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Vertical integration, competition and efficiency in the rail industry: Economic trade-offs

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Executive summary

The European railways have been subject to revolving reforms. The reforms aim at enhancing railways' attractiveness by offering an efficient mode of transport for passengers and freight, while fostering competition, innovation and environmental sustainability. At the same time, railways face several challenges. These include capacity constraints and congestion of rail infrastructure, along with its gradual deterioration and the lack of adequate investment in infrastructure maintenance, modernisation and construction.

Due to the importance of a functioning rail industry for the broader economy and for climate protection, the railway market is subject to high political attention. One policy question arising in this context is the optimal level of vertical integration between rail infrastructure and operations. Since rail is a network industry with a monopolistic infrastructure and a competitively organized transport market, the interplay between the two parts of the industry can be organised in various ways. One question is regularly raised in this debate: Can the rail transport sector respond more efficiently to the future's challenges if infrastructure and train service operators are vertically separated or not?

To build an economically sound fundament for the political debate, Deutsche Bahn AG asked E.CA Economics to derive main insights and trade-offs of vertical separation in the rail sector from economic research and business practice. For this purpose, we carefully reviewed the recent academic literature, screened available market statistics, assessed the experience from other exemplary European countries and other infrastructure-based industries and carried out interviews with industry experts. We focused on the incentives of infrastructure manager and train service operators and on the efficiency of regulation. We hope that our study will promote an informed, professional political discourse and will help decision makers to avoid common pitfalls.

Main result

The academic economic literature does not provide indications that vertical integration or vertical separation of the rail industry is strictly better. The literature rather shows pros and cons for the different industry models which can weigh up to varying degrees depending on specific market characteristics. The optimal level of vertical integration depends on the balancing of the trade-offs within the specific situation and characteristics of the respective railway industry. For example, the higher the train density and the share of mixed traffic, the more important is close coordination which can be supported by a high level of integration. Likewise, the more reliable the regulatory institutions, the less important vertical separation is.

Economic theory predicts that vertical separation of infrastructure and operations can ensure a level playing field for all train service providers using the infrastructure. On the other hand, vertical separation can create coordination failures and contracting problems. Given the rail industry's inherent conflicts between long-term investment and short-term end-customer needs, its operational linkages between the different business segments and the interaction of many stakeholders / competitors, there is a need for "*Systemgedanke*", i.e. a holistic view of the system which takes all the diverse aspects into account and internalises externalities and conflicts. Vertical separation weakens *Systemgedanke* and needs to be compensated in other ways. For example, a proactive regulator would need to be involved in the complexity of short-term timetable coordination across different market segments and railway undertakings (RU), and long-term planning of investment, so that the holistic system view is maintained.

Considering these theoretical pros and cons, an industry model has to be measured by whether it increases efficiency and the quality of train services. Empirical economic literature shows that different forms of horizontal and vertical market organisation can reach the same outcome. This conclusion can be drawn by comparing efficiency scores, which measure the overall productive efficiency of the railway industry across European countries which chose different vertical market models. Efficiency scores, as used in the literature, are bounded between 0 (least efficient country in the sample) and 1 (most efficient country in the sample) and serve to construct a ranking of European countries based on their existing relationship between track length (km), number of employees, passenger and freight fleet and *each* country's output in terms of passenger and freight volumes in 2017 (the latest year available). Countries like Spain, Sweden and Estonia reached a high average efficiency score with a vertically separated market model, while Germany, France and Latvia reached a comparably high efficiency score with a model of organizational separation (independent entities under a holding model). Switzerland reached a top efficiency score based on a fully integrated model.

Given different market fundamentals, different countries will require a different policy mix to reach commonly shared, long-term goals. Regulation, infrastructure, competition and funding are the ingredients of an efficient system, which interact with each other and can substitute or complement each other. Understanding the trade-offs between them and calibrating the policy mix accordingly is an imperative for an efficient organization of the industry.

In the following we summarise the insights from the study in detail.

Regulatory context

Following the literature (see Chapter 3.1), we distinguished three main forms of vertical market organization:

- **Full integration** implies infrastructure management and train service operations within one single undertaking without any organizational boundaries (examples: Switzerland, Japan, USA, Canada).
- **Organisational separation** implies distinct divisions and separate financial accounting for the infrastructure management and the train services within a single undertaking (examples: Germany, Italy, France, Austria).
- **Institutional separation** means that the infrastructure is managed by an entity which is legally separated from the operation of train services (examples: Sweden, UK, Netherlands, Spain).

The European Union directives demand non-discriminatory infrastructure access and a certain degree of independence between infrastructure manager and train service operator, however it leaves member states room to choose between different models ensuring this goal. Fully integrated models can be found in Switzerland and outside European Union.

Economic literature on vertical market organisation and market outcomes

The political motivation for institutional vertical separation is that it is expected to more strongly enable on-track competition in train services. Separation from train services decreases incentives of the infrastructure manager to favour its own RU in the capacity allocation process and access pricing, but at the same time it likely leads to misalignment of incentives of different market players. In a vertically separated organisational structure, each player optimises only its own part of the system and externalities between infrastructure and train services are not internalized. Typically, the infrastructure manager has an incentive to engage in short-term planning and will insufficiently invest in long-term infrastructure. Even abstracting from the misalignment of incentives, separate infrastructure managers and RU might simply not possess the commercial and technical knowledge to take optimal decisions for the rail system as a whole. Furthermore, vertical separation increases transaction costs, as there is an increased need for communication and coordination between infrastructure manager and RU.

Results of the empirical economic literature studying the effects of vertical separation on productive efficiency and modal share vary from positive, to not statistically significant to negative relationship. The differing results could partly be driven by different methodologies used, different measures of vertical separation and different coverage in terms of countries and time period. In our view, however, these differing results also highlight that it might be hard to draw robust policy conclusions based on cross-country/cross-time econometric estimations, because different policy mixes between vertical separation/ integration, competition on the tracks and regulation might well reach the same outcome.

Empirical studies account for these complexities by controlling for additional factors that influence the effects of vertical separation (see Chapter 3.3). The following important factors are identified:

- The form and the **intensity of existing regulation**: The empirical evidence shows that stronger regulatory regimes reduce costs, i.e. result in a more efficient system. However, in more complex specifications of the model, the efficiency-enhancing influence of stronger regulation proves statistically significant only for the systems characterised by vertical separation.

- The **utilisation and characteristics of the rail infrastructure and rolling stock** are further factors influencing the effects of the organisational structure in rail transport. Multiple academic contributions investigated the relationship between train density and the total cost of rail, depending on the vertical organisational structure. Results indicate that at low levels of train density, vertical separation leads to the lowest costs, while at high levels of train density, a vertically integrated organisational structure minimises costs.

- Train density moreover depends on the **technical parameters of the infrastructure**: electrification, the number of parallel tracks, the availability of radio-based signalling system and a dedicated network for one type of transport (in particular high-speed) can have a strong impact on the capacity utilisation of the rail network and thereby the relationship between vertical integration/separation and the efficiency of railways. These parameters vary significantly across European countries, implying that the effects of vertical integration on rail efficiency should be expected to differ depending on the country.

- **Competition on the tracks** is a further factor that influences the effects of the organisational structure. Vertical separation is not required for competition – a regulator can enforce access to the network for competing RU. Economic literature does not provide a clear support for the claim that vertical separation results in more competition or that with vertical separation competition downstream leads to more efficient outcomes. Empirical studies provide either inconclusive or mixed answers to these questions, theoretical studies provide plausible scenarios in which competition does not improve the economic outcomes in case of vertical separation and case studies show that favourable economic outcomes can be achieved also in vertically integrated market structures.

- Lastly, **rail financing** is a further factor influencing the effects of rail transport's organisational structure. Building and maintaining the rail infrastructure requires investments which are designed to last for decades and longer. Assets such as rolling stock are characterised by an estimated useful life of more than 30 years and even innovation happens in railways at a slower pace than many other industries. In this context, adequate and committed long-term financing plays a critical role in sustaining, expanding and improving the quality and performance of the rail system. However, whether adequate rail financing is available is a question of political priorities, state budget and track access charge regulation, regardless of the vertical organisational structure of the rail industry.

Summing up, economic literature explains that in industries with characteristics of a natural monopoly like rail infrastructure, the optimal level of vertical integration and regulation depends on the balancing of the trade-offs withing the specific situation of the country and industry.

Experience from Germany and other countries

An in-depth cross-country comparison illustrates these mixed findings (see Chapter 4). Germany has one of the highest train densities in Europe in both freight and passenger transport. This is the result of Germany's location in the middle of Europe, the high level of urbanization and population density, the ambition to provide train connectivity even in sparsely populated regions and the sharing of the same infrastructure by all transport segments, i.e. regional and long-distance passenger and freight transport. About a half of the rail network is electrified (about 60% of the federal network), mainly on heavily used lines and lagging behind in other areas. Horizontal competition is quite intense: Around 350 railway companies operate on the German railway network. Competitors to the German rail incumbent held an overall market share based on train path kilometres of around 37% in 2022. Bundesnetzagentur (2022) reported 58% in freight (tonne-km), 34% in regional passenger transport and 4% in long-distance passenger transport in 2021 (passenger-km). This is more competition than in most other EU countries. Both freight and passenger volumes have been steadily increasing: the total rail freight volume reached an all-time high at around 125 billion tonne-km in 2021, while the passenger traffic volume was around 100 billion passenger-km in 2019 (although dropped in the aftermath of the pandemic). The increasing utilization of the network given stagnating capacity led to decreasing quality and dissatisfaction of both RUs and end-customers. Punctuality levels deteriorated to 64% in freight, 66% in long-distance passenger and 81% in regional passenger transport in June 2022.

The Swedish rail system can be seen as a successful example of an institutionally separated market. Given a sufficient infrastructure funding, long-term investment planning, competitive tendering and well-functioning authorities, the Swedish railway industry is delivering good operational results on a network with a train density below the European average. Institutional vertical separation in Sweden can been seen as effective in increasing transparency and in achieving a better balance between the regions and the national government.

On the contrary, institutional vertical separation in the United Kingdom (UK) resulted in general dissatisfaction with the railway system. UK's high degree of fragmentation, dense network and misaligned incentives between infrastructure manager and RUs discourage coordination and reduce service quality. The situation was exacerbated by failed franchises, which had to be taken over by the government, and by a centralised infrastructure manager lacking local knowledge to implement the imposed efficiency targets.

Finally, Austria was able to achieve a high degree of service quality and customer satisfaction with the railway industry being organisationally vertically separated as in Germany. The reason is its adequate funding model, which is oriented towards the end-customer and that successfully fosters long-term planning and coordination within the industry.

Experience from other regulated industries

Other regulated industries chose different vertical organisational models (see Chapter 5). In telecommunication services in most of European countries, the infrastructure operator has been allowed to also operate directly in the services market. This has been complemented by the non-discriminatory access regulation and enforcement has fulfilled its role by opening and maintaining access to bottleneck infrastructure to competitors. This has led to a relatively competitive structure and positive outcomes in the end-customer markets and provides another proof that vertical integration does not prevent or eliminate competition. Intense horizontal competition in services is possible also when the infrastructure incumbent is allowed to operate in the service markets. If the indiscriminatory access rights to the bottleneck infrastructure are granted, monitored and enforced, there are generally no obstacles to ensure fair and intense service competition.

Electricity in Germany is an example of an industry where there is substantial separation of generation, transmission and distribution assets. The existence of liquid wholesale, retail and derivative markets ensures fair pricing and efficient allocation of electricity in the spot markets, and it delivers good market results and high quality and security of supply. Still, the industry suffers from underinvestment in naturally monopolistic transmission infrastructure. This shows the potential effects of the misaligned incentives between the infrastructure manager and service operations under vertical separation and/or inadequate funding for the infrastructure.

Trade-offs

Railway industry faces several important trade-offs determining its desired optimal vertical structure, which are summarised in the following take-aways:

- **Infrastructure managers and the rail operators have different incentives:** The infrastructure manager seeks for a high degree of economic and operational predictability, attempts to avoid disruptions on its network and keeps it maintained. Train service operators attempt to serve their customers' needs and benefit from larger infrastructure, more available capacity and more flexible allocation processes. In a vertically integrated market organisation, the integrated train service operator may facilitate the recognition of the interest of operators by the infrastructure manager; in a vertically disintegrated market organization a different institution has to take over this role. Otherwise, the opposing incentives can lead to overutilization of existing infrastructure by train service operators (as they try to compete for new end-customers) or insufficient investment in infrastructure by its manager (as it faces uncertainty if the investment is going to attract new train service operators acting in shorter time frames).

- **High train density favours vertical integration:** The optimal vertical organisational structure differs depending, inter alia, on train density and on the characteristics of the available infrastructure. Multiple academic contributions investigated the relationship between train density and the total cost of rail, depending on the vertical organisational structure (see Chapter 3.3.2). Results indicate that in countries with low train density, vertical separation between train service operations and infrastructure management may minimise total cost, while in countries with high train density a vertically integrated operator may allow cost minimisation.

  Train density varies substantially between countries and between business segments. No country with a train density above 50 train-km per network-km per day opted for a vertically separated model. Germany has one of the highest train densities in Europe, both for freight and passenger transport and thus ranks well above this train density threshold.

- **Mixed infrastructure usage favours vertical integration:** Similarly, countries with dedicated infrastructure for different types of transport (e.g. freight versus passenger or long-distance versus regional) inherently face fewer coordination problems. Therefore, they can more easily opt for vertical separation. For example, this is the case in Spain, which has developed a dedicated network of high-speed rail lines (Alta Velocidad Española, AVE) connecting major cities for trains operating at higher speeds (exceeding 300km/h) and which are separate from conventional railway lines. Germany has very few pieces of dedicated infrastructure and generally its infrastructure is shared among all types of services. This speaks in favour of a vertically integrated model, which according to economic theory helps to solve coordination and contracting problems and minimize costs.

- **Vertical separation may harm investment incentives:** Vertical separation is also more likely to create divergence of incentives between different levels of the vertical chain and various stakeholders. For example, tendering regional passenger routes for short periods may not give sufficient incentives to invest in innovative rolling stock or tracks. Another example: fragmented market structure for rail operations does not favour standardization, which reduces overall costs and increases efficiency of the system. The organisation of the market should be designed in such a way that the downstream service operators and the upstream network operator have incentives that are aligned as much as possible, while providing a reasonable level of horizontal competition at the service level.

- **Different vertical systems require different regulation:** Empirical evidence shows that stronger regulatory regimes reduce costs, i.e. result in a more efficient system, both in integrated and in separated vertical structures (see Chapter 3.3.3). However, different forms of vertical market organization require different forms of regulation. In a vertically integrated market model and with horizontal competition, there is a need for strong regulation to assure non-discriminatory access for competitors to incumbent's infrastructure. In contrast, in a vertically separated market model, there is a need to expose the infrastructure operator to the end-customer perspective to induce the Systemgedanke and promote cost efficiency. Some regulation of prices and quality is necessary in both systems. There is a need for strong regulation in both systems, but regulatory priorities will differ.

Infrastructure requires some form of government funding: Budgetary prudence by the State sets limits to State funding for the railway infrastructure and operations. As the money needs to be earned somewhere, this requires i) higher efficiency in providing these services, ii) higher prices (or lower quality) for end-customers or iii) a reduced coverage of rail services. Higher prices and reduced coverage imply lower competitiveness of the rail sector. As the rail industry stays in inter-modal competition to other modes of transport, this may result in a lower modal share of rail transport in the long run (see Chapter 3.3.4). The chosen vertical structure can influence the efficiency in providing these services. Once efficiency advantages are exhausted, the only remaining measures apart from increased government funding will reduce the modal share of rail.

The political debate on the rail industry is often on the search for quick and easy solutions. This frequently results in an oversimplification of the arguments. We show in this report that while the long-term goals of railway policy are commonly shared, European countries have organised their railways in different ways. Indeed, the economic literature finds that different forms of horizontal and vertical market organisation can reach the same market outcomes. Country-specific characteristics, the regulatory framework, the intensity of competition and the extent and type of funding influence the effect of vertical integration and/or separation. Understanding the trade-offs between these factors is key for calibrating the policy mix that leads to the right choice of organisational model.

Kurzfassung

Der europäische Eisenbahnsektor war und ist Gegenstand von Reformen. Die Reformen zielen darauf ab, die Attraktivität der Eisenbahn zu erhöhen, indem eine effiziente Leistungserbringung für Personen- und Güterverkehr geboten wird, bei gleichzeitiger Förderung von Wettbewerb, Innovation und Nachhaltigkeit. Dabei steht der Eisenbahnsektor in Deutschland vor mehreren Herausforderungen: es bestehen Kapazitätsengpässe und eine allgemeine Überlastung der Eisenbahninfrastruktur, sowie eine zunehmende Abnutzung und ein Mangel an Investitionen in die Instandhaltung, Modernisierung und den Ausbau der Schieneninfrastruktur.

Aufgrund der Bedeutung der Bahn für die Gesamtwirtschaft und die Erreichung der Klimaschutzziele kommt dem Bahnsektor eine hohe politische Aufmerksamkeit zugute. In diesem Zusammenhang stellt sich die Frage nach dem optimalen Ausmaß vertikalen Integration zwischen Eisenbahninfrastruktur und Bahnbetrieb. Bei dem Bahnsektor handelt es sich um eine Netzwerkindustrie, die auf einer weitestgehend monopolistischen Infrastruktur operiert. Das Zusammenspiel zwischen der monopolistisch strukturierten Infrastruktur und einem wettbewerblich organisierten Verkehrsmarkt kann auf unterschiedlicher Weise organisiert werden. Im Mittelpunkt der Debatte steht jedoch die Frage, inwieweit für eine effiziente Leistungserbringung von Personen- und Güterverkehrsleistungen eine Separierung von Infrastrukturmanager und Betreiber des Bahnverkehrs notwendig ist oder nicht.

Um eine fundierte Grundlage für die politische Debatte zu schaffen, hat die Deutsche Bahn AG E.CA Economics beauftragt, die wesentlichen Erkenntnisse und Zielkonflikte, die aus der ökonomischen Forschung und der Unternehmenspraxis heraus für oder gegen eine vertikale Trennung im Bahnsektor streiten, darzustellen. Hierfür haben wir die aktuelle wissenschaftliche Literatur umfassend aufgearbeitet, verfügbare Marktstatistiken gesichtet, Erfahrungen aus anderen europäischen Beispielländern und anderen infrastrukturbasierten Branchen ausgewertet und Interviews mit Branchenexperten geführt. Der Fokus unserer Arbeit liegt dabei auf dem Herausarbeiten der unterschiedlichen Anreize von Infrastrukturmanagern und Zugbetreibern sowie auf der Benennung der Elemente einer effizienten Regulierung. Wir hoffen, dass unsere Studie einen evidenzbasierten politischen Diskurs fördert und Entscheidungsträgern hilft, schwierige Zielkonflikte sinnvoll zu lösen.

