad (4)$$

and where TC = total cost, Q_P = quantity of passenger output, Q_F = quantity of freight output, w_L = labour input price, w_E = energy input price, w_M = materials input price, w_K = capital input price, N = total route length, T = technology (T: percentage of electrified length), V = train density[6], R = proportion of revenue made up by freight, D_{VS} = vertical separation dummy

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[5] In Mizutani (2013) an alternative specification, with a single output, combined with output characteristics, was tested alongside the multiple-output model, though the latter was preferred; see Mizutani and Uranishi (2013).

[6] Measured as train-km per route-km. Alternative measures, such as train-km per track-km were also tried but we had concerns over the quality of the UIC track-km data which was volatile for a number of countries.

(vertical separation =1, otherwise = 0), D_{HC} = holding company dummy (holding company=1, otherwise =0), D_{HS} = horizontal (passenger-freight) separation dummy (horizontal separation = 1, otherwise = 0), *CMP* = measure of passenger competition (0 = no competition, 1 – 4 based on extent of competition; see below), and D_{CF} = freight entry dummy (takes the value unity if actual freight entry has occurred, zero otherwise).

As noted in the introduction, our measure of competition in passenger services takes account of the degree of competition (so competition is not modelled as a "yes/no" variable as in previous studies). This development matters because in some countries the proportion of services tendered is very small, whilst in others, namely Sweden, Germany and Britain it is much higher. The *CMP* measure is developed via the following approach: Level 1: competition is possible, equivalent to the competition announcement effect (dummy 0-1); Level 2: competition has happened but is minor compared to the whole network, it can be through minor open access or a small proportion of the network that was submitted to competitive tendering, around 10% (dummy 0-1); Level 3: competition has happened and is major compared to the whole network (around or more than about 25%, a (dummy 0-1); Level 4: all services are submitted to competition (e.g. the British case) (dummy 0-1).

In order to make the analysis tractable in our preferred model we sum the dummies to produce an overall measure. Whilst this is to some extent arbitrary, we consider that it is preferable to a simpler approach whereby countries with very different levels of competitive threat are given the same value (0 or 1) for the competitive dummy.

As is standard we impose the restriction on input factor prices such that $\Sigma_j\beta_j = 1$, $\Sigma_k\beta_{jk} = 0$, $\Sigma_j b_{jN} = 0$, $\Sigma_j b_{jT} = 0$, $\Sigma_j Y_j = 0$, $\Sigma_j g_{mj} = 0$, $\beta_{jk} = \beta_{kj}$, $b_{jN} = b_{Nj}$, $b_{jT} = b_{Tj}$, $a_{mn} = a_{nm}$, $a_{mj} = a_{jm}$, $a_{mN} = a_{Nm}$, $a_{mT} = a_{Tm}$, $g_{NT} = g_{TN}$. Furthermore, we apply Shephard's Lemma to the total cost function. Then we can obtain the input share equations as follows:

$$S_j = \beta_j + \Sigma_m a_{mj} (\ln Q_m) + \Sigma_k\beta_{jk} (\ln w_k) + b_{jN} (\ln N) + b_{jT} (T) \qquad (5)$$

where S_j: input j's share of total cost.

We apply the seemingly unrelated regression (SUR) method by the total cost function and the input share equations. For the estimation, to aide with the interpretation of the coefficients, we divide all observations of each variable by the sample mean.

3.2 Economic rationale for modelling the impact of institutional arrangements

Before proceeding to the empirical analysis it is worth setting out our a priori expectations regarding the impact of different institutional forms on railway system cost. Starting with the distinction between vertical separation and vertical integration, vertical separation might be expected to bring about cost savings via two primary mechanisms. First of all, vertical separation may lead to greater transparency on cost (and public subsidy), or simply cost reductions resulting from restructuring, which is often associated with careful examination of staffing and costs. Secondly, it might bring about cost reductions through enabling greater competition on the network; with vertical integration, at least in the absence of a strong regulator, making it difficult for new entrants to access the network on the same terms as the incumbent (vertically-integrated) operator.

On the other hand, it might be argued that misaligned incentives (between operators and the infrastructure manager) in a vertically separated rail system might raise costs – or put the other way round, there could be coordination benefits from a single, vertically-integrated company planning investment and operations of infrastructure and operations together. Mizutani and Uranishi (2013) make a further step by noting that the difference between vertical separation and integration in respect of co-ordination costs will depend on how intensely the infrastructure is utilized (drawing on Williamson's transaction cost economics). It is argued that co-ordination costs (co-ordinating the activities of infrastructure and operations) in a separated environment increase more sharply as train density increases. This is because, for example, maintenance operations become more frequent and challenging as a network becomes closer to capacity and it might therefore be expected that the interactions between a separate infrastructure manager and legally separate train operators also becomes more frequent and complex at the day to day operational level. The associated contractual framework also becomes more complex as does investment planning, and there is much scope for incentives to be misaligned, even with detailed contracts in place. Whilst transaction costs, in the narrowest sense, have not been found to be very significant in railways (see Merkert et.

al., 2012), there are wider costs relating to the knock-on effects of sub-optimal decisions due to various types of incentive misalignment between different companies in a vertically-separated environment (see van de Velde et. al., 2012) which could be substantial.