Hauptergebnis

Die wirtschaftswissenschaftliche Literatur stellt die grundsätzliche Überlegenheit eines Modells, vertikale Integration oder vertikale Trennung, im Eisenbahnsektor nicht fest. Vielmehr zeigt die Literatur Vor- und Nachteile für die verschiedenen Organisationsmodelle auf, die je nach den Marktgegebenheiten mal stärker mal schwächer in die eine oder andere Richtung weisen. Das optimale Maß an vertikaler Integration hängt somit von der konkreten Situation und den Merkmalen des jeweiligen Bahnsektors ab. Ein vorsichtiges Abwägen der diversen Wechselwirkungen ist erforderlich. Je höher beispielsweise die Zugdichte und der Anteil des Mischverkehrs sind, desto wichtiger ist eine intensive Koordinierung der Verkehre. Ein hohes Maß an vertikaler Integration kann eine solche Koordinierung unterstützen. In einem Marktumfeld mit einer verlässlichen Regulierung des integrierten Unternehmens sind die Vorteile der vertikalen Trennung weniger ausgeprägt.

Aus wirtschaftswissenschaftlicher Sicht ist einerseits zu erwarten, dass die vertikale Trennung von Infrastruktur und Betrieb ein „Level Playing Field“ für alle Eisenbahnverkehrsunternehmen (EVU), die die

Bahninfrastruktur nutzen, gewährleisten kann. Andererseits kann die vertikale Trennung zu Koordinations- und vertragstheoretischen Problemen führen. In Anbetracht der dem Eisenbahnsektor innewohnenden Konflikte zwischen langfristigen Investitionen und kurzfristigen Endkundenbedürfnissen, der betrieblichen Verflechtungen zwischen den verschiedenen Geschäftsbereichen und der Interaktion zahlreicher Interessengruppen/ Wettbewerber ist ein "Systemgedanke" erforderlich, d. h. eine ganzheitliche Betrachtung des Systems, die alle unterschiedlichen Aspekte berücksichtigt und Externalitäten und Konflikte internalisiert. Eine vertikale Trennung schwächt den Systemgedanken und muss auf andere Weise kompensiert werden. Beispielsweise müsste ein proaktiver Regulierer in die Komplexität der kurzfristigen Fahrplankoordinierung über verschiedene Marktsegmente und EVU hinweg sowie in die langfristige Investitionsplanung einbezogen werden, damit der ganzheitliche Systemgedanke erhalten bleibt.

Unter Berücksichtigung dieser theoretischen Vor- und Nachteile muss ein Marktorganisationsmodell daran gemessen werden, ob es die Effizienz und die Qualität der Bahndienstleistungen erhöht. Die empirische Wirtschaftsliteratur zeigt, dass verschiedene Formen der horizontalen und vertikalen Marktorganisation zu vergleichbaren Ergebnissen führen können. Diese Schlussfolgerung lässt sich durch einen Vergleich der Effizienzwerte ziehen, die die Produktionseffizienz des Eisenbahnsektors in europäischen Ländern messen, die sich für unterschiedliche vertikale Organisationsmodelle entschieden haben. Die in der Literatur verwendeten Effizienzwerte liegen zwischen 0 (am wenigsten effizientes Land in der Stichprobe) und 1 (effizientestes Land in der Stichprobe) und erlauben das Erstellen einer Rangliste der europäischen Länder auf der Grundlage des bestehenden Verhältnisses zwischen der Gleislänge (km), der Zahl der Beschäftigten, der Personen- und Güterverkehrsflotte und dem Produktionsleistung jedes Landes in Form von Personen- und Güterverkehrsaufkommen im Jahr 2017 (dem letzten verfügbaren Jahr). Länder wie Spanien, Schweden und Estland erreichten eine hohe durchschnittliche Effizienzbewertung mit einem vertikal getrennten Organisationsmodell, während Deutschland, Frankreich und Lettland eine vergleichbar hohe Effizienzbewertung mit einem Modell der organisatorischen Trennung (unabhängige Einheiten innerhalb einer Holdingstruktur) erreichten. Die Schweiz erreichte mit einem voll integrierten Modell einen Spitzenwert.

Angesichts unterschiedlicher Marktgegebenheiten benötigen die einzelnen Länder einen unterschiedlichen Policy-Mix, um gemeinsame, langfristige Ziele zu erreichen. Regulierung, Infrastruktur, Wettbewerb und Finanzierung sind die Bestandteile eines effizienten Systems, die in Wechselwirkung zueinanderstehen und sich gegenseitig substituieren oder komplementieren können. Für eine effiziente Organisation der Branche ist es unerlässlich, die Wechselwirkungen zwischen diesen Bestandteilen zu verstehen und den Policy-Mix entsprechend zu kalibrieren.

Im Folgenden fassen wir die Erkenntnisse aus der Studie im Detail zusammen.

Regulatorischer Kontext

In Anlehnung an die Literatur (siehe Kapitel 3.1) haben wir zwischen drei Hauptformen der vertikalen Marktorganisation unterschieden:

- Die **vollständige Integration** bedeutet, dass der Betrieb der Infrastruktur und der Betrieb des Zugverkehrs in einem einzigen Unternehmen ohne organisatorische Grenzen erfolgt (Beispiele: Schweiz, Japan, USA, Kanada).

- Die **organisatorische Trennung** bedeutet getrennte Sparten und eine getrennte Buchhaltung für den Betrieb der Infrastruktur und den Bahnbetrieb innerhalb eines Unternehmens (Beispiele: Deutschland, Italien, Frankreich, Österreich).

- Die **institutionelle Trennung** bedeutet, dass die Infrastruktur von einer Organisation verwaltet wird, die eigentumsrechtlich vom Bahnbetrieb getrennt ist (Beispiele: Schweden, Vereinigtes Königreich, Niederlande, Spanien).

Die Richtlinien der Europäischen Union verlangen einen diskriminierungsfreien Zugang zur Infrastruktur und ein gewisses Maß an Unabhängigkeit zwischen Infrastrukturbetreiber und EVU, lassen den Mitgliedstaaten jedoch die Wahl zwischen verschiedenen Organisationsmodellen, die dieses Ziel gewährleisten. Vollständig integrierte Modelle gibt es in der Schweiz und außerhalb der Europäischen Union.

Wirtschaftswissenschaftliche Literatur zu vertikaler Marktorganisation und Marktergebnissen

Die politische Motivation hinter der institutionellen vertikalen Trennung ist, dass sie den Wettbewerb auf der Schiene stärker fördern soll. Die Trennung vom Bahnbetrieb verringert die Anreize des Infrastrukturmanagers, sein eigenes EVU bei der Kapazitätszuweisung und der Gestaltung der Trassenpreise zu bevorzugen, führt aber gleichzeitig zu möglicherweise fehlgeleiteten Anreizen der verschiedenen Marktteilnehmer aus Sicht des Gesamtsystems. In einer vertikal getrennten Organisationsstruktur optimiert jeder Akteur nur seinen eigenen Teil des Systems, und Externalitäten zwischen Infrastruktur und Bahnbetrieb werden nicht internalisiert. Typischerweise hat der Infrastrukturbetreiber einen Anreiz, kurzfristig zu planen und wird nicht ausreichend in die langfristige Infrastruktur investieren. Selbst wenn man von gegensätzlichen Anreizen absieht, verfügen getrennte Infrastrukturmanager und EVUs möglicherweise nicht über das kommerzielle und technische Wissen, um optimale Entscheidungen für das Bahnsystem als Ganzes zu treffen. Darüber hinaus erhöht die vertikale Trennung die Transaktionskosten, da ein erhöhter Kommunikations- und Koordinationsbedarf zwischen Infrastrukturmanager und EVUs besteht.

Die Ergebnisse der empirischen Wirtschaftsliteratur, die die Auswirkungen der vertikalen Trennung auf die Produktionseffizienz und den modalen Anteil des Schienenverkehrs untersucht, reichen von positiven über statistisch nicht signifikante bis hin zu negativen Effekten. Die unterschiedlichen Ergebnisse könnten zum Teil auf unterschiedliche Methoden, unterschiedliche Maße für vertikale Trennung und unterschiedliche Stichproben in Bezug auf Länder und Zeiträume zurückzuführen sein. Unserer Ansicht nach machen diese unterschiedlichen Ergebnisse jedoch auch deutlich, dass robuste politische Schlussfolgerungen auf der Grundlage länder- und zeitübergreifender ökonometrischer Schätzungen nur schwer gezogen werden können: unterschiedliche Kombinationen aus vertikaler Trennung und Integration, Wettbewerbsintensität auf der Schiene und Regulierung können zu demselben Marktergebnis führen.

Empirische Studien tragen dieser Komplexität Rechnung, indem sie zusätzliche Faktoren berücksichtigen, die die Auswirkungen der vertikalen Trennung beeinflussen (siehe Kapitel 3.3). Die folgenden wichtigen Faktoren werden von der Literatur identifiziert:

- Die Form und die **Intensität der bestehenden Regulierung**: Die empirische Evidenz zeigt auf, dass eine stärkere Regulierung die Kosten senkt, d.h. zu einem effizienteren System führt. Bei Berücksichtigung der Interaktion von Regulierung und des vertikalen Organisationsmodells erweist sich der effizienzsteigernde Einfluss einer stärkeren Regulierung jedoch nur für die Bahnsysteme als statistisch signifikant, die auch vertikal getrennt sind.

- Die **Auslastung und die Eigenschaften der Schieneninfrastruktur und des Rollmaterials** sind weitere Faktoren, die die Auswirkungen des Organisationsmodells im Bahnsektor beeinflussen. So untersuchen mehrere wissenschaftliche Arbeiten die Beziehung zwischen der Zugdichte und den Gesamtkosten des

Bahnsektors in Abhängigkeit vom vertikalen Organisationsmodell. Die Ergebnisse zeigen, dass bei geringer Zugdichte eine vertikale Trennung zu den niedrigsten Kosten führt, während bei hoher Zugdichte ein vertikal integriertes Organisationsmodell die Kosten minimiert.

- Die Zugdichte hängt außerdem von den **technischen Parametern der Infrastruktur** ab: Der Grad der Elektrifizierung, die Anzahl der parallelen Gleise, die Verfügbarkeit eines funkgestützten Signalsystems und ein speziell für eine Verkehrsart (insbesondere Hochgeschwindigkeitszüge) ausgelegtes Netz können sich stark auf die Kapazitätsauslastung des Schienennetzes und damit auf die Beziehung zwischen vertikaler Integration/ Trennung und der Effizienz des Bahnsektors auswirken. Diese Parameter unterscheiden sich erheblich zwischen den europäischen Ländern, so dass man erwarten kann, dass die Auswirkungen der vertikalen Integration auf die Effizienz des Bahnsektors je nach Land unterschiedlich sind.

- Der **Wettbewerb auf der Schiene** ist ein weiterer Faktor, der die Auswirkungen des Organisationsmodells beeinflusst. Eine vertikale Trennung ist keine Voraussetzung für Wettbewerb auf der Schiene – auch eine Regulierungsbehörde kann den Netzzugang für konkurrierende EVU durchsetzen. Die wirtschaftswissenschaftliche Literatur stützt nicht die Behauptung, dass vertikale Trennung *per se* zu mehr Wettbewerb auf der Schiene führt oder dass der Wettbewerb auf der Schiene bei vertikaler Trennung zu effizienteren Ergebnissen führt. Empirische Studien liefern entweder uneindeutige oder gegenläufige Antworten auf diese Fragen, theoretische Studien beschreiben plausible Szenarien, in denen Wettbewerb die wirtschaftlichen Ergebnisse im Falle einer vertikalen Trennung nicht verbessert, und Fallstudien zeigen, dass günstige wirtschaftliche Ergebnisse auch in vertikal integrierten Marktstrukturen erzielt werden können.

- Schließlich ist die **Finanzierung des Bahnsektors** ein weiterer Faktor, der die Auswirkungen des Organisationsmodells beeinflusst. Der Bau und die Instandhaltung der Eisenbahninfrastruktur erfordern Investitionen, die auf Jahrzehnte und länger ausgelegt sind. Vermögenswerte wie Rollmaterial haben eine geschätzte Nutzungsdauer von mehr als 30 Jahren, und auch Innovationen erfolgen im Bahnsektor langsamer als in vielen anderen Branchen. In diesem Zusammenhang spielt eine angemessene und verbindliche langfristige Finanzierung eine entscheidende Rolle für die Aufrechterhaltung, den Ausbau und die Verbesserung der Qualität und Leistung des Eisenbahnsystems. Ob jedoch eine angemessene Finanzierung des Eisenbahnsektors zur Verfügung steht, ist eine Frage der politischen Prioritäten, des Staatshaushalts und der Regulierung der Trassenpreise, unabhängig vom vertikalen Organisationsmodell des Eisenbahnsektors.

Zusammenfassend kommt die wirtschaftswissenschaftliche Literatur zu dem Schluss, dass in Branchen mit Merkmalen eines natürlichen Monopols, wie der Eisenbahninfrastruktur, das optimale Maß von vertikaler Integration und Regulierung von der Abwägung der Wechselwirkungen in der konkreten Situation des Landes und der Branche abhängt.

Erfahrungen aus Deutschland und anderen Ländern

Ein eingehender länderübergreifender Vergleich veranschaulicht diese unterschiedlichen Ergebnisse (siehe Kapitel 4). Deutschland hat eine der höchsten Zugdichten in Europa, sowohl im Güter- als auch im Personenverkehr. Dies liegt an der geographischen Lage Deutschlands in der Mitte Europas, dem hohen Verstädterungsgrad und der hohen Bevölkerungsdichte, des Bestrebens, auch in dünn besiedelten Regionen Zugverbindungen anzubieten, und der gemeinsamen Nutzung derselben Infrastruktur durch alle Verkehrssegmente, d. h. durch den Personennahverkehr, Personenfernverkehr und Güterverkehr. Etwa die Hälfte des Schienennetzes ist elektrifiziert (etwa 60 % des bundeseigenen Netzes), vor allem auf stark befahrenen Strecken, während in anderen Bereichen Nachholbedarf besteht. Der horizontale Wettbewerb ist intensiv: Auf dem deutschen Schienennetz sind rund 350 Eisenbahnverkehrsunternehmen tätig. Die Wettbewerber der Deutschen Bahn hielten im Jahr 2022 einen auf Trassenkilometer bezogenen Gesamtmarktanteil von rund 37%. Die Bundesnetzagentur (2022) meldete für 2021 58% im Güterverkehr (Tonnenkilometer), 34% im Personennahverkehr und 4% im Personenfernverkehr (Personenkilometer). Dies ist stärkerer Wettbewerb als in den meisten anderen EU-Ländern. Sowohl das Güter- als auch das Personenverkehrsaufkommen nehmen stetig zu: Das gesamte Güterverkehrsaufkommen auf der Schiene erreichte mit rund 125 Mrd. Tonnenkilometern im Jahr 2021 einen historischen Höchststand, während das Personenverkehrsaufkommen im Jahr 2019 bei rund 100 Mrd. Personenkilometern lag (obwohl es nach der Pandemie zurückging). Die zunehmende Auslastung des Netzes bei stagnierender Kapazität führte zu sinkender Qualität und Unzufriedenheit sowohl bei den EVU als auch bei den Endkunden. Das Pünktlichkeitsniveau verschlechterte sich im Juni 2022 auf 64% im Güterverkehr, 66% im Personenfernverkehr und 81% im Personennahverkehr.

Das schwedische Eisenbahnsystem kann als ein erfolgreiches Beispiel für einen institutionell getrennten Markt angesehen werden. Angesichts einer ausreichenden Finanzierung der Infrastruktur, einer langfristigen Investitionsplanung, wettbewerblicher Ausschreibungen und gut funktionierender Behörden erzielt der schwedische Eisenbahnsektor gute Betriebsergebnisse auf einem Schienennetz mit unterdurchschnittlicher Zugdichte im europäischen Vergleich. Die institutionelle vertikale Trennung in Schweden hat sich als wirksam erwiesen, Transparenz zu erhöhen und ein besseres Gleichgewicht zwischen den Regionen und der Regierung zu erreichen.

Im Gegensatz dazu führte die institutionelle vertikale Trennung in Großbritannien zu allgemeiner Unzufriedenheit mit dem Eisenbahnsystem. Der hohe Grad an Fragmentierung, das dichte Schienennetz und die fehlgeleiteten Anreize zwischen Infrastrukturbetreibern und EVU aus Gesamtsystemsicht erschweren die Koordinierung und verschlechtern die Dienstleistungsqualität. Verschärft wurde die Situation durch gescheiterte Franchise Verträge, die von der Regierung übernommen werden mussten, und durch einen zentralisierten Infrastrukturbetreiber, dem es an lokalen Kenntnissen zur Umsetzung der auferlegten Effizienzziele mangelte.

Österreich wiederum konnte ein hohes Maß an Servicequalität und Kundenzufriedenheit erreichen, wobei der Eisenbahnsektor wie in Deutschland organisatorisch vertikal getrennt ist. Der Grund dafür ist das adäquate Finanzierungsmodell, das sich an den Bedürfnissen der Endkunden orientiert und eine langfristige Planung und Koordination innerhalb der Branche erfolgreich fördert.

Erfahrungen aus anderen regulierten Branchen

Andere regulierte Branchen haben sich für andere vertikale Organisationsmodelle entschieden (siehe Kapitel 5). Im Telekommunikationssektor ist es dem Netzbetreiber in den meisten europäischen Ländern gestattet, auch direkt auf dem Dienstleistungsmarkt tätig zu werden. Die Regulierung für diskriminierungsfreien Netzzugang und ihre Durchsetzung haben den Zugang zur Engpassinfrastruktur für Wettbewerber geöffnet und aufrechterhalten. Dies hat zu einer relativ kompetitiven Marktstruktur und positiven Ergebnissen auf den Endkundenmärkten geführt und ist ein weiterer Beleg dafür, dass die vertikale Integration den Wettbewerb nicht verhindert oder ausschaltet: Ein intensiver horizontaler Wettbewerb im Dienstleistungsmarkt ist auch dann möglich, wenn der etablierte Infrastrukturbetreiber auf den Dienstleistungsmärkten aktiv ist. Bei wirksamer Durchsetzung eines diskriminierungsfreien Zugangs zur Netzinfrastruktur kann ein fairer und intensiver Wettbewerb auf den Dienstleistungsmärkten gewährleistet werden.

Die Elektrizitätswirtschaft in Deutschland ist ein Beispiel für eine Branche, in der eine weitgehende Trennung von Erzeugung, Übertragung und Verteilung besteht. Die Existenz liquider Großhandels-, Einzelhandels- und Derivatemärkte gewährleistet eine faire Preisbildung und eine effiziente Vergabe von Strom auf den Spotmärkten und sorgt für effiziente Marktergebnisse sowie eine hohe Qualität und Sicherheit der Versorgung. Dennoch leidet auch diese Branche unter unzureichenden Investitionen in die monopolistische Infrastruktur für die Stromübertragung. Nach unserer Einschätzung ist dies eine Folge von Fehlanreizen zwischen Infrastrukturbetreiber und Dienstleistungsbetrieb bei vertikaler Trennung und/oder einer unzureichenden Finanzierung der Infrastruktur.

Wechselwirkungen

Der Eisenbahnsektor steht bei der Bestimmung der gewünschten optimalen vertikalen Struktur vor der Abwägung mehrerer wichtiger Wechselwirkungen, die in den folgenden Schlussfolgerungen zusammengefasst sind:

- **Infrastrukturmanager und Eisenbahnverkehrsunternehmen haben unterschiedliche Anreize:** Der Infrastrukturbetreiber strebt ein hohes Maß an wirtschaftlicher und betrieblicher Vorhersehbarkeit an und versucht, Störungen auf seinem Netz zu vermeiden und es instand zu halten. Die Eisenbahnverkehrsunternehmen versuchen, die Bedürfnisse ihrer Kunden zu erfüllen und profitieren von einer breiten Infrastruktur, höheren verfügbaren Kapazitäten und flexibleren Zuweisungsverfahren. In einer vertikal integrierten Organisationsstruktur kann das integrierte Unternehmen die Berücksichtigung der Interessen der Eisenbahnverkehrsunternehmen durch den Infrastrukturmanager erleichtern; in einer vertikal getrennten Organisationsstruktur muss eine andere Institution diese Rolle übernehmen. Andernfalls können die unterschiedlichen Anreize zu einer Überbeanspruchung der bestehenden Infrastruktur durch die EVU (da diese, um neue Endkunden konkurrieren) oder zu unzureichenden Investitionen in die Infrastruktur durch den Infrastrukturmanager führen (da dieser sich der Unsicherheit ausgesetzt sieht, ob die Investitionen zu zusätzlichen Verkehren der EVU führen; letztere planen ihre Verkehre kurzfristig).

- **Eine hohe Zugdichte begünstigt vertikale Integration:** Die optimale vertikale Organisationsstruktur hängt u. a. von der Zugdichte und den Eigenschaften der bestehenden Infrastruktur ab. In mehreren wissenschaftlichen Beiträgen wurde die Beziehung zwischen der Zugdichte und den Gesamtkosten des Bahnsektors in Abhängigkeit von der vertikalen Organisationsstruktur untersucht (siehe Kapitel 3.3.2). Die Ergebnisse zeigen, dass in Ländern mit geringer Zugdichte eine vertikale Trennung zwischen Zugbetrieb und Infrastrukturmanagement die Gesamtkosten minimieren kann, während in Ländern mit hoher Zugdichte ein vertikal integrierter Betreiber Kostenminimierung ermöglichen kann.

  Die Zugdichte variiert erheblich zwischen den Ländern und den einzelnen Segmenten. Kein Land mit einer Zugdichte von über 50 Zugkilometern pro Netzkilometer und Tag hat sich für ein vertikal getrenntes Modell entschieden. Deutschland hat eine der höchsten Zugdichten Europas, sowohl im Güter- als auch im Personenverkehr, und liegt damit weit über diesem Schwellenwert bezüglich der Zugdichte.

- **Eine gemischte Nutzung der Infrastruktur begünstigt die vertikale Integration:** Länder, die über separate Infrastruktur für die verschiedenen Verkehrsarten verfügen (z. B. Güterverkehr versus Personenverkehr oder Fernverkehr versus Nahverkehr), haben naturgemäß weniger Koordinierungsprobleme. Daher können sie sich leichter für die vertikale Trennung entscheiden. So hat beispielsweise Spanien ein eigenes Netz von Hochgeschwindigkeitstrassen (Alta Velocidad Española, AVE) für Hochgeschwindigkeitszüge (über 300 km/h) gebaut, welches die Großstädte miteinander verbindet und von den herkömmlichen Eisenbahnstrecken getrennt ist. In Deutschland gibt es nur sehr wenig speziell für bestimmte Verkehre vorgesehene Bahnstrecken. Üblicherweise wird die Schieneninfrastruktur von allen Segmenten gemeinsam genutzt. Dies spricht für ein vertikal integriertes Modell, das gemäß der ökonomischen Literatur, dazu beiträgt, Koordinierungs- und Vertragsprobleme zu lösen und die Gesamtkosten zu minimieren.

- **Die vertikale Trennung kann Investitionsanreize beeinträchtigen:** Durch die vertikale Trennung ist es auch wahrscheinlicher, dass die Anreize zwischen den verschiedenen vertikalen Ebenen und den verschiedenen Akteuren divergieren. Beispielsweise kann die Ausschreibung von Personennahverkehrsstrecken für kurze Zeiträume keine ausreichenden Anreize für Investitionen in modernes Rollmaterial oder Gleise setzen. Ein weiteres Beispiel: Eine fragmentierte Marktstruktur im Bahnbetrieb erschwert Standardisierung. Eine Standardisierung wiederum senkt die Gesamtkosten und erhöht die Effizienz des Gesamtsystems. Die ideale Marktorganisation sollte jedenfalls so gestaltet werden, dass die Anreize für die nachgelagerten Dienstleistungsanbieter und den vorgelagerten Netzbetreiber so weit wie möglich gleichgerichtet sind und gleichzeitig ein hinreichendes Maß an horizontalem Wettbewerb auf der Dienstleistungsebene gewährleistet ist.

- **Unterschiedliche vertikale Organisationsmodelle erfordern unterschiedliche Regulierung:** Die empirischen Arbeiten zeigen, dass eine stärkere Regulierung sowohl in integrierten als auch in getrennten vertikalen Organisationsmodellen die Kosten senkt, d.h. zu einem effizienteren System führt (siehe Kapitel 3.3.3). Verschiedene Formen der vertikalen Marktorganisation erfordern jedoch unterschiedliche Formen der Regulierung. In einem vertikal integrierten Marktmodell und gleichzeitigem horizontalem Wettbewerb ist eine starke Regulierung erforderlich, um den diskriminierungsfreien Zugang der Wettbewerber zur Infrastruktur des etablierten Unternehmens zu gewährleisten. In einem vertikal getrennten Marktmodell hingegen muss der Infrastrukturmanager der Endkundenperspektive ausgesetzt werden. Dies ist notwendig, um den Systemgedanken zu stärken und dadurch die Kosteneffizienz zu steigern. Eine gewisse Regulierung der Preise und der Qualität ist, schon wegen der natürlichen Monopol Situation bei der Infrastruktur, in beiden Organisationsmodellen notwendig. Eine starke Regulierung ist in beiden Marktmodellen erforderlich, die Prioritäten der Regulierung sind jedoch sehr unterschiedlich.

- **Die Infrastruktur bedarf staatlicher Finanzierung:** Die Haushaltsdisziplin des Staates setzt der staatlichen Finanzierung von Eisenbahninfrastruktur und -betrieb Grenzen. Neben einer erhöhten Subventionierung des Bahnsektors verbleiben jedoch nur die folgenden Optionen: i) Eine höhere Effizienz bei der Erbringung dieser Dienstleistungen, ii) höhere Preise (oder eine geringere Qualität) für die Endkunden oder iii) ein reduziertes Streckenangebot. Höhere Preise und ein geringeres Angebot bedeuten eine geringere Wettbewerbsfähigkeit des Eisenbahnsektors. Da der Eisenbahnsektor im intermodalen Wettbewerb mit anderen Verkehrsträgern steht, kann dies langfristig zu einem geringeren Anteil des Schienenverkehrs im Verkehrssektor führen (siehe Kapitel 3.3.4). Die Wahl der vertikalen Struktur kann die Effizienz der Erbringung der Dienstleistungen beeinflussen. Sind diese Effizienzvorteile jedoch ausgereizt, verbleiben neben einer stärkeren staatlichen Förderung nur Maßnahmen, die den modalen Anteil der Bahn verringern.

Die politische Debatte im Eisenbahnsektor ist oft auf der Suche nach schnellen und einfachen Lösungen. Dies führt häufig zu einer zu starken Vereinfachung der Argumente. In diesem Bericht zeigen wir auf, dass die langfristigen Ziele der Eisenbahnpolitik zwar allgemein geteilt werden, der Eisenbahnsektor jedoch auf unterschiedliche Weise in den europäischen Ländern strukturiert ist. Tatsächlich stellt die ökonomische Literatur fest, dass mit unterschiedlichen Formen horizontaler und vertikaler Marktorganisation dasselbe Marktergebnis erreicht werden kann. Länderspezifische Besonderheiten, der Regulierungsrahmen, die Intensität des Wettbewerbs und Umfang und Art der Finanzierung beeinflussen die Wirkung vertikaler Integration bzw. Trennung. Das Verständnis der Wechselwirkungen zwischen diesen Faktoren ist der Schlüssel zur Bestimmung eines Politikmixes, der zur Wahl des richtigen Marktmodells führt.

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1 Introduction

The European railways face pressure to reform, driven by the overarching ambition to create a more sustainable and customer-focused European industry that can effectively contribute to the overall mobility and economic goals of the European Union. The key objectives and challenges of these reforms include improved service quality and customer experience by encouraging intramodal competition, promoting open access to tracks and supporting investment in new infrastructure and upgrades and modernisation of existing infrastructure. Overall, the reforms aim to make rail transport an attractive and efficient mode of transport for both passengers and freight, while fostering innovation and environmental sustainability.

The rail industry in most European countries was historically organised as a single, mostly state-owned monopolistic company that operated both the network infrastructure and the passenger and freight train services. In the late twentieth century, the railway sector faced challenges such as the declining rail modal share due to increasing competition from other means of transport, decreasing efficiency and increasing government expenditures. This led to a trend of deregulation, where in the past decades, many countries – including Germany - vertically separated the organisation of track infrastructure from the provision of train services and started to introduce competition on the tracks. Different forms of vertical separation were chosen to foster competition - from an organisational separation to a full institutional separation of infrastructure and transport in terms of ownership. Sweden was the first country to start deregulating the railway sector as early as 1988. The first European directive about vertical separation in the railway sector followed in 1991.[1] The following four European railway packages (2001, 2004, 2007 and 2016) have further stimulated these developments and were aimed at the successive deregulation of different market segments. Given the successive introduction of competition on the tracks, the different railway packages also include provisions regarding the capacity allocation and track access charging.

Within the common European legislative background, the exact policy mix between the different forms of vertical separation, the degree and the type of competition on the tracks, the regulatory framework, the role of the government and the financing model for the infrastructure differs across countries. This suggests that the same goals can potentially be reached with different policy mixes and which degree of vertical separation or integration is optimal depends on several factors. Economic theory stipulates that activities should be undertaken externally through market transactions, unless the costs of these activities are lower when conducted internally within the firm.[2] In well-functioning, liquid markets, when transaction costs are low, vertical separation is efficient. However, there are factors that can result in market failure and in an increase of market transaction costs. These factors include externalities[3]

[1] Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways.

[2] See Williamson, O. E. (1985) The Economic Institutions of Capitalism, Free Press, New York.

[3] An externality is a cost or benefit to an uninvolved third party that arises from another party's activity. According to Mas-Collel et al. (1995, p. 352), "an externality is present whenever the well-being of a consumer or the production possibilities of a firm are directly affected by the actions of another agent in the economy". An example is a factory polluting a river that is used by the population for recreational activities.

between market participants, asymmetric information,[4] regulatory failure, contractual hold-up,[5] costs of contractual incompleteness and bounded rationality[6] and the costs of market power imbalances. Vertical integration can reduce and eliminate some of these costs, e.g. costs related to asymmetric information or incomplete contracting. However, it can also increase other costs such as the costs of collective decision making, higher agency costs and the costs of risk bearing (i.e. lack of diversification and access to capital in imperfect capital markets). Ultimately, the optimal organisational structure of a firm is determined by the lowest combined costs of ownership and market contracting.

In many European countries, there is a heated policy debate about further reform of their railway industry. The industry faces several challenges. These include capacity constraints and congestion of rail infrastructure, along with its gradual deterioration and the lack of adequate investment for its maintenance, modernisation and construction. Furthermore, transport services are lagging behind the planed level of modal shift to rail and the achievement of related sustainability and electrification goals. One example is Germany. It has been generally recognised that since the rail reform in 1994, which had as one of its objectives to relieve the federal budget, too little has been invested in the network infrastructure. The consequences are emerging now with an identified investment gap of about EUR 50 billion in 2018/2019[7] (that has risen even further according to industry experts) and a network infrastructure that is old, overutilised and has little resilience, leading to capacity constraints and routes having to be closed for maintenance and renewal. This results in capacity conflicts, disrupted operations, delays and dissatisfied end-customers.

Separation of ownership between the network infrastructure and the operation of train services (henceforth referred to as institutional separation) is often proposed as a potential solution to the current problems. For example, the German Monopolies Commission continues to argue in favour of an ownership separation between the infrastructure part of DB and its other business units in its latest railway sector reports.[8] The Bundesrechnungshof suggested that ownership separation could at least contribute to solving the current problems regarding the performance of train services and the status of the infrastructure.[9] But can the rail transport sector respond more efficiently to those challenges if infrastructure and operators are vertically integrated or not? The answer to this question is not a simple one and various stakeholders may have different views on it. Still, the political debate needs to be grounded in sound economics. To provide an economic basis for the political debate, E.CA Economics was asked by Deutsche Bahn (DB) to review the status of the recent academic and industry discussion on the

[4] Asymmetric information refers to transactions in which one party to the transaction has more information than the other party. For example, a seller of a good typically has more knowledge about the quality of the good. Another example is a worker having more knowledge about her innate ability than the employer at the time of hiring her.

[5] The hold-up problem is central to the theory on incomplete contracts. It arises in situations where (i) prior to the transaction, parties must make non-contractible relationship-specific investments and (ii) the specific form of the optimal transaction (for example the quality level or the time of delivery) cannot be specified in the contract ex ante with certainty. In these situations, the party with higher bargaining power can ex post impose conditions on the other party that do not allow to recover the costs of the initial relationship-specific investments. Anticipating this, the party that needs to make the upfront investment might not invest and agree to the contract in the first place, even though the transaction would be efficient.

[6] Bounded rationality is the idea that in practice individuals do not take fully rational decisions, as presumed by neoclassical economic theory. Limitations to rationality include the complexity of the problem requiring a decision, the limited cognitive abilities of the decision taker and the time available to take the decision.

[7] Dornier Consulting and Mazars (2019), Bedarfsermittlung LUFV III 2020-2024, Gutachten im Auftrag des Bundesministeriums für Verkehr und Digitale Infrastruktur.

[8] Monopolkommission (2023), 9. Sektorgutachten.

[9] Bundesrechnungshof (2023). Bericht nach § 99 BHO zur Dauerkrise der Deutschen Bahn AG. Hinweise für eine strukturelle Weiterentwicklung.

vertical market organisation in the rail industry. The objective of this study is to identify the economic trade-offs in terms of prices, efficiency and quality of infrastructure and services for alternative organisational structures of the railway industry. We discuss them with a focus on the misalignment of incentives between infrastructure manager and train service providers and the efficiency of regulation. For this purpose, we carefully reviewed the academic literature, screened available market statistics, assessed the experience from exemplary European countries and other infrastructure-based industries and carried out interviews with experts on the intersection between rail infrastructure and operations.

This report presents our findings. In Chapter 2 we describe the fundamentals of the European rail industry. Chapter 3 discusses the main conclusions from the literature regarding the effects of vertical separation on different policy objectives. Chapter 4 reviews the railway industry in European countries with a focus on Germany, Sweden, the United Kingdom and Austria. Chapter 50 provides the lessons learned from other network industries like telecommunication and electricity, regarding core properties and trade-offs. Chapter 6 summarises the results of the previous chapters and formulates the main trade-offs and policy insights regarding the optimal organisational structure of the railway industry. Typical pitfalls in the political debate close the report.

Summary

- The European railway reforms aim to improve service quality and customer experience by encouraging intramodal competition, promoting open access to tracks and supporting investment in new and existing infrastructure.

- The rail industry in most European countries was historically organised as a single, mostly state-owned monopolistic company that operated both the network infrastructure and passenger and freight train services. By now all EU member states implemented at least organisational separation between infrastructure management and train service operations.

- Institutional separation (i.e. ownership separation) between network infrastructure and operation of train services is often proposed as a potential solution to the current challenges of the rail sector. These challenges include capacity constraints and congestion of rail infrastructure, its gradual deterioration and the lack of adequate investment for its maintenance, modernisation and construction.

- In this report, we investigate whether the rail transport sector can respond more efficiently to the current challenges if infrastructure and operators are vertically integrated or not. We review academic literature, market statistics, country and industry studies and expert interviews. The objective of this study is to identify the economic trade-offs in terms of prices, efficiency and quality of infrastructure and services for alternative organisational structures of the railway industry.

2 European rail industry

The rail industry has historically been organised as a single, mostly state-owned monopolistic company that operated both the infrastructure and the passenger and freight train services in a country. The rail infrastructure is comprised of the track network, train stations and service facilities (e.g. shunting yards and terminals, refuelling and maintenance facilities etc.). The rail infrastructure is an example of a natural monopoly, i.e. a market structure where a single firm can operate more efficiently than multiple competing firms. Natural monopolies can arise in industries with significant economies of scale, i.e. when the average cost per unit of output decreases as the level of output increases. In this case, due to the large scale of its operation, a single firm can operate more efficiently than several smaller firms. Natural monopolies are usually associated with high barriers to entry and high upfront fixed investment costs relative to variable costs. As output increases, the fixed initial investment in infrastructure can be spread over a larger output leading to lower average costs (and more efficient operation) (Sharkey, 2011). The economic characteristics of a natural monopoly highlight the complexities involved in balancing economic efficiency, i.e. total welfare (which would favour a single firm) against other public interest objectives, such as distributing the welfare to consumers, which could be achieved through competition among multiple (but less efficient) firms.[10] On the contrary, train service operations, even though they might display some economies of scale, do not share these natural monopoly characteristics. In case of formerly vertically integrated organisational market structures, the integrated company running the infrastructure also used to be the monopolistic supplier of train services. Thus, a state monopoly was also granted in the part of operations that does not have natural monopoly characteristics, leading to market power also in the downstream rail transport markets.

In the late twentieth century, the European railway sector faced challenges such as the declining rail modal share due to increasing competition from other means of transport, decreasing efficiency and increasing government expenditures. This led to a trend of deregulation in the past decades. Several European countries vertically separated the organization of track infrastructure from the provision of train services and started to introduce competition on the tracks. Sweden was the first country to start deregulating the rail sector as early as 1988. The first European directive about vertical separation in the rail sector followed in 1991.[11] Four European railway packages have further stimulated these developments and were aimed at the successive deregulation of different market segments. The first railway package in 2001 required all member states to at least guarantee accounting separation between infrastructure and train services and introduced open access for cross-border freight as of March 2003. The second railway package in 2004 stipulated open access for domestic freight services as of 2007. The third railway package in 2007 introduced open access for international passenger services by 2010 and additional rail passenger rights, such as delay compensation. With the fourth railway package in 2016, open access for domestic passenger train services followed and had to be implemented for commercial passenger services in 2020 and for passenger services operated under public service contracts in 2023. Public tendering was introduced as the general rule for the allocation of public service contracts starting from 2019.

European regulation guides railway policy harmonisation across member states towards common long-term goals. Still, individual countries retain autonomy in shaping their specific approaches and policies. National railway policies can vary significantly among individual European countries due to differences in

[10] OpenStax Economics, Principles of Economics. OpenStax CNX. May 18, 2016 http://cnx.org/contents/69619d2b-68f0-44b0-b074-a9b2bf90b2c6@11.330. Chapter 11.3 ("Regulating Natural Monopolies").

[11] Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways.

historical development and condition of their existing railway networks, geographic (e.g. topography) and demographic (e.g. population density or urbanization) considerations, economic structures and political priorities. The RUs providing freight and passenger train services can include the incumbent RU, that might either remain state-owned or be privatised, new national companies and/or other competitors from abroad (incumbents or new entrants). In all countries the infrastructure is still run by a state-owned company. Sweden, as an exception, has passed this task to an independent government agency, while ProRail in the Netherlands is state-owned but independent. The UK privatised the infrastructure manager in 1996, but after its insolvency in 2001, the infrastructure is now managed by a state-owned non-profit organisation. At the global level, 98 percent of railway traffic is still carried on vertically integrated railways (Transport and ICT, 2017, p.77).