Taken together, we might (perhaps weakly) conclude that, a priori, vertical separation might be expected to reduce costs for lightly used railways, whilst potentially increasing cost for more intensely-used railways. For the purpose of this paper we want to know where the cut-off point is as this gives us important information regarding appropriate policy with regard to vertical separation of railways in the sample (see Figure 1).

[Figure 1 here]

In this paper we go further, building on the above theoretical framework, first by considering also the holding company model. The supposed advantage of this model is that by enacting an internal separation of infrastructure from operations, but within the same holding company new entrants can get fair access to the network, whilst at the same time, the potential coordination cost advantage of having the infrastructure and the dominant operator within the same group is retained. Particular benefits include the ability to better coordinate investment (internalising infrastructure and rolling stock considerations) as well as production planning (e.g. wear and tear at the wheel / rail interface) and timetable planning coordination (though noting the possible conflict with fair access). Discussions within the industry suggest that in some cases, including Germany, the holding company does fulfil these functions, although it appears there are Europe-wide differences in practice even within the holding company model which we have not been able to take into account. The argument for this structure is further strengthened if there is a strong economic regulator with powers to ensure that all operators have fair access to the network, so that the possible disadvantage of encouraging discrimination is avoided. Further, the separation within the parent should enable the transparency and focus on cost that full, legal vertical separation itself might achieve. As noted earlier, the holding company is one means by which railway systems in Europe have sought to meet the European Commission's requirements for greater transparency and fair access to the rail network. However, its effectiveness (particularly in respect of fair access) has been questioned both by potential entrants and also by the European Commission.

The second innovation of our paper is that we permit the cost difference between vertical separation and the other institutional forms (vertical integration and the holding company) to depend not only on the intensity of use of the network, but also on the proportion of freight running on the network. A priori, it might be expected that freight services, which are not subject to a timetable in the same way as passenger services, could raise transaction and other costs in a separated environment.

4.0 Results

4.1 Definition of variables

As we explained in section 3, we collected data for 33 railway networks, covering 26

European and 7 East Asian countries over the 17 year period from 1994 to 2010. In total we have 481 observations (it is an unbalanced panel).

Our measure of total system costs (TC) is defined as the sum of labor, energy, material costs and capital costs. However, as noted in section 3, to avoid double counting, infrastructure charges in rail operating companies are excluded in the vertically separated total system cost measure (because the total costs of infrastructure companies are included).

In line with the previous literature (e.g. Cantos and Maudos (2001), Mancuso and Reverberi (2003), Farsi et al. (2005) and Mizutani and Uranishi (2013), for our output measures we include both revenue passenger km (Q_p) and revenue tonne km (Q_f). Mizutani and Uranishi (2013) also considered an alternative specification with total train-km as the main output variable, plus hedonic characteristics variables, though the former (two output model) was preferred. In our model, output characteristics, train density (*V*) and the proportion of freight revenues (*R*) are included as interaction terms with the institutional dummy variables, so that we can see how the effects of these industry structures depend on the intensity of usage (V) and type of traffic running on the network (R).

We use four input prices: labour, energy (fuel), materials and capital prices. These are defined in detail in Mizutani and Uranishi (2013). As for the other control variables, following Mizutani and Uranishi, we include a network variable, route length (*N*), and a technology variable, the percentage of electrified lines (*T*). We include two competition variables. First, passenger competition (*CMP*) is the overall passenger competitive threat variable. As we explained in section 3, this variable captures not just whether competition has occurred, but the differing degrees of competition in different countries. Second, freight competition (D_{CF}) is captured via a dummy variable taking the value unity when actual freight entry has occurred (not potential entry, as in previous studies), but which is otherwise zero.

As set out in section 3, there are three kinds of structural dummy variables in this study. The first two dummy variables capture the effects of vertical separation (D_{VS}) and the holding company model (D_{HC}) respectively. Vertical integration is the omitted dummy. We also include a horizontal (passenger-freight) separation dummy (D_{HS}) taking the value unity when horizontal separation has taken place; zero otherwise.