Given the successive introduction of competition on the tracks, the different railway packages also include provisions regarding the capacity allocation and track access charging. Generally, capacity allocation and the scheduling of timetables takes place on a yearly basis. Yearly timetables and no grandfathering of slots are principles to give a yearly chance to new entrants to enter the market.[12] This contrasts with rail being a long-term business requiring long-term investment in the network infrastructure and rolling stock. The typical lifetime and amortisation of rolling stock is between 20 and 30 years. Franchise contracts for regional passenger transport typically oblige RUs to provide rolling stock with minimum requirements on age, type and furnishing of trains. As the contract duration is usually shorter than the lifetime and amortisation of rolling stock, financing solutions (such as buyback guarantees or leasing solutions) need to be provided to lower RUs' risk. In the segments with open access competition and without a franchise contract, the misalignment between short-term planning with yearly capacity allocation and long-term investment in rolling stock is most evident. In most European member states this is the case in freight transport and in long-distance passenger transport

Managing infrastructure also requires long-term planning and investment in the construction of network infrastructure, which is designed to last for decades, and in its continuous maintenance. Both the infrastructure and the train service operations utilising rolling stock come with strict technical specifications and strong interdependencies. This determines not only the scope for possible cooperation but also implies that there are externalities from tracks and service facilities to rolling stock and vice versa. For example, investment in new wheels for rolling stock can decrease wear and tear of the tracks, leading to lower maintenance costs of the network infrastructure. Another example is routes with tunnels, where the infrastructure can put limits on the type of rolling stock driving through the tunnels, some tunnels might even require custom-made trains.[13]

The railway industry is characterised not only by technological but also by transactional interdependencies between the infrastructure and train service operations. These include the capacity allocation and timetable coordination, the investment planning and the day-to-day operational decisions on traffic coordination, such as train length or speed (Growitsch and Wetzel, 2009). Technical dependencies are likely to increase even further with innovation and digitisation. For example, the development and rollout of the European Train Control System (ETCS) requires a high degree of coordination of investment between infrastructure and rolling stock and blurs the dividing line between infrastructure and rolling stock. New train technologies such as Automated Train Operation (ATO) reduce

[12] See in particular EU directive 2001/14/EC of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure, which was is part of the first EU railway package.

[13] This is the case on the route between Munich and Nuremberg in Germany, where custom-made trains had to be ordered to operate short-distance routes.

capacity demand per train of the railway infrastructure and consequently allow more trains on the tracks. They require close coordination and communication between infrastructure and RUs.

Given the rail system's inherent conflicts between long-term investment and short-term end-customer needs, its strong technological and operational linkages between the different business segments and the interaction of many stakeholders / competitors, there is a need for ***Systemgedanke***, i.e., a holistic view of the system which takes all the diverse aspects into account and internalises externalities and conflicts. Optimizing the technical combination of rolling stock and tracks, infrastructure utilization and timetables for the entire system might be easier in an integrated market structure. For example, the infrastructure benefits from the RUs' knowledge about current and future needs of the end-customers, which makes timetable- and end-customer-oriented infrastructure planning possible. In a vertically separated organizational market structure costs increase as mechanisms must be found to coordinate and interact with a number of stakeholders, to resolve capacity allocation conflicts and to ensure that standards are met in the track-rolling stock interface. There also needs to be a regulator or other public entity that takes over the role of system integrator.

Summary

- Rail infrastructure is an example of a natural monopoly. Train service operations do not share these natural monopoly characteristics.
- European regulation imposed accounting separation between infrastructure management and train service operations and gradual introduction of competition in all train service segments. Member states retained autonomy in shaping their policies and vertically separated their rail industry to different degrees.
- There is a misalignment between the short-term perspective in yearly capacity allocation and scheduling of timetables on the one hand, and the required long-term investment in network infrastructure and rolling stock with a 20 - 30 years planning horizon on the other hand.
- The railway industry is characterized by strong technological and transactional interdependencies between the infrastructure and train service operations, which are likely to increase further with digitization.
- There is a need for a holistic view of the system (***Systemgedanke***) which takes all the interdependencies into account and internalises externalities and conflicts.

3 Economic theory and empirical evidence on vertical market organisation

This chapter presents the key insights from the economic literature on the relationship between vertical market organisation and the different policy objectives that can be pursued by the railway industry. Chapter 3.1 lists policy objectives discussed in the literature and highlights some high-level trade-offs between them. Chapter 3.2 discusses the different forms of vertical separation and their effects on policy objectives. Finally, Chapter 3.3 explores four factors that influence the effects of vertical separation: regulation, train density and infrastructure, competition and financing models.

3.1 Policy objectives

Rail transport serves basic needs of modern societies like mobility, accessibility and connectivity, safety, energy efficiency, reduced air pollution and other environmental benefits. Rail transport helps to achieve economic and industrial policy goals as it facilitates movement of goods and trade and commerce. It also creates jobs in the railway and in related sectors.

There are many different policy objectives related to the railway sector. In the long term, the commonly shared goal of rail policy is achieving the best end-user performance (output and availability, speed, punctuality/resilience, service) under the side constraint of a high modal share, produced at lowest costs (low prices, low funding). Increasing modal share requires decreasing prices compared to other modes of transport, which is in conflict with providing the highest quality service. In the short- or mid-term, different countries may pursue different policy objectives. To evaluate whether and to which degree vertical separation of the railway industry is “beneficial” compared to its vertical integration, the objective that should be reached needs to be clearly defined in the first place.

A common objective is high output or the coverage of the railway sector: maximising output (passenger-km for passenger transport and tonne-km for freight transport) or maximising coverage of the population or industry locations by the railway network. Policy can also maximise productivity or minimise costs of the railway system. A third potential objective is enabling effective competition on the tracks, though competition is usually not a goal in itself, but a means to increase efficiency. A fourth possible goal is increasing the rail’s modal share, i.e. the share of passenger and freight rail transport in the total transport output. This measure focuses on the attractiveness of rail compared to other modes of transport. Yet another policy objective is to foster innovation and investment into a modern network. In the long term, innovation and investment lead to high quality service that meets the end-customers’ future needs. Finally, governments may aim at reducing the need of public financial support for railways. While some of these policy objectives can be pursued simultaneously, such as increasing rail traffic overall and its modal share, others are conflicting. For example, the policy objectives of decreasing costs to relieve the federal budget and fostering investment into a high quality and innovative future network are unlikely to be reached at the same time.

Most countries pursue a mix of policy goals. For example, the German rail reform of 1994 aimed at increasing passenger and freight rail traffic while simultaneously decreasing federal spending on railway infrastructure. One means to reach this goal was to introduce competition on the tracks. One of the explicit goals of the current German government and promoted also by the European Union is to increase the modal share of rail transport compared to other means of transport as one instrument to decrease

CO_2 emissions and to reach environmental long-term goals. The empirical literature that will be discussed in the following mostly studies the effect of vertical separation on costs and efficiency and to a smaller extent also on the modal share.

Summary

- In the long-term, the commonly shared goal of railway policy is achieving the best end-user performance (output & availability, speed, punctuality/ resilience, service quality) under the constraint of a high modal split and lowest costs (low prices, low funding).
- In the short or mid-term, different countries may pursue different objectives, such as the maximisation of output or population coverage, the quality of transport services, the minimisation of costs of the railway system or effective competition on the tracks. While some of these policy objectives can be pursued simultaneously, others are conflicting.

3.2 Forms of vertical separation

This chapter first defines the different forms of vertical separation, discusses the theoretical consequences of vertical separation and finally reviews the effects of vertical separation based on the empirical academic literature.

Definitions

The vertical market organisation of the railway industry differs across countries. While in some countries the railway industry is vertically integrated, it is vertically separated to different degrees in others. A vertically integrated organisational market structure implies that the infrastructure, which includes tracks, signals, traction and stations on the one hand, and the operation of train services on the other, i.e. passenger and freight transport, are incorporated in a single firm. Often one state-owned company is at the same time the infrastructure manager and the incumbent train service operator, such as in Switzerland and most other countries outside the European Union. On the contrary, a vertically separated organisational structure of the rail industry means that the infrastructure is separated from the operation of train services, such as in Sweden or the UK (see Chapter 4 for detailed country descriptions). The responsibilities of the distinct infrastructure manager typically include the development and maintenance of the tracks, traffic control and capacity allocation and sometimes also real estate and stations (Ait Ali and Eliasson, 2022).

There are different forms of vertical separation. We follow the European Commission's (EC) definition introduced in its directive on vertical separation in the railway industry.[14] The EC distinguishes between accounting separation, organisational separation and institutional separation.[15] The directive required member states to at least ensure accounting separation, which guarantees separate financial accounts between the management of railway infrastructure and the provision of train services. Organisational

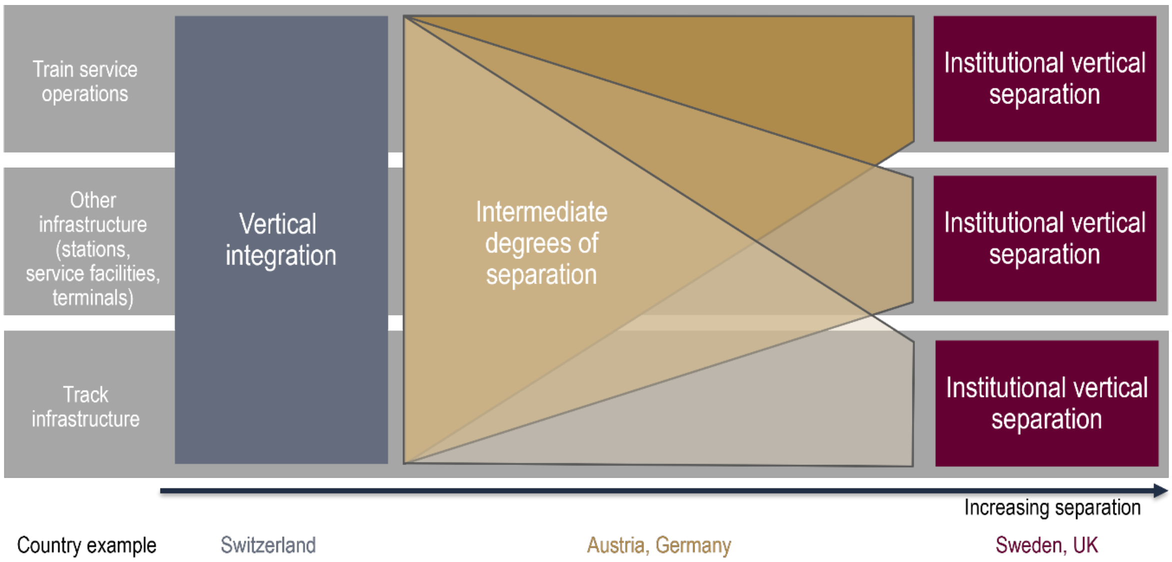
[14] Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways.

[15] See Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways, Article 1.

separation implies distinct divisions for the infrastructure management and the train services within a single undertaking. This can be operationalised by the infrastructure manager being an independent division of an integrated company or being a legally separated subsidiary of a holding company This form of organisational market structure is also often called the holding model. In case of accounting or organisational separation, third-party access arrangements can guarantee that train services can be provided by an incumbent train operator and competing railway undertakings. Institutional separation, also called complete separation, means that the infrastructure is managed by a legally separate entity from the operation of train services. All EU member states implemented at least organisational separation which also includes accounting separation. Thus, accounting separation as a standalone model is irrelevant in practice.

Figure 1 illustrates the different existing forms of vertical organisation. Vertical integration shown as the left vertical bar combines all assets and business activities under one company jointly optimising its behaviour. Institutional vertical separation shown as three bars to the right is the other extreme as it separates ownership of all assets and train services. There are also two organisational structures in the middle: Accounting separation is the weakest form of vertical separation; organisational separation implements managerial in addition to accounting separation. As the red bars illustrate, apart from the track infrastructure and the train service operations, there are other types of infrastructure, such as for example stations or service facilities and terminals. Different combinations of the two types of infrastructure and train service operations are feasible. For example, in Germany with organisational vertical separation, until recently stations were a separate entity from the network infrastructure. In Sweden with institutional vertical separation, most of rail stations, freight terminals and office buildings are combined in an entity separate from the network infrastructure that is owned by the state.[16] These examples illustrate that the classification into one form of vertical separation does not necessarily imply the same organisational market structure in every country.

Figure 1: Forms of vertical integration and separation



Source: E.CA Economics.

[16] Jernhusen AB received the ownership of most of stations, terminals, and buildings for rolling stock maintenance in 2001. In Sweden some railway stations are still in the hands of the infrastructure manager (Trafikverket) or local and regional authorities.

Theoretical considerations

All countries within the European Union implemented at least organisational separation and are thus already vertically separated to some degree. The ongoing political debate about vertical separation usually refers to institutional vertical separation, i.e. ownership separation between infrastructure manager and train service operations.

The main theoretical driver for institutional vertical separation is that it will enable on-track competition in train services (Abbott and Cohen, 2017). Competition is not a goal in itself, but it is expected to increase efficiency and quality of service (see Chapter 3.3.3). Institutional vertical separation is not required to allow for competition – it can be introduced by enforcing access to the network for competing RUs in all forms of vertical market structure. However, allowing different operators on the tracks means that they might have conflicting requests for capacity. An integrated railway company may have the incentives to discriminate between RUs and to favour its own RUs over competing ones in the capacity allocation process and access pricing regime to obtain a competitive advantage in the downstream market (see for example Laabsch and Sanner, 2012).[17] Thus, a transparent, non-discriminatory capacity allocation process and access price regulation need to ensure that the incumbent RU and infrastructure manager have no anticompetitive practices in place (Ait Ali and Eliasson, 2022).[18] The role of regulation will be further discussed in Chapter 3.3.1.

While vertical separation decreases the discrimination incentives of the infrastructure manager, it entails other consequences.

First, and most importantly, by separating the infrastructure from the operation of trains, incentives become misaligned. Misalignment of incentives results when one party carries the cost, but another party receives the benefits associated to these costs. This can occur between the infrastructure manager and RUs, since in a vertically separated organisational structure of the industry each player tries to optimize its own outcome regardless of the impact on other players. Typically, the infrastructure manager will insufficiently invest in long-term infrastructure, as track access charges are regulated, and thus he will not benefit from higher end-user ticket prices due to better quality of service. One example is the investment in internet access in trains. A pure infrastructure manager that does not directly benefit from providing better quality of service to end-customers does not have strong incentives to push or support the telecom provider to build the necessary sites along the tracks. An integrated railway company, which is directly affected by end-customers, has stronger incentives to ensure internet access. This is the case in Germany, where Deutsche Bahn is putting forward connectivity along tracks by identifying obstacles and common action together with the mobile network operators (MNO) or by initiating innovating pilot projects such as Gigabit Innovation Track (GINT), which provides for a dual use of trackside masts both for train radio signals and public mobile communication at a lower cost. Furthermore, an integrated railway company has an incentive to efficiently coordinate investments between infrastructure and rolling stock. A pure infrastructure manager that does not own the rolling stock has no incentive to invest in tracks to prevent wear and tear of rolling stock. Similarly, a pure RU has no incentive to invest in rolling stock only to reduce wear and tear of the tracks. Thus, in a vertically separated organisational market structure, underinvestment can occur both on the side of the infrastructure manager and on the side of

[17] It is further argued that, even without actual discrimination, the mere possibility of discrimination, might hamper downstream market entry. See for example Growitsch and Wetzel (2009) and Laabsch and Sanner (2012) for a review of the arguments pro and contra vertical separation.

[18] Note that discrimination incentives still exist in case of accounting or organisational separation as the (parent or holding) company controlling the infrastructure manager typically also owns RUs active in the market. Thus, dependencies between the infrastructure manager and the incumbent RUs remain, implying that conflicts of interest may emerge.

train service operators (Growitsch and Wetzel, 2009). An illustration of this point is the change in the construction of locomotives, which allows current locomotives with four axes to reach the performance of former locomotives with six axes. Even though this saves costs for the RUs, it increases wear and tear of the tracks at the cost of the infrastructure manager.[19] Another example with a high need of coordination of investment between infrastructure and rolling stock is the development and rollout of the ETCS. The introduction of the most recent ETCS version implies that part of the infrastructure tasks (e.g. the signaling) shall be taken over by on-board-units in the locomotives. From a pure infrastructure manager's perspective, it would be best if as many tasks as possible were installed on board of the locomotives, minimising investment in trackside installations. A pure RU on the other hand would unilaterally want to invest as little as possible in onboard units. A third example is so-called "predictive maintenance": by installing cameras and monitoring points along the tracks, defects on rolling stock can be detected quickly and maintenance and spare part needs determined prior to the arrival at the repair workshop. A pure infrastructure manager has no incentive to invest in this type of technology that exclusively benefits the RUs. Thus, it might be difficult to reach an investment solution that is optimal from the system perspective rather than from the perspective of the separate entities. On the contrary, a vertically integrated company can coordinate operating decisions with infrastructure maintenance and investment decisions, decide optimally from the system's perspective and then also reap the full benefits of efficiency enhancing investments (Abbott and Cohen, 2017).

Second, even abstracting from the misalignment of incentives, separate infrastructure managers and RUs might simply not possess the commercial and technical knowledge to take optimal decisions for the rail system as a whole (Systemgedanke). There are many technical and operational dependencies between the infrastructure and the trains running on the tracks, like the ETCS. In a vertically integrated organisational structure, this commercial and technical knowledge is bundled within one company or holding. For example, the infrastructure benefits from the RUs' knowledge about current and future needs of the end-customers, which makes timetable- and end-customer-oriented infrastructure planning possible. A vertically integrated RU has incentives to organise the exchange of the industry. In a vertically separated organizational market structure, a regulator or ministry would have to fulfill this role of system integrator. It is questionable whether a regulator or ministry would have the necessary operational and technological knowledge, especially because the end-customers' needs and the technical requirements are constantly evolving.

Third, the client of the railway sector is the end-customer. However, a monopolistic infrastructure manager is not directly confronted with the dissatisfaction, needs and demands of the end-customers since it is only providing (regulated) access to its network for RUs. In a vertically integrated organisational structure, the infrastructure manager experiences the competitive pressure from the downstream end-customer markets via its integrated RU(s) and thus gets faster and more direct feedback about the customers' evolving needs in terms of routes, station facilities, timetables, punctuality and prices. This helps to focus timetable and infrastructure planning on the needs of the end-customer and to find innovative solutions to increase system performance to the benefit of the end-customers. Employing artificial intelligence (AI) in disposition and in continuous track monitoring are two examples from Germany that illustrate how an integrated company directly confronted with the demands of end-customers can come up with innovative solutions to improve performance. Deutsche Bahn develops an AI-based software solution for disposition that helps to determine the optimal sequence of train departures at train stations after a disruption of the timetable from a system perspective. This significantly increases

[19] See for example Deutsches Zentrum für Schienenverkehrsforschung beim Eisenbahn-Bundesamt (2023), Berichte des Deutschen Zentrums für Schienenverkehrsforschung, Bericht 36, Table 4 for an analysis of the effect of new wheel profiles on the maintenance of tracks.

overall train punctuality in selected pilot projects.[20] In continuous track monitoring, onboard sensors installed on the rolling stock monitor and detect defects and maintenance needs of the track infrastructure on a continuous basis during regular operations. Major defects can be prevented or detected faster, which again increases overall train punctuality.

Fourth, and related to the two previous aspects, a pure infrastructure manager, that maximises revenues from track access charges, has an incentive to engage in short-term rather than long-term planning. An example regards the incentives to plan infrastructure maintenance and renewal. An infrastructure manager maximises access charge revenues and has an incentive to close routes for maintenance as shortly as possible. Consequently, it has an incentive to only undertake small (but fast) repairs repeatedly, even if it was optimal from a long-term system and end-customer perspective to rather close routes for a longer period to renew or renovate the tracks more sustainably. Second, long-term investment in innovation is also more difficult to reach in a vertically separated organizational market structure, as infrastructure manager and RUs must agree and coordinate upon which technologies to invest in.

Fifth, and related to the previous example on investment in innovation, vertical separation increases transaction costs. In a vertically separated railway industry, there is an increased need for communication and coordination between infrastructure manager and RUs because of strong technological and transactional interdependencies between infrastructure and train operations. This includes long-term capacity allocation, timetable coordination, investment planning and day-to-day operational decisions on traffic coordination such as train length or speed (Growitsch and Wetzel, 2009). Within an integrated company, optimising the technical combination of rolling stock and tracks, infrastructure utilization and timetables might be easier in terms of communication and coordination. In a vertically separated organizational market structure costs increase as new mechanisms must be found to coordinate and interact with a number of stakeholders, to resolve conflicts in the capacity allocation process, to ensure standards are met in the track-rolling stock interface and for identifying who is responsible for delays (Abbott and Cohen, 2017).[21]

Sixth, a separate infrastructure manager that is only maximizing his own profits has lower incentives to ensure high quality of the infrastructure in the short-term than an integrated company would have. In the situation of high capacity utilisation and penalties for delays, a pure infrastructure manager may have the incentive to reduce the number of trains on the network to increase punctuality and avoid penalties. In comparison, a vertically integrated company, which takes the revenues from the end-customers into account via its integrated RUs, will accommodate more traffic on the network. In the long term, a separate infrastructure manager also has lower incentives to invest in capacity expanding innovation and to allow the growth of RUs or to reach the political goal of increasing the modal share of rail, as track access charges are low compared to profits on the end-customer side.

[20] Currently, it is investigated how this technology can be rolled out in line with regulatory rules.

[21] However, Merkert et al (2012) compute bottom-up transaction costs for UK, Germany and Sweden. They find that even tough institutional vertical separation raises transaction costs, they are at most 2-3% of total costs. Modest benefits of vertical separation, for example in terms of increased competition, could outweigh these increased transaction costs.

Summary

- A vertically separated organisational structure of the rail industry means that the infrastructure is separated from the operation of train services. There are different degrees of vertical separation. Accounting separation guarantees separate financial accounts between the management of railway infrastructure and the provision of train services. Organisational separation implies distinct divisions for the infrastructure management and the train services within a single undertaking. Institutional separation implies that the infrastructure is managed by an entity legally separated from the operation of train services.

- The main theoretical driver for institutional vertical separation is that it will enable on-track competition in train services by decreasing the discrimination incentives of the infrastructure manager.

- The theoretical drawbacks of vertical separation are that it leads to

  1. misalignment of incentives between infrastructure manager and train service operations,
  2. loss of commercial and technical knowledge to take optimal decisions for the rail system as a whole (Systemgedanke),
  3. less competitive pressure from the downstream end-customer market felt by the infrastructure manager,
  4. incentives for the infrastructure manager to engage in short-term rather than long-term planning,
  5. higher transaction costs and
  6. lower incentives for the infrastructure manager to ensure high quality of the infrastructure in the short-term.

Results from the empirical literature

As discussed above, economic theory shows both benefits and risks of vertical separation. Equally, the empirical evidence provided by the existing literature is mixed. Depending on the policy objective pursued by a country, the answer as to which organisational structure of the industry performs best in terms of this objective might also differ. The existing empirical literature primarily studies the effects of vertical separation on productive efficiency and modal share.

The empirical literature studying the effect of vertical separation on efficiency finds different effects: effects vary between positive (e.g. Cantos et al., 2010; Lerida-Navarro et al., 2019), negative (e.g. Fitzová, 2022) and no statistically significant effects (e.g. Cantos-Sanchez et al., 2012). However, the papers differ in important aspects such as the empirical method used, the exact measurement of the organisational structure of the industry, and the sample period and countries covered in the dataset. Most studies use non-parametric data envelopment analysis (DEA) and/or parametric stochastic frontier analysis (SFA) to estimate efficiency scores.[22] In a second step, these efficiency scores are then regressed on a measure for the organisational market structure, other variables of interests and rail system and country structural variables. Typically, a rail system's output is measured by passenger-km for passenger transport and tonne-km for freight transport. Input variables typically are the number of employees, the number of rolling stock and total network length. The main variables of interest besides variables measuring vertical separation are variables related to regulation, train density, the size of the network and the type and intensity of competition in rail passenger and freight transport. These factors are further discussed in Chapter 3.3.

The most recent paper in this strand of literature is Fitzová (2022), which empirically studies the impact of rail reforms (both vertical separation but also horizontal competition) on efficiency. She finds institutional vertical separation to have a robust negative impact on efficiency compared to organisational vertical separation across all methods and specifications used. However, she concludes that possible benefits in form of increased competition must be considered at the same time. The analysis is based on a dataset covering 28 European countries[23] over the period 1999 to 2017. The dataset is combined from different sources including the railway statistics published by the Union Internationale des Chemins de Fer (UIC data), the European Commission, Independent Regulators' Group – rail and Eurostat. Efficiency scores are estimated using DEA and SFA.[24] Fitzová (2022) is one of the few papers that distinguishes between vertical integration and organisational vertical separation (which she calls the holding model). She therefore estimates the effect of institutional vertical separation, i.e. complete ownership separation between infrastructure and train service operations, and vertical integration on efficiency compared to the base group of organisational vertical separation, i.e. the holding model. The indicator variable for vertical integration is mostly statistically insignificant, also because this form of organisational structure of the industry is rarely observed in Europe.

Lerida – Navarro et al. (2019) empirically study the relationship between efficiency scores and different dimensions of the rail liberalization process. They find a weak positive link between rail liberalization and efficiency. The study is based on UIC data for 27 European railway systems[25] over the period 2002-

[22] DEA is based on information on inputs used and outputs generated by each rail system. Organisational efficiency is estimated by measuring the ratio of total inputs employed to total output produced for each decision unit. A production frontier is then obtained based on the observations of the most efficient decision units without imposing a particular specification of the frontier. The efficiency score of each decisions unit is measured as the distance to the frontier (i.e. the most efficient decision units have a score of one and are on the production frontier). Thus, all deviations from the frontier are assumed to stem from inefficiency; random shocks are not included in the model. The basic DEA model assumes constant returns to scale, however variable returns to scale can also be included. Instead, an SFA model is based on estimating the parameters of a pre-specified functional form representing the production function of decision units. Different functional forms of the production function, such as Cobb-Douglas or Translog, can be assumed. The function has an error term with two components: one standard error term accounting for measurement error and other random factors and one random error term representing technical inefficiency. The technical inefficiency of a decision unit in a given time period is then the conditional expectation of the error term representing technical inefficiency given the standard error term.

[23] Included countries are Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

[24] As Cantos-Sanchez et al. (2012), Fitzová (2022) uses two-step procedures, where the efficiency scores obtained from DEA or SFA are regressed on reform variables in a second step, and one step procedures, which allow to calculate efficiency scores simultaneously with the impact of the reform variables.

[25] Included countries are Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

2011. This dataset is combined with the Kirchner liberalization index for 2002, 2004, 2007 and 2011 (Kirchner 2002, 2004, 2007, 2011). As in Fitzová (2022), efficiency scores are estimated using DEA and SFA.[26] The authors use the composite rail liberalization index from Kirchner (based on 230 variables), two subindices for legal and institutional changes and market access and a separate index for effective competition in the second step regression of efficiency scores on liberalization indicators. However, the organisational structure of the incumbent is just one aspect in the index for legal and institutional changes, together with regulation on market access and regulatory authority power. For instance, Germany has a particularly high liberalization score due to openness of its railway markets and a high degree of competition. Thus, the paper does not explicitly study the isolated effect of vertical separation on efficiency.

Cantos et al. (2010) empirically study the impact of vertical and horizontal reforms on efficiency and productivity. They find a positive relationship between vertical separation and productivity growth, technical change and efficiency change. The paper is also based on UIC data for a sample of 16 national railway systems in Europe[27] over the period 1985 to 2005. Besides DEA the authors use the Malmquist productivity index to evaluate the relative position of each railway system.[28] In the second step regressions, vertical separation is measured by an indicator variable for institutional vertical separation. This implies that countries being vertically integrated and countries with accounting or organisational vertical separation are in the base group compared to which the effect of institutional vertical separation is estimated. Based on an updated dataset, Cantos-Sanchez et al. (2012) on the contrary find no statistically significant relationship between vertical separation and efficiency independently of the method used. The empirical analysis is based on an updated UIC data set of Cantos et al. (2010) which includes a sample of 23 national railway systems in Europe[29] for the period 2001 to 2008, aggregated at country level. Cantos-Sanchez et al. (2012) estimate efficiency scores using both DEA and SFA to test whether the ambiguous results in the literature studying the effects of deregulation and restructuring on efficiency can be explained by the different methods used to estimate efficiency.[30] As in Cantos et al. (2010), vertical separation is measured by an indicator variable for institutional vertical separation, implying that effects of institutional vertical separation are estimated compared to a base group including both vertically integrated countries and countries with accounting or organisational vertical separation. The inefficiency levels obtained are broadly comparable to the ones of the countries included also in Cantos et al. (2010). The newly added countries from Central and Eastern Europe are not at the frontier. While the exact levels of inefficiency measures differ across methods, there is an appreciable degree of

[26] Differently from other papers, Lerida-Navarro et al. (2019) measure output of a railway system by a composite index of passenger km and tonne-km (rather than the sum or the product of the two measures), which takes into account the interaction between them as there is operative inefficiency when both passenger and freight trains must share the same rail lines. In particular, systems with a balanced mix of passenger and freight transport are slightly penalised by this index compared to systems with a high specialisation on passenger or freight transport.

[27] The included railway systems are from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden and Switzerland.

[28] The Malmquist index allows the decomposition of productivity growth into efficiency change (catching up effect, i.e. essentially changes in how far an observation is from the efficiency frontier) and technical change (shifts in the production frontier). See Malmquist (1953) for more details.

[29] In additional to Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden and Switzerland, the data set is updated by including additionally Bulgaria, the Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia.

[30] Within the SFA model, the authors use two approaches to investigate the influence of regulatory and environmental factors on efficiency. In the first one, they use the widely employed two-step procedure, where the efficiency scores obtained in the first step are then in the second step regressed on the reform variables of interest and further controls. The second approach is a one step estimation of the distance function and determinants of inefficiency based on Battese and Coelli (1995).

consistency in the ranking of countries across methods. The authors see the addition of new countries and the enlarged time period until 2008 as potential explanations for the differing regression results between the two papers, especially because the effect of reforms might materialize only after a period of adaption.

There are fewer empirical studies investigating the effect of vertical separation on the modal share of rail passenger and rail freight transport. Modal share is measured as the share of rail in total transport using rail and road, explicitly excluding other modes of transport, such as air, inland waterways and short sea shipping. The underlying argument to study the impact of vertical separation on modal share is that the modal share is a comprehensive measure for the attractiveness of rail transport. It incorporates that, for example, lower prices through cost reductions, increases in punctuality or friendlier staff all have a positive impact on the attractiveness of rail compared to other modes of transport. Furthermore, the increase in the modal share of rail is also an explicit goal of European and many national transport policies.[31] These papers typically find that vertical separation decreases the modal share in rail passenger transport and has no effect on the modal share of rail freight transport. Typically, separate panel regressions are run for passenger and freight modal share, where the modal share is regressed on a variable measuring vertical separation and further controls accounting for infrastructure, demand and supply factors such as for example the length of railway lines compared to the length of road highways, the share of rail in total transport budgets, GDP per capita, employment rate, real prices of fuel or a price index of real passenger rail prices.

The most recent paper by Tomes (2017) empirically studies the effect of institutional vertical separation on the modal share of rail passenger and rail freight transport. He finds a weakly negative effect of institutional vertical separation on the modal share of rail passenger transport and on the modal share of rail freight transport. The paper is based on data for 27 European countries[32] for the period 1995 to 2013, mostly obtained from Eurostat. The vertical organisational market structure is measured by an indicator variable for institutional vertical separation, thus the effect of institutional vertical separation on the modal share is measured compared to all other organisational structures of the rail industry, including vertical integration and accounting and organisational separation.

Earlier papers include Laabsch and Sanner (2012) and Van de Velde et al. (2012) who also investigate the effect of vertical separation on the modal share of rail passenger transport and rail freight transport within their broader study. Laabsch and Sanner (2012)[33] find that complete vertical separation reduces the share of rail in passenger transport while it is insignificant in most specifications for the rail freight modal share. As in Tomes (2017), the vertical organisational market structure is measured by an indicator variable for institutional vertical separation.[34] Differently from the other two studies, Van de Velde et

[31] The underlying reasoning is that separation reinforces intramodal competition and that on-track competition would be a major spur to competitiveness of rail.

[32] Included countries are Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

[33] The paper is based on data for Austria, Denmark, France, Germany, Italy, Netherlands, Sweden, Switzerland, and United Kingdom over the period 1994 to 2009 and combined from different data sources (Eurostat and national statistical offices, NERA, Kirchner liberalization index).

[34] This is the case for the Netherlands as of 1998, Denmark as of 2005, Sweden and UK as of 1994. Austria, Germany, Italy and Switzerland are all counted as “holding model”, France as “hybrid”. France is considered as “hybrid” since the infrastructure was fully separated from the rail undertaking SNCF since 1997, but the owner of infrastructure RFF has delegated several functions of the infrastructure manager back to SNCF. Since in the regressions, the indicator variables for institutional vertical separation and the hybrid model are included, the base group to which effects are compared to is the holding model.

al. (2012)[35] distinguish vertical integration, organisational vertical separation (called "holding model") and institutional vertical separation. They find no effect of organisational vertical separation or institutional vertical separation on the modal share of national rail freight transport compared to vertical integration. For passenger transport, they find no difference in modal share between organisational and institutional vertical separation when the passenger transport market is open to competition.

The differing results of the empirical literature studying the first-order effect of vertical separation on the different policy objectives partly result from differences in methodology used, differences in the exact definition of the variable measuring vertical separation and the difference in the countries and time periods covered in the analysis (Table 5 in Appendix 2 provides an overview of the literature discussed in this chapter).

However, these differing results also highlight that it might be difficult to draw robust policy conclusions based on cross-country/cross-time econometric analyses. This is because vertical separation is not a goal in itself. Rather, it is expected to enable competition on the tracks, which should increase efficiency and the quality of train services. Each country chooses a specific and complex mix of policies regarding not only the degree of vertical separation versus vertical integration, but also regarding competition on the tracks and regulation of the sector given very different (historical) network infrastructure. Different policy combinations on different networks might well reach a similar outcome, which is difficult to disentangle in an empirical model with relatively few observations.

Summary

- Equally to theoretical considerations, the empirical evidence provided by the recent academic literature studying the effect of vertical separation on rail productive efficiency or modal share is mixed. The differing results of the literature highlight that it might be difficult to draw robust policy conclusions based on cross-country/cross-time econometric analyses. Each country chooses a specific and complex mix of policies regarding not only vertical separation versus vertical integration, but also regarding competition on the tracks and regulation of the sector given very different (historical) network infrastructure. Different policy combinations on different networks might well reach the same outcome.

- The effects of vertical separation therefore depend (i) on the policy objective pursued and (ii) on the interaction between the organisational structure of the industry and regulation, train density, infrastructure, competition on the tracks and the financing model.

[35] The empirical analysis is based on 26 OECD countries for the period 1994 to 2010. The dataset is combined from different sources such as the International Transport Forum (ITF), OECD, Eurostat, EU KLEMS, Worldbank, WTO and GTZ. Included countries are Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Latvia, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

3.3 Factors influencing the effects of vertical separation on policy objectives

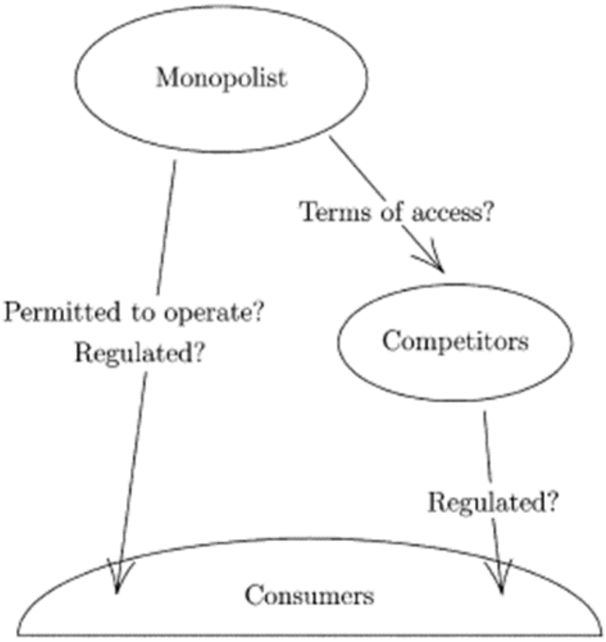
This chapter discusses several factors that influence the effects of vertical separation on the policy objectives in the railway industry. Chapter 3.3.1 starts with the role of the regulatory framework, Chapter 3.3.2 introduces the constraints imposed by the existing train density and infrastructure, Chapter 3.3.3 explores the scope for and impact of competition in train services and Chapter 3.3.4 elaborates on different models of financing railways. Table 5 in Appendix 2 provides an overview of the literature discussed in this chapter.

3.3.1 Regulation

One important factor when considering the impact of vertical market organisation on market outcomes is the form and the intensity of the existing regulation. From a more general and theoretical viewpoint, regulated industries often encompass several complementary segments that differ in their potential for competition. In an industry like railways, the supply of essential infrastructure may exhibit features of a natural monopoly (at least locally, as it might be inefficient to duplicate rail tracks connecting two nodes). On the other hand, the supply of downstream services can potentially be more competitive. In such a setting, downstream competitors need to rely on the access to naturally monopolistic infrastructure.

One question is how to assure that the integrated train service operator sets prices at a level of effective competition (no incumbency advantages and disadvantages). This may include cross-subsidization (advantage) or legacy costs (disadvantage). Another question is which rivals and on what terms should be allowed access to the inputs supplied by the monopolist. It may need to be considered how to assure that the vertically integrated company is pricing at an efficient level, i.e. that incumbent's advantages or disadvantages are properly considered. These considerations may lead to allowing the operator to set its own prices, but they can also lead to various forms of price or rate regulation. Specifics depend on the extent of the monopolist's participation in the retail market, the capacity of the infrastructure, whether the monopolist's access fee is regulated, whether there are inputs available alternative to the input supplied by the monopolist, and whether the competition downstream (e.g. end-consumer prices) is regulated. Schematically, the decision process can be illustrated as below.