We note that the vertical structure for some companies in the sample did not change during the period covered by our analysis (including Britain, Sweden and the Japanese companies). Therefore we do not include company dummies (fixed effects) as we would then be relying entirely on the "within" variation in the data to study the impact of reforms which, as noted, is zero for part of the sample. In this respect our approach is in line with the previous literature on the impact of industry structure on costs, to which our paper adds[7]. The previous literature has instead dealt with the issue of heterogeneity between countries by

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[7] Cantos et. al. (2010) do estimate a panel model but that is part of a second stage analysis with DEA as a first stage; and their model does not cover all inputs (it omits other costs which can be substantial). The later work, Cantos et. al. (2011) does not appear to include firm dummies.

including a range of characteristic variables within the cost function. In the discussion of the results below we therefore consider the robustness of the findings to an alternative model specification, also used in Mizutani and Uranishi (2013), which includes train-km as the single output measure, together with a set of hedonic variables capturing different railway characteristics. We also consider the robustness of our findings with respect to the choice of sample.

4.2 Empirical Results

The SUR estimation results are summarized in Table 2. Table 2 shows five cases with Case 1 being the model estimated in Mizutani and Uranishi (2013): (i) Case 1 (base case: vertical separation and horizontal separation); (ii) Case 2 (Case 1 + holding company); (iii) Case 3 (Case 1 + holding company + proportion of freight revenues); (iv) Case 4 (Case 1 + holding company + competition); (v) Case 5 (Case 1 + holding company + proportion of freight revenues + competition). We are thus able to test the impact of the innovations proposed in this paper.

The goodness-of-fit in all cases of regressions is acceptably high because pseudo R^2 of the cost functions is very high at over 0.98. The required properties in the cost function are in general satisfactorily met. First, the required symmetry and homogeneity conditions in input factor prices are satisfied via the restrictions imposed on the model. Second, we evaluated the required monotonicity conditions by checking that the partial derivative of the cost function with respect to output and input factor prices is not negative (i.e. $\partial \ln C/\partial \ln Q_i \geq 0$, $\partial \ln C/\partial \ln w_j \geq 0$); these being satisfied at the sample mean. Global concavity in input prices was tested based on whether the Hessian matrix is negative semi-definite for the whole sample. The condition holds for around one fifth of the observations; however, we note that there is no convenient way of imposing global concavity, and it is recognised in the literature that imposing this condition may seriously undermine the flexibility properties of the translog (see for example Coelli et. al., 2005, page 229). We tested a range of specifications which performed better on the concavity criterion[8]. In all cases the key results on the impact of railway structure were little affected; and we thus retain model 5 as our preferred model.

Based on likelihood ratio tests of the five cases we can say the following. First, the addition of the holding company institutional form (Case 2) adds to the model statistically (at the 1% level) compared to Case 1, so this appears to be a useful innovation both statistically and from an a prior perspective. Case 3 (the addition of the freight proportion interaction)

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[8] These included the three input price alternative model specification shown in Mizutani and Uranishi (2013), a Cobb-Douglas model, and a model in which concavity was imposed at a single point, following Ryan and Wales (2000). Further, as Wales (1977) notes, violations of concavity do not necessarily imply that there is no underlying optimisation (in this case, cost minimisation) process.

likewise adds to the model compared to Case 2. Case 4 (adding competition variables, but not the freight interaction term) to Case 2 also adds to the model (at the 5% level but not at the 1% level). Finally, Case 5, which includes all innovations together, is clearly preferred to all of the other models based on likelihood ratio tests (at the 1% level in all cases except the comparison against model 3, where Case 5 is preferred at the 5% level). Case 5 is therefore preferred from a statistical and a priori perspective. It is perhaps the competition variables where there is some doubt – these variables are individually statistically insignificant, though jointly significant (at least at the 5% level).

[Table 2 here]

Based on the preferred model (Case 5), our results are as follows. First, the effect of vertical separation on costs (compared to vertical integration, the omitted dummy variable) at the sample mean is not significantly different from zero (the coefficient on (D_{VS}) is 0.0042 and is not statistically significant). However, the interaction term of vertical separation and train density (VD_{VS}) is statistically significant at the 1% level, which means that the effect of separation varies with train density. For average train density levels[9], vertical separation therefore has little effect. Below that level, vertical separation reduces costs and above that level, vertical separation increases costs. This finding is in line with that of Mizutani and Uranishi (2013), though vertical separation starts to raise cost at lower density levels than in

[9] More precisely, the break-even point is at 0.99 times the sample mean.

the latter paper (where vertical separation did not start to raise costs until density levels reached around 1.5-1.9 times the sample mean). It could be that the addition of Britain, a vertically-separated railway where costs have increased very sharply, has led to this change in the break-even point.

The finding that vertical separation raises costs at high train density levels is intuitive in that the coordination problems associated with vertical separation might be expected to be more severe when there are high levels of traffic relative to the size of the network. It may be less clear why vertical separation reduces costs on more lightly used networks, given that we have sought to account separately for the impact of competition. We speculate that this finding may result from the increased cost and public subsidy transparency brought about by separation.