Figure 2: Regulation of a monopolist



Source: M. Armstrong, D.E. Sappington, Recent developments in the theory of regulation, Handb. Ind. Organ. 3 (2007) 1557–1700.

The theoretical literature generally assumes that the regulator is fully independent, knowledgeable about the industry, benevolent and perfectly informed about industry demand and cost conditions. Under such ideal assumptions, the regulator can regulate the industry in a way that restores the competitive outcome (e.g. by regulating prices at competitive levels). The departure from the complete information requirements, which would be needed to properly reflect complexity of regulation in the presence of vertical relationships, is generally beyond the scope of most academic models of regulation. In practice, the regulator might not be able to achieve competitive outcomes, because of limited knowledge, insufficient information or resource constraints. Other potentially related issues are regulatory capture or lack of commitment to a regulatory policy. Economists generally are of the view that, whenever the market is not subject to failure, competition will deliver better outcomes than any regulator could or would achieve. However, it is acknowledged that in situations with market failure (e.g. in cases of natural monopoly) regulation at least has some potential to improve the market outcome, even though market failure has to be weighed against "regulatory failure" due to the practical limits of regulation.[36] It is important to note that in case of a natural monopoly – as in the railway sector – regulatory intervention is necessary regardless of the vertical structure.

Regulation can take different forms. Regulatory setups can be driven by different policy objectives and can affect the market outcomes in different ways. For example, aggressive downstream price regulation, e.g. incentive regulation can aim to achieve an outcome equivalent to intense price competition, at least in the short term. However, it requires very strong regulatory discretion and while it may create strong incentives for firms to reduce their costs, it can also be expected to weaken incentives for durable sunk investments. In contrast, if one of the policy goals is to strengthen the infrastructure investment incentives, "rate-of-return" regulation might be more advisable. Even though rate-of-return regulation is often criticised for its lack of strong incentives for regulated firms to operate efficiently (i.e. to reduce their costs), it has been used in many network industries like electricity, natural gas or

[36] M. Armstrong, D.E. Sappington, Recent developments in the theory of regulation, Handb. Ind. Organ. 3 (2007) 1557–1700.

telecommunications due to its ability to sustain the long-term investment incentives for infrastructure support.

Multiple economic empirical studies assess the impact of railway regulation reforms and reach diverse conclusions. The literature generally focuses on aspects of the reforms and the industry other than vertical separation, and the impact of regulation is either totally ignored or at best measured in a very simple way (e.g. through a dummy variable indicating the presence of an independent regulator), while the real-life complexity of regulatory systems may require more refined measures.

The paper by Smith et al. (2018) attempts to address this shortcoming. The authors construct a composite "regulation index" as a weighted average of individual characteristics of the regulatory system. The authors of the paper identify no fewer than 30 of such dimensions such as competence, objects of regulation and powers of the regulatory body, its independence and transparency, etc. In theory, each of the regulatory dimensions could have different impact on market outcome. The authors acknowledge that, but they do not have enough data to test the impact of each individual dimension on market outcome and instead construct a single index of regulatory intensity, which essentially measures the average impact of each of the many regulatory factors. An econometric model is then used to establish an empirical relationship between the index and efficiency of the railways system measured by its total cost.

The authors find that stronger regulatory regimes (indicated by a higher value of the regulatory index) reduce costs, i.e. result in a more efficient system. This is generally true for all the econometric models analysed in the paper. However, in more complex specifications of the model (preferred by the authors), a stronger regulator brings cost efficiencies to the system only if the system is also characterised by institutional rather than organisational vertical separation. In terms of policy implications, the authors conclude that "*institutional vertical separation and strong regulation are both needed in order to bring about cost reductions*".

However, the vertical separation variable appears in the model in a number of places. The authors include it as a separate variable and interacted with several other variables: beside regulation strength, the impact of vertical separation is measured also with respect to the share of freight revenue and train

Summary

- The form and the intensity of existing regulation is one important factor when considering the impact of vertical market organisation on market outcomes. Rail infrastructure is a natural monopoly. Downstream train services can potentially be competitive.
- Access regulation to allow for downstream competition can take different forms. Aggressive downstream price regulation, e.g. incentive regulation, can aim to achieve an outcome equivalent to intense price competition. This form of regulation may create strong incentives for firms to reduce their costs, but it can also be expected to weaken incentives for durable sunk investments. "Rate-of-return" regulation might be more advisable if one of the policy goals is to strengthen incentives to invest in infrastructure.
- A recent empirical academic study finds that stronger regulatory regimes reduce costs, i.e. result in a more efficient rail system. In more complex specifications of the model, a significant impact of a strong regulator on cost efficiencies could be statistically proven only for systems characterised by institutional vertical separation.

density. In the most preferred model, the isolated impact of vertical separation (relative to the holding model) and in relation to the freight revenue share is not statistically significant (i.e. the impact is statistically negligible, although both coefficients have a negative sign). However, the impact of vertical separation related to train density is positive and statistically significant. This finding has been reported also in other papers (see Chapter 3.3.2). This means that in case of high train density, vertical separation is expected to reduce the overall efficiency and to increase costs.

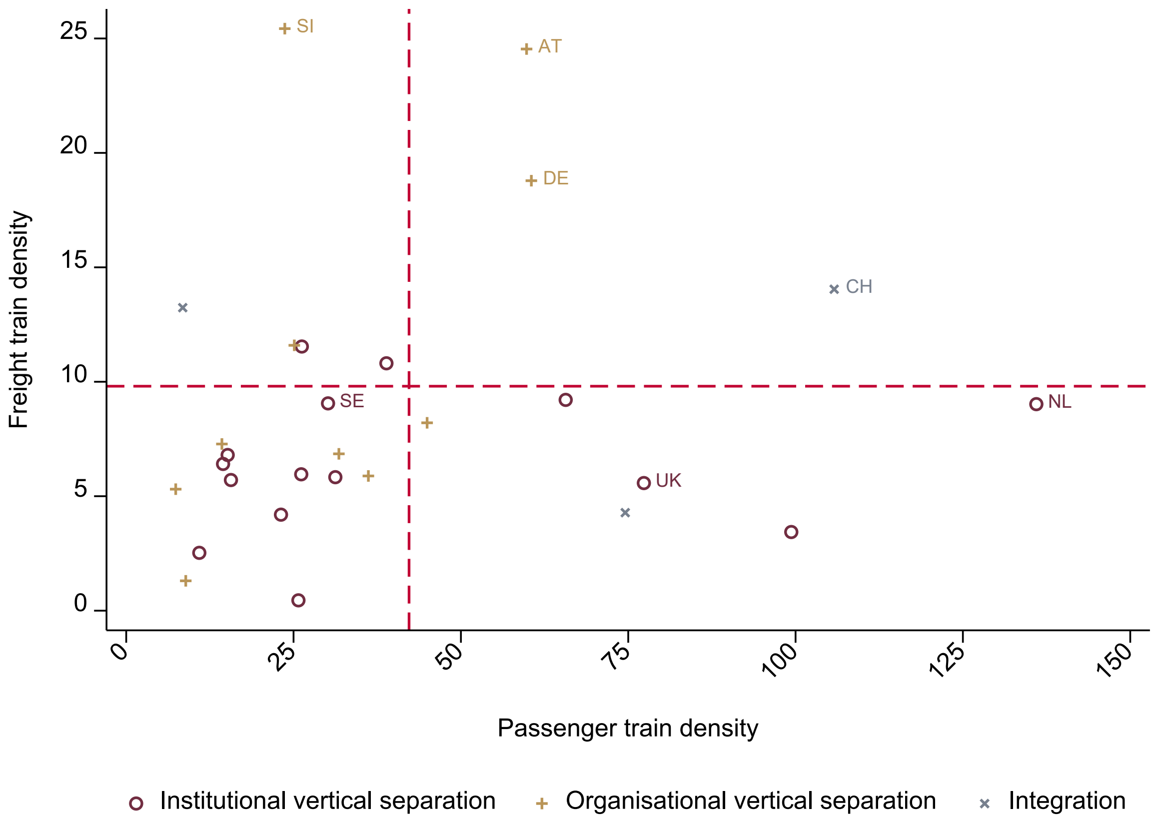
3.3.2 Train density and infrastructure

The utilisation and characteristics of the rail infrastructure and rolling stock are further factors influencing the effects of the organisational structure in rail transport. In the short-term, these factors are given by the evolution of the rail transport in the specific country and can change only very slowly. Economic literature such as Smith et al. (2018) (see previous chapter) shows that depending on the utilisation and characteristics of the rail infrastructure and rolling stock, optimal vertical organisational structure differs.

Train density

Train density is a measure of infrastructure capacity utilisation that is used in the economic literature. It is defined as train-km per network-km per day and can be calculated separately for freight and for passenger transport. The following Figure 3 presents the passenger train density and freight train density for several European countries in 2021 together with their industry organisation.

Figure 3: Heterogeneity of train density in 2021



Source: E.CA Economics based on data from the 11th IRG Report. Notes: The dashed red lines indicate the volume-weighted average passenger and freight train density.

The above Figure shows that train density varies significantly across countries in Europe and within a country between freight and passenger transport. Germany has a high passenger- and freight train density. There is no country in Europe outperforming Germany in both measures at the same time. The most similar country is Austria, where the passenger train density is a little bit lower than in Germany, while the freight train density is around 25% higher than in Germany. The UK has the fourth highest passenger train density in Europe, while the freight train density is below the European average. Sweden's freight train density and passenger train density are below the European average and lower than in Germany, Austria or UK.

Multiple academic contributions investigated the relationship between train density and the total cost of rail, depending on the vertical organisational structure.[37] Empirical research has shown that the cost differential between vertically separated and integrated railways depends on train density.

Mizutani and Uranishi (2013) used UIC data from 30 railway companies from 23 European and East Asian OECD countries from 1994 until 2007. They analysed the effect of vertical separation interacted with train density on the total cost whilst using output as a control variable. They find that vertical separation decreases cost, but the interactive term of vertical separation and train density is cost increasing. The explanation of that result is that the total cost is higher in a vertically integrated organisation compared to a vertically separated one, but the cost differential gets smaller when the train density increases. Once train density exceeds a certain threshold, an integrated rail industry minimises cost. The same result was shown empirically in Wheat and Smith (2015).

Based on a similar empirical model, Mizutani et al. (2015)[38] calculated the train density threshold of 62.72, beyond which vertical integration is the most efficient organisational structure. This can be compared to the train density data in the Figure above: In Austria, Germany, Switzerland, the UK and the Netherlands train density was higher than this threshold, implying that the cost-minimising market organisation in those countries would be integration. The authors estimated that imposing vertical separation in the EU to all countries without separation at the train density levels from 2010 would increase the total cost by EUR 5.8 billion annually. This value is higher when train density increases.

The theoretical analysis by Mizutani (2020) confirmed the empirical results of previous research within a theoretical total cost model. It determines four types of effects of vertical integration: cost saving technological effects due to economies of scope; effect on managerial costs; effect on competition, and the effect of service quality investments.[39] This led to a parameter-based model, which is then used to

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[37] The first analysis of the effect of the train density on costs was by Mizutani and Uranishi (2013). An update was provided by Mizutani et al (2015) with a more detailed analysis and the implementation of the holding company as third option delivered a more detailed result. These results fed into Mizutani (2020), which took a theoretical, parameter-based approach.

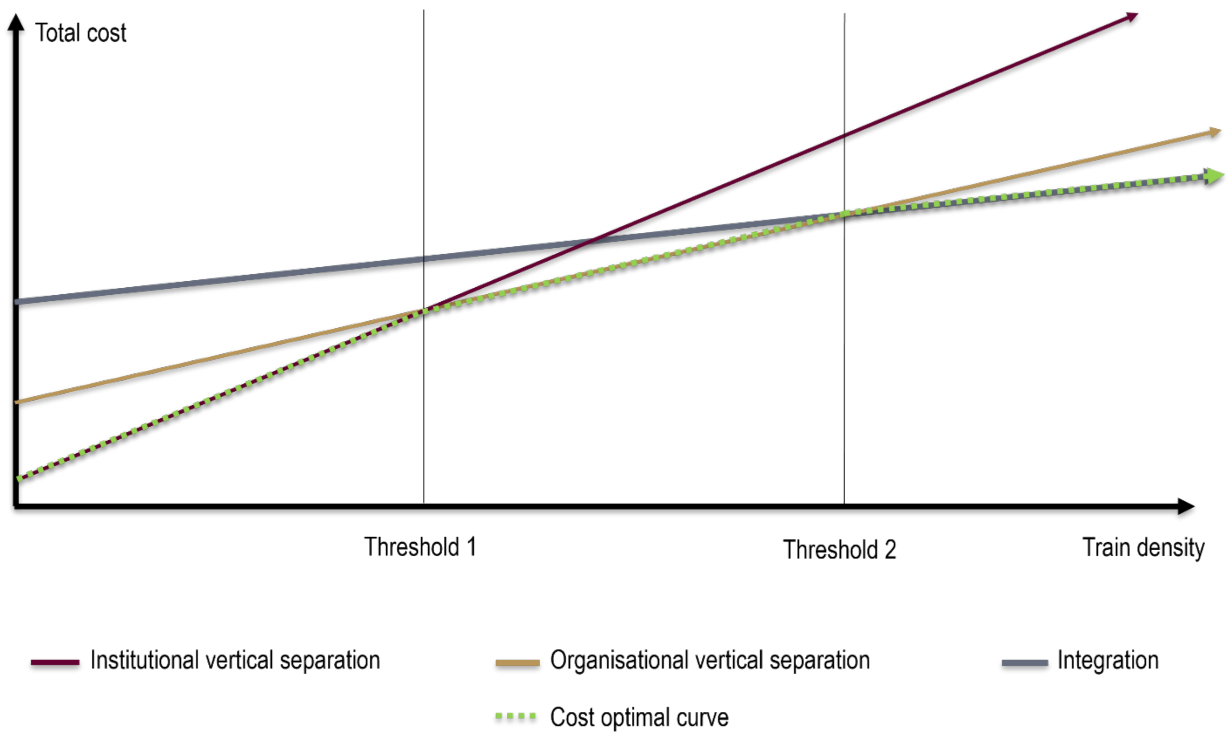
[38] The paper used the extended database of Mizutani and Uranishi (2013) and differentiated between three types of organisation: vertically separated, holding and integrated.

[39] The technological effects are reduced with the increase of separation in the market organisation. An example would be the reduction of maintenance costs by optimising the wheel-profile. See Forschungsbericht 36/2023 Table 4. The second effect can be divided into increasing misalignment costs and cost saving due to specialization. Misalignment costs are categorised by Van der Velde et al (2012) into four categories: investment coordination, production planning coordination, timetable planning coordination and production (real-time) coordination. Due to separation, employees are more specialised and therefore more efficient in their

find the cost-minimising market organisation structure depending on the value of train density. These results were used for developing the stylised figure below.

Figure 4 shows the total cost function of the three organisation structures. The cost-minimising structure given the train density is marked in green colour. For low levels of train density, vertical separation is optimal. In the mid-range (between threshold 1 and threshold 2), an intermediate form of vertical separation like organisational separation is optimal. For countries with a high train density (above threshold 2), a vertical integrated organisation minimises cost.

Figure 4: Optimal ownership structure



Source: E.CA Economics based on Mizutani (2020).

An additional insight from a series of papers by Smith and Wheat (2012) and Wheat and Smith (2015) on passenger train operations in the UK is that passenger rail services exhibit constant or even decreasing returns to scale but increasing returns to density. This means that the unit cost of operations (not taking infrastructure into account) decreases with higher train density: Operating more trains at higher frequency can reduce the cost of operations per passenger. Wheat and Smith (2015) found that the potential for cost decreases differs across different types of services: London commuting services and regional train operators had more scope for unit cost savings than intercity train operators. When heterogeneity of services is not considered, estimates on returns to scale and density are biased and may lead to wrong policy conclusions, for example investments which will not bring expected returns in practice.

tasks. The competition effect is decreasing the operational costs and just focus on competition of the operation. Competition in maintenance of infrastructure is not included in that model. The last effect, the service quality investment, is increasing with competition because operators are competing for passengers also with the quality. It can be possible, that these cost increasing investments can be welfare maximising.

Table 5 in Appendix 2 provides an overview of the literature discussed in this chapter.

Rail infrastructure characteristics

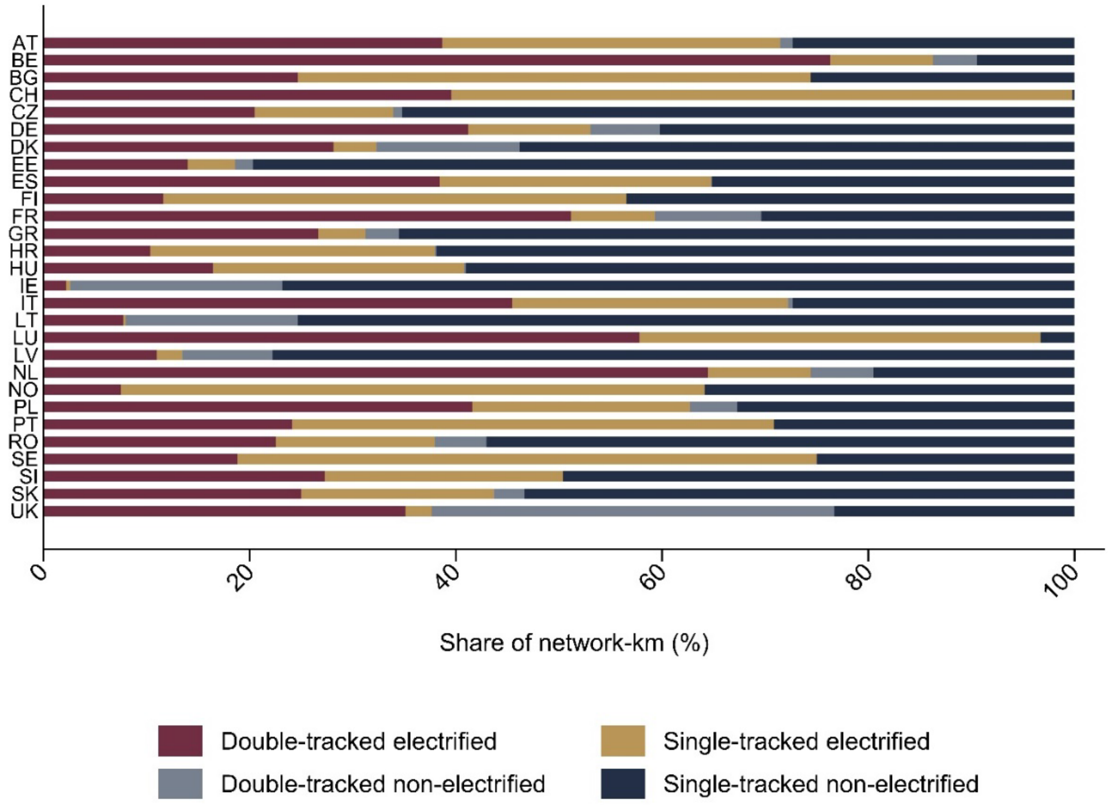
Train density is an important determinant of the optimal market organisation structure, but when calculated at country level it hides relevant heterogeneity. More precise capacity utilization measures can differ significantly within and across countries depending on the technical parameters of infrastructure. The capacity of a network-km depends on its many characteristics, including (but not limited to) i) electrification,[40] since electric trains are faster; ii) the number of parallel tracks, since more trains can use them in parallel and/or there is a possibility to bypass a train; iii) the availability of radio-based signalling system (e.g. ETCS) which is less prone to signal malfunction. In addition, a dedicated network for one type of transport can have a huge impact on the capacity of the rail network. A typical example here is infrastructure for high-speed passenger trains, which typically is dedicated to only this type of trains and in this way allows a higher frequency and smaller delays.[41] Except for Germany, all countries with high-speed trains operate them on a dedicated network. In some countries, there is also a dedicated network for freight trains, which allows a separation from passenger trains. In Germany, there is no such a separation, implying that typically slower freight trains must share tracks with faster or even high-speed passenger trains. Different countries also have a different mix of freight vs. passenger traffic, which has implications for the complexity of the infrastructure use. See Appendix 5 for a systematic comparison on infrastructure characteristics across the EU countries.