Second, the effect of the holding company model is to reduce costs by around 5% at the sample mean (compared to vertical integration, the omitted dummy). This effect is statistically significant at the 10% level (but not at the 5% level). The interaction term of holding company and train density (VD_{HC}) is also not statistically significant. Thus, overall, we conclude that the holding company model has a small impact on costs, though at the margins of statistical significance; and this effect does not very with train density. The cost reduction could result from increased transparency resulting from the internal separation, whilst any loss of coordination benefits is avoided (though it should be recognised that in practice the degree of coordination within the holding model varies considerably from country to country and that is has not yet been possible to include this factor in our analysis).

Third, the interaction term of vertical separation and proportion of freight revenues (RD_{VS}) is positive and statistically significant at the 1% level, indicating that where there is a higher proportion of freight revenues on the network, vertical separation tends to increase costs. Thus, for a given level of train density, it seems that freight traffic causes more coordination problems in a separated environment than passenger traffic. This finding appears to be intuitive, and could result from the fact that typically passenger services on a route are provided by a single operator, whereas freight may involve multiple operators. Further, freight services are not set by a rigid timetable but vary from day to day. It could also reflect the increased problems of handling mixed traffic.

Fourth, horizontal separation reduces costs. The effect of horizontal separation is to reduce costs, other things equal, by 24%[10]. This effect is statistically significant at the 1% level. An explanation might be that in a number of cases cost reductions took place because freight divisions were sold to new owners rather than as a direct consequence of horizontal separation. Another explanation is that there could be diseconomies of scope between passenger and freight services, as Kim (1987) finds.

Last, the variables representing the introduction of freight and passenger competition

[10] The effect is computed as exp (-0.2719) -1.

do not have any statistically significant impact on costs. This finding is surprising, though it might reflect the problem mentioned earlier of specifying appropriate competition measures and it may be that the impacts of competition are in part being picked up by other variables because of this problem.

It should be noted that the above findings are robust to alternative model specifications. In particular, the single output hedonic model (see Mizutani and Uranishi, 2013), which includes total train-km as the single output variable, but adds in hedonic variables capturing passenger revenue share, passenger loads, average trip length, and the number of freight cars per train, produces very similar results. Further, to guard against the danger that our results are picking up differences between non-EU and EU railways, rather than industry structure effects, we tested the model without Japan, South Korea and Turkey, and found the results to be very similar.

Returning to the question of which institutional form is preferred, on cost grounds, it is clear first of all that the holding company model only has a marginal (and weakly significant) cost advantage relative to vertical integration. On the other hand, when comparing vertical separation and vertical integration, it is clear from the results that the impact depends on how intensely the network is used (as Mizutani and Uranishi (2013) find) and also how much freight is running on the network. Taking account solely of the former effect (i.e. ($\square_{VS1}$ + $\square_{VS2}\ln V$) D_{VS} in Equation (2)), the train density at the break-even point is 62.72 (or 0.99

times the sample mean train density), which is lower than found by Mizutani and Uranishi (2013) as noted earlier. Other things equal, when the train density is above this level, vertical separation starts to increase costs. We note that for most of the railways in the sample the cost difference between vertical separation and the holding company model is statistically significant.

Many railway networks are included in this latter category, for example those of Belgium, Switzerland (both BLS and SBB CFF FFS), Germany, Great Britain, Japan (except JR Hokkaido), South Korea, Netherlands and so on. However, the overall effect on costs of vertical separation also depends on the amount of freight running on the network, with increased amounts of freight leading to higher costs under vertical separation. Countries with a higher than average value for the freight revenue proportion include, for example, Germany, Austria, Czech Republic, Poland, and Hungary.

Recall that our objective in this paper is to consider the impact of the European Commission's policy with respect to reforming Europe's railways. We have noted the Commission's preference for full vertical separation, over vertical integration and alternative models such as the holding company model. In Table 3 we therefore use our model to compute the cost of imposing vertical separation across the EU (i.e. for those countries that are not already vertically separated). This calculation therefore includes imposing vertical separation on countries that have gone part way to reforming their railways through implementing the holding company model. The results show that the cost of such a policy would be around 6 billion euro/ year at 2010 traffic density levels (see Table 3). Further, bearing in mind the Commission's aims for future traffic growth as stated in the 2011 Transport White Paper, we also show the cost of imposing vertical separation assuming that train density levels increase by 10%, 20% and 50% respectively. Since the model shows the cost of separation increasing with train density levels, the cost of vertical separation at these higher density levels is correspondingly higher, at nearly 8 billion, 10 billion and 15 billion euro respectively on a year basis. Thus, imposing vertical separation across all railways in Europe is not an appropriate policy when viewed purely from a cost perspective (though there could, potentially be other benefits of separation).