Figure 5 below shows cross-country differences in the characteristics of rail infrastructure: number of tracks and electrification.

[40] Under the assumption that the electrification of a railway route is endogenous, higher train density should lead to an electrification of a line. However, this is not the case in the vertically separated system of the UK, which has the highest train density on non-electrified lines in Europe (57, compared to the European average of 42). The share of electrification is lower compared with countries who has the same level of train density in 2021 (38%, compared to 75% in the Netherlands, 72% in Austria and 54% in Germany).

[41] High-speed trains between Tokyo and Osaka achieve up to 433 trains per day with an average delay of below 24 seconds in 2016 (see ECA Special Report 19/2018, Box 2).For comparison, the highest average train density in Europe in 2019 was observed in the Netherlands with 147 trains per network km per day, while the European average is 54 train-km per network-km per day for all types of trains.

Figure 5: Rail infrastructure characteristics across countries in 2021



Source: E.CA Economics based on data from Eurostat and UIC. Notes: Values for Belgium, Germany and United Kingdom refer to 2020.

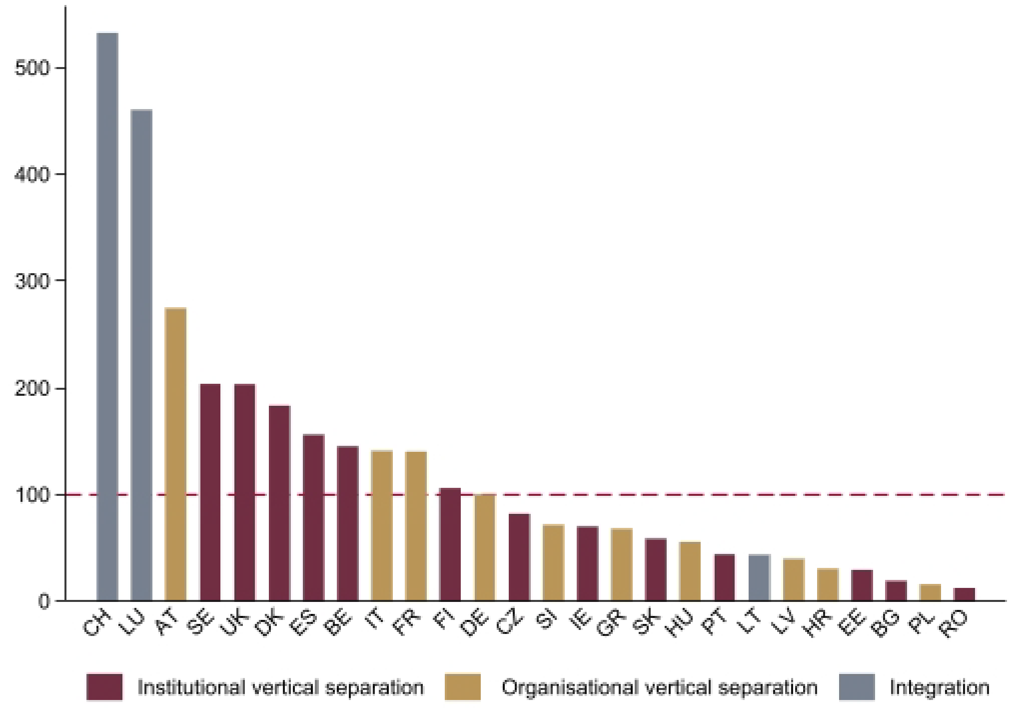
The tracks are heterogenous across Europe: while the electrification share in Switzerland and Luxemburg is close to 100%, it is below 20% in Ireland and the Baltic states. Germany is close to the European average with around 58%. An outlier is also the United Kingdom. Even with their high train density, the electrification share of 38% is clearly below the European average. It also has the highest share of double-tracked and non-electrified network km Europe wide (39%) compared with the European average of 6.7%.

It appears that investments like electrification, which require coordination and exchange of information between infrastructure and operator, have been introduced by vertically integrated or intermediate-type organisations to a larger extent. The highest electrification share is by countries with an integrated or intermediate vertical organisation as Belgium, Luxemburg and Switzerland. In contrast, the UK is having a below average electrification share while having a high passenger train density. Also UK is having the highest share of double-tracked and non-electrified tracks.

Investment in rail infrastructure

In the long term, the capacity and the characteristics of rail infrastructure can be upgraded with investment. Figure 6 shows that there is a lot of heterogeneity in the level of investment across the EU countries. Investment is measured as the total investment in infrastructure from 2000 to 2018 divided by the average population, indexed to the value for Germany.

Figure 6: Investment in infrastructure per capita between 2000 and 2018. Index with Germany = 100



Source: E.CA Economics based on data from Eurostat and OECD. Notes: The Figure shows the average investment per capita in railway infrastructure between 2000 and 2018. The values are indexed on Germany which has a value of 100 by definition. Luxemburg is an outlier because the number of rail users is much higher than its population due to the high number of commuters. While having 640,000 inhabitants, there are around 200,000 commuters from outside the country.

Figure 6 shows that Switzerland, Luxembourg and Austria are European leaders in rail infrastructure investment. In terms of organisational structure, they are all not vertically separated and the two top countries even have vertically integrated railways. Many other countries outperform Germany in terms of rail infrastructure investment, too.

Trade-off between efficiency and resilience of rail infrastructure

Finally, there is a trade-off between efficiency and resilience of rail infrastructure. It involves finding the right balance between the rail system's ability to operate smoothly, use resources optimally, and provide reliable and timely services against ensuring the system's ability to withstand and recover from disruptions or unexpected events. Efficiency in this case is defined in terms of high train density, i.e. high utilization of existing capacity, tight timetables and streamlined processes to maximize throughput. However, in pursuit of maximal short-term efficiency, there may be a tendency to schedule operations to the point where the system becomes vulnerable to unexpected disruptions. Planning for resilience acknowledges that some disruptions are going to take place and thus involves purposefully leaving aside some resources as idle so that they can be used as back-ups in case of potential disruptions. Contingency planning may also involve coordination with intermodal services (e.g., usage of bus services as emergency replacement for passenger rail transport). Balancing efficiency against resilience is a complex task that requires careful risk assessment, planning, and consideration of the specific needs and priorities of the rail network. If the balance is not reached the infrastructure will either not be efficiently used in day-to-day operations (e.g., resulting in lower frequency of train services) or the system might not have enough spare resources to be able to recover easily from unexpected disruptions. As the complexity and interdependencies of the rail network increase (e.g., due to different types of transport using the same infrastructure, larger number of independent entities using the infrastructure or simply higher capacity utilization) the task of balancing these effects becomes more difficult. To the extent that vertical integration allows to eliminate some of the interdependencies, it makes the balancing task easier.

Summary

- Multiple academic contributions investigate the relationship between train density and the total cost of rail, depending on the vertical organisational structure. Empirical papers generally find that vertical separation decreases cost, but the interaction term between vertical separation and train density is cost increasing. This means that total costs are higher in a vertically integrated organisation than in a vertically separated one, but the cost differential gets smaller as train density increases. Once train density exceeds a certain threshold, an integrated rail industry minimises cost. A recent theoretical analysis confirms the empirical results, where a vertically integrated organisational structure minimises costs above a certain train density threshold.

- While train density is an important determinant of the optimal organisational structure, it hides relevant heterogeneity between countries. The capacity of the network depends on many characteristics including electrification, the number of parallel tracks, the availability of radio-based signalling systems such as ETCS and whether freight, regional passenger and long-distance passenger transport run on the same tracks versus dedicated network infrastructure.

- In the long term, the capacity and the characteristics of rail infrastructure can be upgraded with investment.

- There is a trade-off between efficiency and resilience of rail infrastructure. Planning for resilience acknowledges that some disruptions are going to take place. The complexity and interdependencies in the rail system render the task of balancing difficult. To the extent that vertical integration allows to eliminate some of the interdependencies, it makes the balancing easier.

3.3.3 Competition

The main objective of the railway reforms in Europe three decades ago was to raise the efficiency of the railway sector by enabling entry of service competition on the existing infrastructure networks. Competition is often promoted as means of achieving positive economic outcomes in the form of efficient resource allocation and consumer benefits. This chapter summarises some empirical results investigating the link between vertical structure of the rail industry and its competitiveness, empirical case study of entry and theoretical foundations for the observed outcomes. We start with a description of different forms of competition possible in railway industry.

Intra-modal competition in the provision of rail services, both for freight and passenger, can take two primary forms, e.g. either the form of open-access competition (competition in the market) or tender competition (competition for the market). Open-access competition allows multiple train operators to use the same railway infrastructure, including tracks, stations and other facilities on a non-discriminatory basis. In contrast, tender competition is a process (usually procurement) through which public authorities or regional transport agencies solicit bids or proposals from rail operators to provide rail services to select the most suitable (usually, but not always single) operator to provide rail services on specific routes or networks. Open-access competition is usually the model of competition applied to freight and long-distance passenger services, while tender competition is most common for regional passenger travel.

Rail transport services are also subject to strong inter-modal competition, as evidenced by generally low modal share of railway transport. Depending on the origin and the destination, road, air and water transportation can all be sources of competition for railway transport. When available, inter-modal competition can bring similar benefits as intra-modal competition. Because incumbents for different modes of transportations are different, inter-modal transportation can overcome “natural monopoly bottleneck” problems and foster efficient usage of different transportation technologies. On the other hand, different modes of transportation can contribute differently to different policy goals (e.g. with respect to climate change), so economic policy can strive to steer economic activity towards modes of transportation fulfilling the broader policy objectives.

Both types of intramodal competition can be implemented in vertically integrated and in vertically separated industry structures. Therefore, vertical separation is not a required condition for the introduction of downstream competition. The relevant question is therefore whether vertical separation can improve the economic outcomes and to what extend this depends on the nature and the intensity of the competition downstream. The answer to this question is not clear, because there might be pros and cons of the infrastructure operator being active in the downstream competitive market.

In line with Coase / Williamson theory of the (optimal) boundaries of the firm (for which the Nobel-prizes have been awarded in 1991 and 2009), economic activities are presumed to be undertaken externally (through market transactions), unless the costs of such activities are lower when conducted internally (within the firm). Generally, in well-functioning markets transactions costs are low and hence vertical separation (or outsourcing) makes sense. However, there are factors that can result in (partial) market failure and in an increase of market transaction costs. These factors include costs of contractual hold-up, costs of contractual incompleteness and bounded rationality, costs of market power imbalances and asymmetric information and costs of regulation. Common ownership (i.e. vertical integration) can reduce and eliminate some of these costs, e.g. costs related to asymmetric information or incomplete contracting. However, it can also increase other costs such as higher agency costs, the costs of collective decision making and the costs of risk bearing (i.e. lack of diversification and access to capital in imperfect capital markets). Ultimately, the optimal ownership structure of a firm is determined by the lowest combined costs of ownership and market contracting. Thus, when the costs of market contracting exceed those of ownership, firms will have an incentive to integrate vertically. A central prediction of that theory is that the more complex the transactions are and the more special their assets, the more efficient it is that they are executed within the boundaries of a firm rather than externally.[42] Independent of these considerations, industrial or competition policy can also be an important factor in the decisions to vertically separate existing enterprises.

Empirical results

There is ample empirical evidence which shows that institutional vertical separation is not required to achieve effective competition in the train service operations. A general and comprehensive analysis of

[42] Williamson, O. E. (1985) The Economic Institutions of Capitalism, Free Press, New York.

effects of competition on railway efficiency has been conducted by Fitzová in her recent paper (2022). Her research was partly motivated by a survey of earlier empirical literature, which found inconclusive (mixed) impact of vertical separation: about half of the analysed studies did not find any significant effect of vertical separation, while several studies identified a positive effect and remaining ones reported a negative effect.

As regards the direct impact of vertical separation, Fitzová in her paper finds robustly that it significantly reduces economic efficiency.[43] This finding can be explained by the observation that the vertically integrated organisation has some advantages, namely that the coordination process in railways can be managed at much lower transaction costs within a vertically integrated organisation than between vertically separated entities. A vertically integrated structure facilitates better coordination of maintenance, modernisation, conflict settlement and better alignment of investment incentives. In contrasts, a vertically separated structure might generate additional costs like negotiating, monitoring and enforcing contracts.

On the other hand, vertical separation could also affect efficiency indirectly. For example, vertical separation could result in increased competition. In such a case, part of the impact of vertical separation could be indirectly attributed to competition variables, which are included separately from the vertical separation variable in Fitzová's models. Depending on the exact specification of the model, she measures separately the impact of competition in passenger and in freight services as well as the intensity of competition (measured either by entry indicators or by the competitive market share in the downstream market) in the two market segments. Her two main findings on competition can be summarised as follows: First, when the intensity of competition is relatively low, it does not improve the efficiency, but reduces it further. This result is particularly significant for passenger competition, if the competitors' share does not exceed 10%, and for freight if the competitors' share does not exceed 5%. As competition intensifies (above 10%), the models suggest it might start generating economic efficiency, as the estimated coefficients are positive, although generally they are not statistically significant. Fitzová presents also models in which competition is measured not in terms of competitor's share but rather in terms of entry. In these models the estimated impact of entry is positive for freight and direct open access head-on entry, but it is unclear in case of tender entry or open entry in niche markets.

In terms of policy implications, the results of the models estimated by Fitzová suggest that there is no immediate and direct evidence for a positive effect of vertical separation on efficiency. In fact, the direct effect seems to be negative as vertical separation can increase transaction coordination costs and misalignment of various incentives, so that a vertically integrated (or holding) structure might have some efficiency benefits. Only in the case in which a vertically separated structure results in strong competition downstream, the benefits of such competition can be sufficient to offset the loss of efficiency due to the transaction costs. However, because the link between vertical separation and competition is not modelled directly, it is unclear if such an outcome could be achieved. The increase in competition can also be achieved in vertically integrated (or organisationally separated) organisational structure. Therefore, the results of the paper present a strong case for vertical integration.

Case study

There are also academic papers which present "case studies" showing that the beneficial market outcomes due to competition can also be achieved in vertically integrated (or holding) industry structures.

[43] Even though she claims to have estimated a large number of differently specified models, in her paper Fitzová presents the results of only a single model specification, based on the largest number of observations and most up-to-date values (24 countries in period 1999-2017).

For example, Bergantino et al (2015) analyse empirically the effects of entry into the high-speed passenger rail market that took place in 2012 in Italy. The Italian rail market is organised in an integrated system. In the high-speed-sector, new entrant NTV (Nuovo Transporto Viaggiatori) could gain significant market shares with it's ITALO-trains. The authors find that in response to entry, the incumbent increased its capacity on the affected routes by some 30%, which together with the additional capacity added by the entrant resulted in substantially larger utilisation of the existing infrastructure (by almost 60% on the Rome-Milan connection). This is clearly a positive development from the consumer welfare perspective. The authors also find that the incumbent did not engage in aggressive price competition against the entrant, charging prices on average 30-35% higher than the incumbent. One can view this as a form of market segmentation, which might not be feasible with a single franchise operating on the route.

Moreover, Bergantino et al (2015) analyse not only the intra-modal competition between the vertically integrated incumbent and the entrant, but also effects of the inter-modal competition between the high-speed rail segment and airline pricing behaviour on equivalent routes.[44] Indeed, the authors find that the high-speed rail entry has stimulated competition also with the airlines: Not only have air fares on the affected routes decreased by some 15-30% on average but also a substantial share of passengers has been diverted from air to rail transport. In summary, the Bergantino et al (2015) study can be viewed as an empirical example of well-functioning downstream competition in the presence of vertical integration (in the form of a holding company).

Theoretical foundations

The idea that there is no clear link between competition and vertical integration has not only been analysed empirically, but also has some theoretical foundations. For example, Cantos-Sanchez et al. (2023) have recently proposed a theoretical framework (which builds on their earlier empirical research) that allows for an analysis of the interaction between vertical separation and competition in the railway industry.

They consider a theoretical model in which the infrastructure monopolist enjoys economies of scale and sets the access fee, while the rail operators (which can be either monopolistic or oligopolistic) with constant returns to scale maximize their profits by setting the ticket prices paid by users. By considering different vertical market structures (vertically integrated and institutionally vertically separated) and different horizontal market structures downstream (monopolist versus duopoly) and solving the model in each case they can compare the outcomes in different scenarios. In particular, for each scenario they evaluate the value of the Lerner index, which is a standard economic measure of market power (higher values of Lerner index are associated with higher margins, i.e. worse functioning competition).

For the purposes of this chapter, their key proposition states that if economies of scale upstream (monopolistic infrastructure) are sufficiently large then in case of vertical separation the Lerner index for downstream monopoly can be higher than for downstream duopoly. This could be considered counterintuitive, because it presents a plausible scenario where competition downstream does not improve the market outcome. The intuition behind this result can be described as follows: In the presence of a downstream duopoly, the access fee can be lower, because the total traffic increases, so that the economies of scale can be better exploited. However, for certain values of economies of scale, the pass-through of access fees to ticket prices can be larger than the percentage increase in the access fee. This generates the counterintuitive result. It is also worth noting, that a presence of (sufficiently strong)

[44] As the high-speed rail journey on the Rome-Milan connection takes only about three hours, it can be considered an effective alternative to flights.

economies of scale upstream is necessary for the result: without the economies of scale the value of the Lerner index is always lower in case of duopoly than in the case of monopoly downstream.

As regards the theoretical impact of vertical integration on competition, generally, the main concern is the (potentially anticompetitive) behaviour of the integrated operator against its downstream rivals in the retail market. It can take forms such as margin squeeze, foreclosure and more generally discriminatory access conditions to the infrastructure. The risks of such negative behaviour can be mitigated to some extent if the regulator has the ability to detect them and to enforce the fair access rules. There are examples in other industries, where the infrastructure incumbent is allowed to operate also in the retail markets, without negative competitive effects.[45] Therefore, vertically integrated market structure can lead to desirable market outcomes, although it might require more regulatory and enforcement oversight than vertically separated structure.

In contrast, in case of full vertical separation the monopoly infrastructure manager in principle has no intrinsic incentives to treat any of the downstream firms - who are its customers – asymmetrically. A fully separated infrastructure manager would have incentives to optimize the utilization of the infrastructure and would have no incentive to discriminate across its customers, potentially requiring less regulatory oversight. This approach, however, focuses mostly on the short-term, price-oriented aspects of competition and ignores some of the relevant industry characteristics, like the need to coordinate different assets, etc.