[Table 3 here]

5.0 Conclusion

The main contributions of this paper are as follows:

1. Our paper is the first econometric study in an established literature to compare the effects of the holding company model as well full, legal vertical separation and vertical integration on costs, using a sample of European and East Asian railways. The previous literature has focused on only the latter two forms. The choice between the holding company model and vertical separation lies at the heart of a major policy debate within Europe on how best to promote within-mode competition on rail

networks, whilst minimising system costs. We find that the holding company model does reduce costs compared to vertical integration but this effect is small (around 5%) and this finding is statistically significant only at the 10% level (but not at the 5% level). The effects of this model also do not change appreciably as train density on the network changes.

2. On the other hand we find that the effects of full, legal vertical separation depends on the intensity of usage of the network with vertical separation increasing costs (relative to vertical integration) on intensely used networks and reducing them on lightly used networks. This latter finding is intuitive in that the coordination problems associated with vertical separation might be expected to be more severe when there are high levels of traffic relative to the size of the network. This finding is in line with that in Mizutani and Uranishi (2013), directionally, but importantly the train density break-even point is lower in our study. Thus, other things equal, our model predicts that vertical separation will increase costs for more railways than in Mizutani and Uranishi (2013); see also point 4 below.
3. Second, in this paper we further develop the ideas in Mizutani and Uranishi (2013) by testing whether the type of traffic running on the network, as well as the intensity of its use overall, impacts on the cost effects of different railway structures. We find that that where there is a higher proportion of freight on the network, vertical separation tends

to increase costs. The finding that freight traffic causes more coordination problems in a separated environment than passenger traffic seems intuitive given that freight services are not set by a rigid timetable and also may involve several different operators. It could also partly reflect the challenges raised by managing mixed traffic.

4. The paper estimates the EU-wide cost implications of enforcing full, legal vertical separation across the EU (the policy preference expressed by the European Commission). Based on our model, the cost of imposing vertical separation, where it is not already in place, would increase EU-wide rail costs by around 6 billion Euros per year; with this cost likely to be higher in future years if the Commission's ambitious growth targets for rail are achieved. The clear policy conclusion from this work is that a one-size fits all policy is not appropriate. Our research suggests that, at least on cost grounds, countries should be free to choose between vertical integration, the holding company or vertical separation.
5. It is important to note that the model and data used to derive the above results have been developed in a number of important ways. The paper is the first to include Britain and updates the previous literature with data extending to 2010. Both these extensions are important. Britain was one of the pioneers in Europe (along with Sweden) of the vertically-separated model and its inclusion thus enhances our understanding of the impact of this model on costs. There have also been a number of

reforms in recent years, and it is important to study those effects. The paper also enhances the modelling of market opening by considering whether actual entry in freight has occurred (rather than potentially entry as in previous studies) and distinguishing between degrees of entry in passenger, given the vastly different extents of market entry in the sample (previous studies have treated passenger competition as a binary variable). That said, in our estimations we were unable to find strong evidence that competition has any cost reducing effects.

In the 2013 Fourth Railway Package proposals the European Commission articulated its preference for the Swedish, full legal separation model as the best means of guaranteeing fair access to the network for new entrants. However, under pressure from some European countries, it stopped short of requiring all railways to implement the Swedish model. Potentially the cost effects of vertical separation, compared to the other structural forms may change in future as the market develops. On the one hand, our model suggests that the costs of implementing vertical separation will increase in future as traffic growth leads to networks being more intensively used. On the other hand, as competitive entry expands across the EU, as envisaged by the 4th Railway package, the power of the holding company model – based on a dominant operator, combined in the same holding company as the infrastructure company – loses some of its appeal, as new entrants take a much more significant market share. It remains to be seen how the European Commission's policy will develop over time in response to market developments.

We consider that new work on the dataset would be useful (to all researchers in this area), in particular in obtaining more comparable measures of capital and capital costs. It would also be interesting to explore (either statistically or via case studies) the relationship between costs, competition, railway structure and economic regulation in future work, as well as considering different types of holding company arrangement, as no two counties are the same in that regard.

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Table 1 Structural Types and Competition from 1994 to 2011

Country Network	Structural Types				Competition	
	Full Integration	Holding Company	Vertical Separation	Horizontal Separation	Passenger Entry	Freight Entry
Austria (OBB)	- 2004	2005 -	-	-	-	1999 -
Belgium (SNCB/NMBS)	- 2004	2005 -	-	-	-	2006 -
Bulgaria (BDZ)	-2001	-	2001 -	-	-	2007 -
Switzerland (SBB CFF FFS)	- 2008	2009 -	-	-	-	2004 -
Switzerland (BLS)	- 2011	-	-	-	-	2004 -
Czech Rep. (CD)	- 2002	-	2003 -	-	-	1995 -
Germany (DBAG)	- 1999	2000 -	-	-	2000 -	1994 -
Denmark (DSB)	- 1997	-	1998 -	2001 -	2003 -	1999 -
Spain (RENFE)	- 2004	-	2005 -	-	-	2007-
Finland (VR)	- 1994	-	1995 -	-	-	-
France (SNCF)	- 1996	-	1997 -	-	-	2006 -
Great Britain (TOC)	- 1994	-	1994 -	1996 -	1996 -	1994 -
Greece (OSE)	- 2006	2007 - 2009	2010 -	-	-	-
Hungary (GySEV/ROEE)	1994 -	-	-	-	-	2006 -
Hungary (MAV)	- 2006	2007 -	-	2008 -	-	2004 -
Ireland (CIE)	1994 -	-	-	-	-	-
Italy (FS)	- 2000	2001 -	-	-	2001 -	2002 -
Japan (JR Hokkaido)	1987 -	-	-	1987 -	-	-
Japan (JR East)	1987 -	-	-	1987 -	-	-
Japan (JR Central)	1987 -	-	-	1987 -	-	-
Japan (JR West)	1987 -	-	-	1987 -	-	-
Japan (JR Shikoku)	1987 -	-	-	1987 -	-	-
Japan (JR Kyushu)	1987 -	-	-	1987 -	-	-
South Korea (KORAIL)	1994 -	-	-	-	-	-
Latvia (LDz)	- 2006	2007 -	-	-	-	2007 -
Luxembourg (CFL)	1994 -	-	-	-	-	2007 -
Netherlands (NS)	- 1994	1995 - 2001	2002 -	2001 -	1999 -	1998 -
Norway (NSB)	- 1996	-	1997 -	2002 - 2009	2005 -	2007 -
Poland (PKP)	- 2000	2001 -	-	-	2008 -	2003 -
Portugal (CP)	- 1996	-	1997 -	-	1999 -	-
Sweden (SJ)	-	-	1988 -	2002 -	1990 -	1996 -
Slovakia (ZSSK)	- 2001	-	2002 -	2006 -	-	2004 -
Turkey (TCDD)	1994 -	-	-	-	-	-

Table 2 Full Econometric Estimation Results

Parameters	Case 1	Case 2	Case 3	Case 4	Case 5
Q_P	0.1345*** (0.0132)	0.1263*** (0.0139)	0.1227*** (0.0139)	0.1317*** (0.0146)	0.1281*** (0.0146)
Q_F	0.3717*** (0.0235)	0.3708*** (0.0236)	0.3629*** (0.0250)	0.3648*** (0.0243)	0.3574*** (0.0258)
w_L	0.3327*** (0.0054)	0.3324*** (0.0054)	0.3323*** (0.0054)	0.3321*** (0.0054)	0.3320*** (0.0055)
w_E	0.0383*** (0.0035)	0.0385*** (0.0035)	0.0380*** (0.0033)	0.0384*** (0.0034)	0.0380*** (0.0032)
w_M	0.3108*** (0.0069)	0.3101*** (0.0070)	0.3112*** (0.0069)	0.3104*** (0.0070)	0.3113*** (0.0069)
w_K	0.3183*** (0.0050)	0.3190*** (0.0050)	0.3185*** (0.0050)	0.3192*** (0.0050)	0.3187*** (0.0050)
N	0.4786*** (0.0278)	0.4927*** (0.0287)	0.5092*** (0.0295)	0.4949*** (0.0288)	0.5097*** (0.0295)
T	-0.0748** (0.0299)	-0.0539* (0.0313)	-0.0290 (0.0322)	-0.0593* (0.0315)	-0.0345 (0.0324)
$Q_P\,Q_P$	0.0479*** (0.0158)	0.0546*** (0.0169)	0.0504*** (0.0169)	0.0541*** (0.0169)	0.0503*** (0.0169)
$Q_F\,Q_F$	-0.0293 (0.0189)	-0.0252 (0.0188)	-0.0217 (0.0189)	-0.0290 (0.0190)	-0.0249 (0.0191)
NN	-0.3862*** (0.0587)	-0.3625*** (0.0602)	-0.3214*** (0.0617)	-0.3743*** (0.0604)	-0.3332*** (0.0619)
$w_L\,w_L$	0.1599*** (0.0076)	0.1596*** (0.0076)	0.1579*** (0.0077)	0.1594*** (0.0077)	0.1579*** (0.0077)
$w_L\,w_E$	-0.0041 (0.0034)	-0.0039 (0.0034)	-0.0034 (0.0033)	-0.0037 (0.0034)	-0.0033 (0.0033)
$w_L\,w_M$	-0.0537*** (0.0052)	-0.0534*** (0.0052)	-0.0537*** (0.0052)	-0.0538*** (0.0052)	-0.0540*** (0.0053)
$w_L\,w_K$	-0.1021*** (0.0049)	-0.1023*** (0.0049)	-0.1007*** (0.0049)	-0.1019*** (0.0050)	-0.1006*** (0.0050)
$w_E\,w_E$	0.0479*** (0.0031)	0.0481*** (0.0031)	0.0473*** (0.0030)	0.0478*** (0.0030)	0.0471*** (0.0029)
$w_E\,w_M$	-0.0131*** (0.0032)	-0.0132*** (0.0033)	-0.0128*** (0.0031)	-0.0133*** (0.0032)	-0.0129*** (0.0030)
$w_E\,w_K$	-0.0307*** (0.0027)	-0.0310*** (0.0027)	-0.0311*** (0.0026)	-0.0308*** (0.0027)	-0.0310*** (0.0026)
$w_M\,w_M$	0.1057*** (0.0065)	0.1052*** (0.0067)	0.1048*** (0.0066)	0.1056*** (0.0067)	0.1051*** (0.0066)
$w_M\,w_K$	-0.0389*** (0.0041)	-0.0387*** (0.0042)	-0.0383*** (0.0042)	-0.0385*** (0.0042)	-0.0382*** (0.0042)
$w_K\,w_K$	0.1716*** (0.0048)	0.1720*** (0.0048)	0.1702*** (0.0048)	0.1713*** (0.0048)	0.1697*** (0.0048)
$Q_P\,Q_F$	-0.0279* (0.0156)	-0.0298* (0.0155)	-0.0170 (0.0159)	-0.0314** (0.0156)	-0.0190 (0.0160)
$Q_P\,w_L$	0.0391*** (0.0044)	0.0391*** (0.0044)	0.0382*** (0.0044)	0.0389*** (0.0044)	0.0380*** (0.0044)
$Q_P\,w_E$	0.0112*** (0.0028)	0.0109*** (0.0029)	0.0119*** (0.0027)	0.0111*** (0.0028)	0.0119*** (0.0027)
$Q_P\,w_M$	0.0056 (0.0051)	0.0070 (0.0052)	0.0057 (0.0051)	0.0067 (0.0052)	0.0057 (0.0051)
$Q_P\,w_K$	-0.0560*** (0.0040)	-0.0570*** (0.0041)	-0.0558*** (0.0040)	-0.0567*** (0.0041)	-0.0557*** (0.0040)
$Q_P\,N$	-0.0072 (0.0217)	-0.0139 (0.0225)	-0.0217 (0.0226)	-0.0111 (0.0225)	-0.0189 (0.0226)
$Q_P\,T$	-0.0097	-0.0099	-0.0047	-0.0099	-0.0050

	(0.0210)	(0.0209)	(0.0209)	(0.0209)	(0.0209)
$Q_F\, w_L$	0.0351*** (0.0056)	0.0353*** (0.0057)	0.0350*** (0.0057)	0.0351*** (0.0057)	0.0348*** (0.0057)
$Q_F\, w_E$	0.0015 (0.0035)	0.0014 (0.0035)	0.0014 (0.0033)	0.0016 (0.0035)	0.0016 (0.0033)
$Q_F\, w_M$	0.0369*** (0.0068)	0.0371*** (0.0070)	0.0377*** (0.0069)	0.0367*** (0.0070)	0.0373*** (0.0069)
$Q_F\, w_K$	-0.0735*** (0.0054)	-0.0738*** (0.0054)	-0.0741*** (0.0054)	-0.0734*** (0.0054)	-0.0737*** (0.0054)
$Q_F\, N$	0.1974*** (0.0327)	0.1921*** (0.0324)	0.1693*** (0.0331)	0.1993*** (0.0326)	0.1761*** (0.0333)
$Q_F\, T$	0.0763*** (0.0186)	0.0711*** (0.0185)	0.0595*** (0.0188)	0.0727*** (0.0185)	0.0609*** (0.0189)
$w_L\, N$	-0.0975*** (0.0086)	-0.0983*** (0.0086)	-0.0981*** (0.0087)	-0.0984*** (0.0086)	-0.0982*** (0.0087)
$w_L\, T$	-0.0190*** (0.0046)	-0.0190*** (0.0046)	-0.0190*** (0.0046)	-0.0188*** (0.0046)	-0.0189*** (0.0046)
$w_E\, N$	-0.0155*** (0.0051)	-0.0152*** (0.0052)	-0.0159*** (0.0049)	-0.0156*** (0.0050)	-0.0161*** (0.0048)
$w_E\, T$	0.0054* (0.0028)	0.0057** (0.0029)	0.0050* (0.0027)	0.0055** (0.0028)	0.0049* (0.0026)
$w_M\, N$	-0.0280*** (0.0098)	-0.0287*** (0.0100)	-0.0273*** (0.0099)	-0.0275*** (0.0100)	-0.0267*** (0.0100)
$w_M\, T$	-0.0138** (0.0056)	-0.0145** (0.0057)	-0.0142** (0.0057)	-0.0145** (0.0057)	-0.0141** (0.0057)
$w_K\, N$	0.1410*** (0.0078)	0.1422*** (0.0079)	0.1412*** (0.0079)	0.1416*** (0.0079)	0.1409*** (0.0079)
$w_K\, T$	0.0275*** (0.0043)	0.0278*** (0.0043)	0.0281*** (0.0043)	0.0277*** (0.0043)	0.0280*** (0.0043)
NT	-0.2176*** (0.0348)	-0.1923*** (0.0368)	-0.1702*** (0.0375)	-0.1982*** (0.0369)	-0.1752*** (0.0377)
TT	-0.0032 (0.0082)	-0.0005 (0.0082)	0.0049 (0.0083)	-0.0015 (0.0082)	0.0039 (0.0084)
D_{VS}	-0.0536** (0.0239)	-0.0585** (0.0239)	0.0171 (0.0328)	-0.0667** (0.0280)	0.0042 (0.0352)
VD_{VS}	0.2366*** (0.0356)	0.2578*** (0.0371)	0.3905*** (0.0528)	0.2485*** (0.0396)	0.3758*** (0.0546)
RD_{VS}	-	-	0.1261*** (0.0363)	-	0.1222*** (0.0368)
D_{HC}	-	-0.0388 (0.0266)	-0.0413 (0.0269)	-0.0507* (0.0301)	-0.0546* (0.0302)
VD_{HC}	-	0.0586 (0.0457)	0.0405 (0.0540)	0.0594 (0.0461)	0.0387 (0.0541)
RD_{HC}	-	-	-0.0113 (0.0421)	-	-0.0133 (0.0424)
D_{HS}	-0.2693*** (0.0241)	-0.2717*** (0.0238)	-0.2636*** (0.0244)	-0.2796*** (0.0253)	-0.2719*** (0.0259)
CMP	-	-	-	-0.0127 (0.0108)	-0.0081 (0.0110)
D_{CF}	-	-	-	0.0460* (0.0236)	0.0388 (0.0236)
C_0	8.8617*** (0.0156)	8.8640*** (0.0168)	8.8660*** (0.0167)	8.8640*** (0.0170)	8.8653*** (0.0169)
Log of likelihood	107.742	112.695	119.846	117.091	123.194
Pseudo R^2	0.979	0.979	0.980	0.980	0.980
Number of observations	481	481	481	481	481

Table 3 Cost Changes Relative to the Status Quo of Imposing Vertical Separation on All EU-Railways

Billions of Euros (2005 constant prices)	Train density level			
	Current level	+10%	+20%	+50%
Yearly cost of imposing vertical separation across EU (for those countries not already separated)	5.8	7.8	9.6	14.5

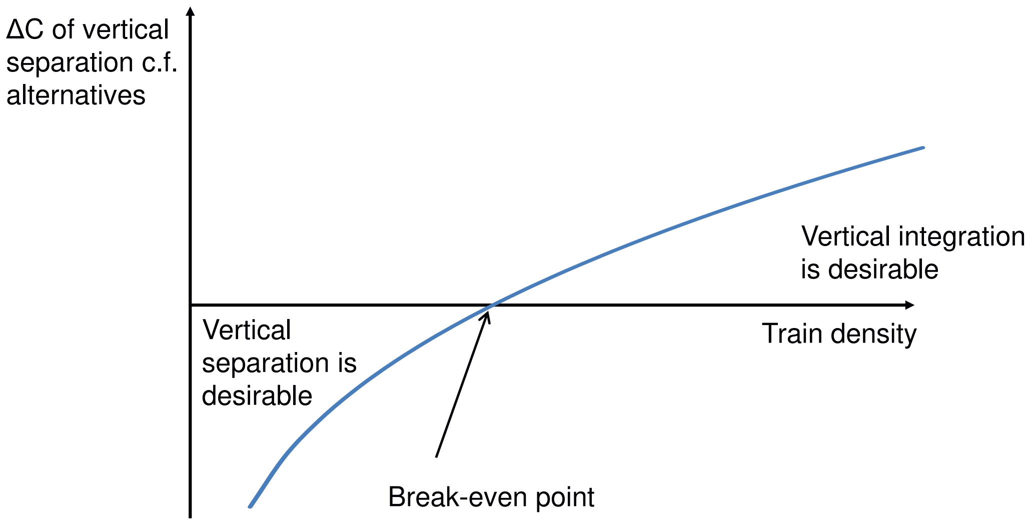

Figure 1: The cost difference between vertical separation and vertical integration and its relationship with train density