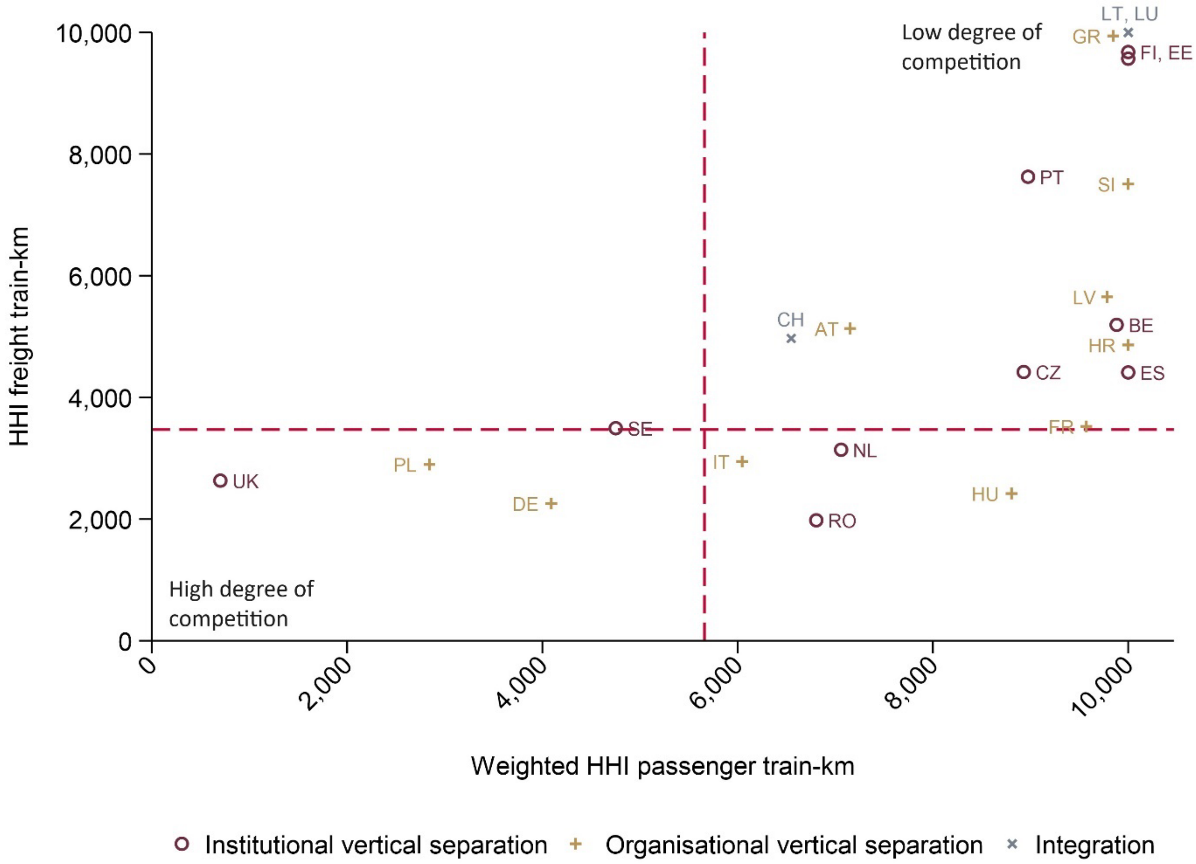
Competition indicators

The competitive situation of the railway sector in Germany is quite strong compared to other countries. Thus, the lack of institutional vertical separation does not seem to be the core obstacle to competitive market structure. There are several countries with institutional vertical separation that have a higher HHI in freight and passenger than Germany[46] – determining lower intensity of competition. There is no clear indication that institutional vertical separation is necessary for a competitive railway sector. Figure 7 shows the HHI index in the freight and passenger services based on train-km in 2018. The HHI for passenger services is often higher than for freight services.

[45] For example, in telecommunications services the infrastructure incumbents (e.g. Deutsche Telekom) remains integrated with its downstream retail unit, see Chapter 5.1 below for details.

[46] A scientifically recognized measure for quantifying the intensity of competition in markets is the Herfindahl-Hirschmann Index (HHI). In 2020 IRG Rail, an association of the European competition authorities, has determined HHI-values for major European railmarkets (reporting year 2018) and made them internationally comparable. 8th IRG Market Monitoring Report (March 2020).

Figure 7: HHI Index of European countries for freight and passenger services based on train-km in 2018



Source: E.CA Economics based on data from the 8th IRG Report. Notes: The dashed red lines indicate the weighted average of the HHI based on the train-km. The HHI for passenger service is the weighted average of the PSO-HHI and the non-PSO-HHI based on the train-km. this method is necessary due to the lack of a combined HHI for the total passenger railway sector.

Based on the competition statistics presented in Figure 7 above, there seems to be large variation across countries and industry structures. For example, In Germany, the HHI is below the weighted average for freight and passenger. There is also no country, that has a lower both freight and passenger HHI than Germany. Only UK and Poland have comparable HHI in the freight sector and a lower HHI for passenger services. These two countries are also the only two countries with a lower passenger HHI than Germany. Only Romania has a lower freight HHI than Germany in Europe. Sweden has an average HHI for freight and a below average HHI for passenger Service. Austria has an above average HHI for freight and passenger services, but is still below other countries. Switzerland, which is vertically integrated, also has comparable HHI values.

A disadvantage of the HHI measure is that there is no distinction between competition *in* the market and competition *for* the market. Also, other aspects such as the number of bids for the market are not covered through the HHI.[47]

[47] For direct competition: in 2018, there were 4.5 million train-km per week in direct competition. Around 2 million of them were in Italy (31% of the total traffic) and only around 0.6 million (6%) of them in the UK, which has a the lowest HHI in Europe. Germany has around 0.45 million (3%) train-km per week in 2018 in direct competition.

Furthermore, an increase in competition should not be considered an end in itself. Of course, in most economic settings, an increase in competition results in increases on consumer welfare (e.g. in the form of increased quality of service or lower prices) and total welfare, but there are also exceptions from this rule. For example, for a fixed level of infrastructure, increasing competition can increase utilization levels of the infrastructure to inefficient levels, so that congestion, delays, etc. actually reduce the outcome for the consumers. While using a shared infrastructure pool for different kind of services might generate clear efficiencies (in particular when the utilization of the infrastructure is low), in case of high utilization these problems manifest themselves most strongly if the same infrastructure is utilised for different types of freight (e.g. freight, regional passenger or long-distance passenger transport). These different types of freight services induce negative externality on each other, which can create severe market failure. It is the desirable effects of competition that are relevant for the assessment of public policy, rather than some structural indicators of competition.

To summarise, economic literature, both empirical and theoretical, does not support the claim that vertical separation results in more competition or that with vertical separation competition downstream leads to more efficient outcomes (see Table 5 in Appendix 2 for an overview of the literature discussed in this chapter). Empirical studies provide either inconclusive or mixed answers to these questions, theoretical studies provide plausible scenarios in which competition does not improve the economic outcomes in case of vertical separation and case studies show that favourable economic outcomes can be achieved also in vertically integrated market structures (i.e. that vertical separation is not required to achieve such positive outcome).

Summary

- The main objective of the railway reforms in Europe was to raise the efficiency of the railway sector by enabling train service competition on the existing network infrastructure. Vertical separation is not a necessary condition for the introduction of downstream competition.
- Competition in the provision of train services can take two primary forms, either open-access competition (competition in the market) or tender competition (competition for the market). Open-access competition allows multiple train operators to use the same rail infrastructure on a non-discriminatory basis. Tender competition is a process through which public authorities or regional transport agencies solicit bids for the provision of train services from rail operators and select the most suitable operator to provide train services on specific routes. Open-access competition is usually the model of competition applied to freight and long-distance passenger transport. Tender competition is most common for regional passenger transport.
- There is ample empirical evidence showing that full vertical separation is not required to achieve effective competition in train service operations. In particular, the results of a recent empirical study suggest that there is no direct positive effect of vertical separation on efficiency. On the contrary, the direct effect seems to be negative as vertical separation can increase coordination costs and misalignment of various incentives. Only when a vertically separated structure results in strong competition downstream, the benefits of such competition can be sufficient to offset the loss of efficiency due to the transaction costs.
- Theoretical studies also provide plausible scenarios in which competition does not improve the economic outcomes in case of vertical separation.
- Structural indicators of competition, such as the incumbent's (or the competitors') share in the market, vary widely across European countries independent of organisational market structure. In particular, the industry structure in Germany appears much more competitive than in most other European countries, despite the German rail system being only organisationally separated. Lastly, an increase in competition should not be considered an end in itself.

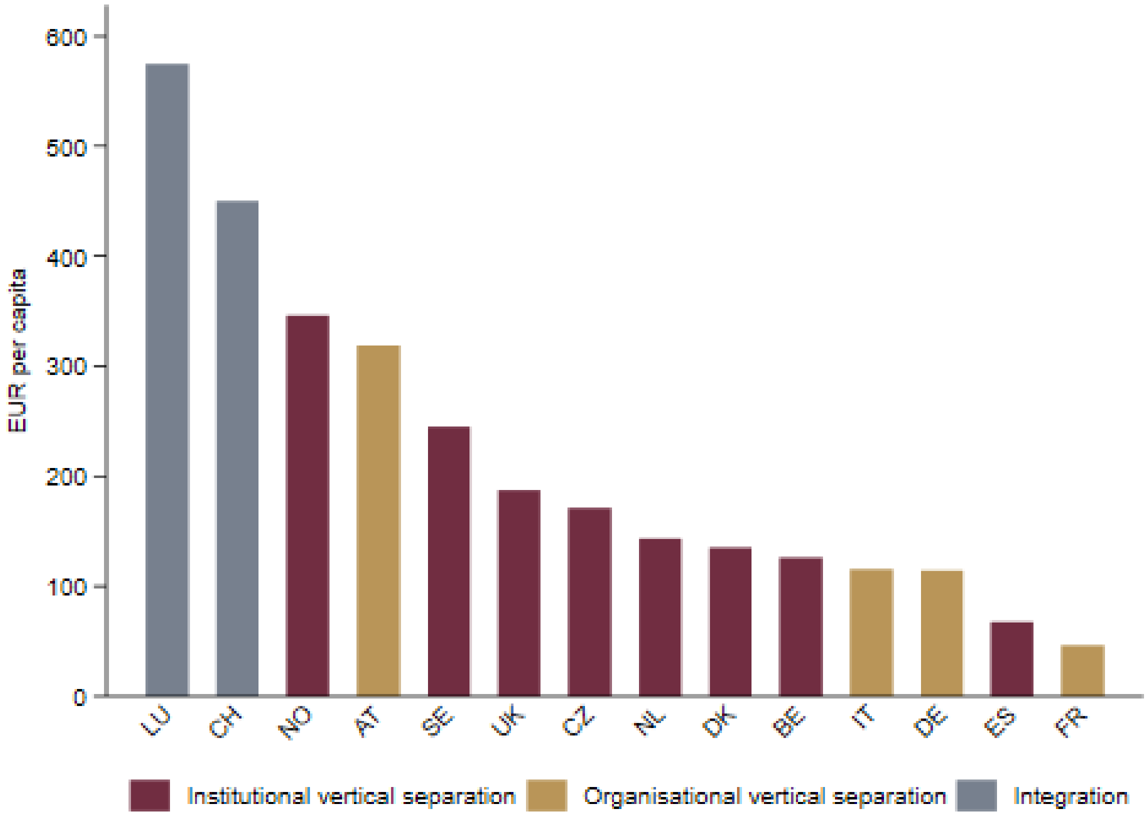
3.3.4 Financing model

Rail financing is a further factor influencing the effects of rail transport's organisational structure. The rail industry operates with a long-term perspective. Building and maintaining the rail network's infrastructure requires substantial investments which are typically designed to last for decades and longer. Assets such as rolling stock are characterised by an estimated useful life of more than 30 years and even innovation in rail happens at a slower pace compared to many other industries.[48] In this context, adequate long-term financing plays a critical role in sustaining, expanding and improving the quality and performance of the rail system regardless of its organisational structure.

[48] The slow rate of innovation in rail relates also to the fact that equipment not only needs to be fully compatible with the existing one but must also be completely safe before being placed in regular service.

The main categories of rail infrastructure funding as classified in the literature[49] are funds from public budgets (revenue contributions, grants, etc.), revenue from track access charges and related services and revenue from other commercial sources.[50] They will be discussed in the remainder of this chapter.

Figure 8: Subsidies per capita in rail infrastructure in Europe in 2022



Source: E.CA Economics based on data from Allianz Pro Schiene.

Figure 8 above shows that Luxembourg, Switzerland, Norway, Austria and Sweden granted the highest subsidies per capita in Europe in 2022. It is interesting to notice that the two countries with the highest investment have a vertically integrated rail industry. Norway and Sweden are vertically separated. Austria's rail system, alike Germany, is characterised by organisational vertical separation and is the fourth country in terms of highest subsidies per capita. While Sweden's government has historically been active in supporting the country's rail sector, Switzerland finances rail mainly with the Railway

[49] Schäfer and Götz (2017) and European Parliament (2015).

[50] Alternative project financing methods require the involvement of the private sector (e.g. public private partnerships – PPPs) which presents both strengths and limitations in Europe. For instance, rail projects are often characterised by cost and demand risks that are inherently high. Such barriers have held back the development of several private rail concessions, with numerous projects being either delayed or completed only via the direct intervention of the State. Generally, when considering the value for money of different procurement options for rail infrastructure investment, PPPs are an inferior alternative to direct public sector financing. Rail operations tend to be structurally unprofitable, with market revenues for rail projects that are generally not high enough to cover the cost of capital and generate a return for the investor. Revenues, on the other hand, are highly volatile as demand is affected by economic fluctuations in addition to the availability and cost of road infrastructure alternatives. Overall, PPPs do not create viable additional resources and can only be successful for those projects that would have been "profitable" irrespectively of the type of contract (Casullo, 2017).

Infrastructure Fund (RIF), which funds the entirety of operation, maintenance and investment projects in perpetuity and is closely linked to a long-term rail development program.

Aside from public funding, infrastructure managers in many countries have also been able to raise finance by issuing debts which can in turn be covered either by State contributions, track access charges, or a combination of both. Financial markets have traditionally trusted the financial sustainability of European infrastructure managers given the presence of State backing and, periodically, direct debt transfers to public accounts. However, the indebtedness of rail infrastructure managers has grown substantially over the past 20 years (Casullo, 2017).

Additionally, while the rail sector requires sustained, long-term public funding for its maintenance and development, political decision-makers often operate within shorter timeframes dictated by electoral cycles and might lack the political self-commitment needed to ensure prolonged support to rail investment. Political influence on subsidies can, therefore, create challenges in terms of investment priorities between what rail companies need and what is politically expedient (Xuto et al, 2023). In this sense, the existence and availability of a perpetual, open-ended, multi-annual fund for rail financing is necessary to reduce the risk of change in the availability of funds and to avoid annual competition with other areas of expenditure in the government budget.

The solution adopted in Switzerland in 2016 with the Rail Infrastructure Fund (RIF) is often regarded as the optimal funding model for rail financing. The legal basis for the fund is the country's constitution, which established it as a legally dependent special fund outside of the federal budget itself with specific revenue sources[51]. This ensures a high degree of political self-commitment and increases the planning security of RUs in the country. The fund is managed by the Swiss Confederation and funds the entirety of operation, maintenance and investment projects on the national rail network in perpetuity. Additionally, it is linked to a long-term rail development program [52]. Switzerland's RIF represents the next stage of coordination for a rail system thanks to its ability to become more efficient while retaining high standards of service, thereby creating strong trust among national and regional administrations, citizens and users. Coordination in Switzerland is made possible by appropriate governance arrangements including close integration of "track and train," planning and strategic decision-making at the federal level over 15-year periods (Casullo, 2017).

Overall, the "Swiss Financing Model" is particularly praised for the ability to ensure political self-commitment and reduce political transaction costs (Becker and Beckers, 2018), foster planning certainty and avoid competition with other items in the federal budget. Additionally, the preservation and maintenance of rail infrastructure is financed with the same resources as for expansion and new construction projects. This enables both the Federal Government and network operators to consider follow-up costs when making expansion decisions.

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[51] Differently from its predecessor (FinöV Fund), RIF's funding comes from a variety of sources, including national and cantonal budgets, but also revenues from a road charge on heavy vehicles and, until 2030, some VAT receipts and a tax on mineral oils (Casullo, 2017).

[52] The annual withdrawals from the RIF and their allocation to various areas of expenditure are determined by the Swiss Parliament by means of a federal decree in the context of the adoption of the budget. Every four years, the Swiss Parliament approves a framework payment including targets to be achieved for the operation, maintenance and technical development of the Swiss rail infrastructure. Such a framework determines both operating compensation and an investment contribution within the four-year period. The disbursement of the allocated funds is conditional to a performance agreement defining the annual payments and quality targets.

Despite the potential advantages resulting from the introduction of a rail infrastructure fund, rail infrastructure financing still presents challenges and issues. First, the decision to prioritise rail in the allocation of funds must be made independently from the introduction of a fund model. Fund resources also come from the government’s budget and are a burden on the government’s debt. Cautious budget management aimed at maintaining a low State budget and debt level, can result in reduced government funding for railways. To this extent, the success of the Swiss financing model is primarily based not on its design as a fund model but on the availability of adequate funding. Second, the existence of a rail fund does not make the withdrawal of funds more flexible or any simpler, as funds will continue to be drawn via contracts and contract design determines the degree of bureaucracy involved in the financing process. Therefore, general optimisation of the funding process by means of more streamlined regulations and the reduction of bureaucracy should be pursued independently of the establishment of a rail infrastructure fund. Finally, an essential element in rail financing is political self-commitment, which can be successfully obtained via fixed revenue sources and multi-annual spending decisions. Nonetheless, these advantages, which are undeniable from the perspective of institutional economics, could be perceived as a disadvantage by political stakeholders, who would be potentially restricted in their scope for action by long-term commitment of funds. The way in which these challenges are to be addressed will impact a country’s rail system profoundly and influence its performance and quality over time regardless of the choice of organisational structure.

Summary

- Independent of the vertical organization of the industry, adequate rail financing is crucial for maintaining, expanding, and improving the quality and performance of the rail system, regardless of its organisational structure.
- The main categories of rail infrastructure funding include funds from public budgets, TACs and revenues from other commercial sources. However, the rail industry requires a perpetual, open-ended, multi-annual fund for rail financing due to its long-term perspective. The Swiss Rail Infrastructure Fund (RIF) is often considered the best model for funding rail infrastructure.
- Yet, rail infrastructure financing still presents challenges, such as ensuring adequate per-capita funding, optimising contract design and regulation, and securing political commitment. Addressing these challenges will profoundly impact a country's rail system and influence its performance and quality over time, regardless of the chosen organisational structure.

4 Cross-country comparison

This chapter presents major characteristics of the railway industry across European countries. A focused comparison of railway performance for all countries is provided in Chapter 4.1, while a more detailed overview can be found in Appendix 3, Appendix 4 and Appendix 5. The following chapters dive into the detailed historical background, organisation, regulation, funding and performance for Germany (4.2) Sweden (4.3), the United Kingdom (4.4) and Austria (4.5). The latter three countries were selected as interesting benchmark cases to discuss the potential effects of vertical separation in Germany, since Sweden and the UK have a vertically separated railway industry and Austria has a similar vertical organisational structure as Germany, but different performance.

4.1 European comparison of key indicators

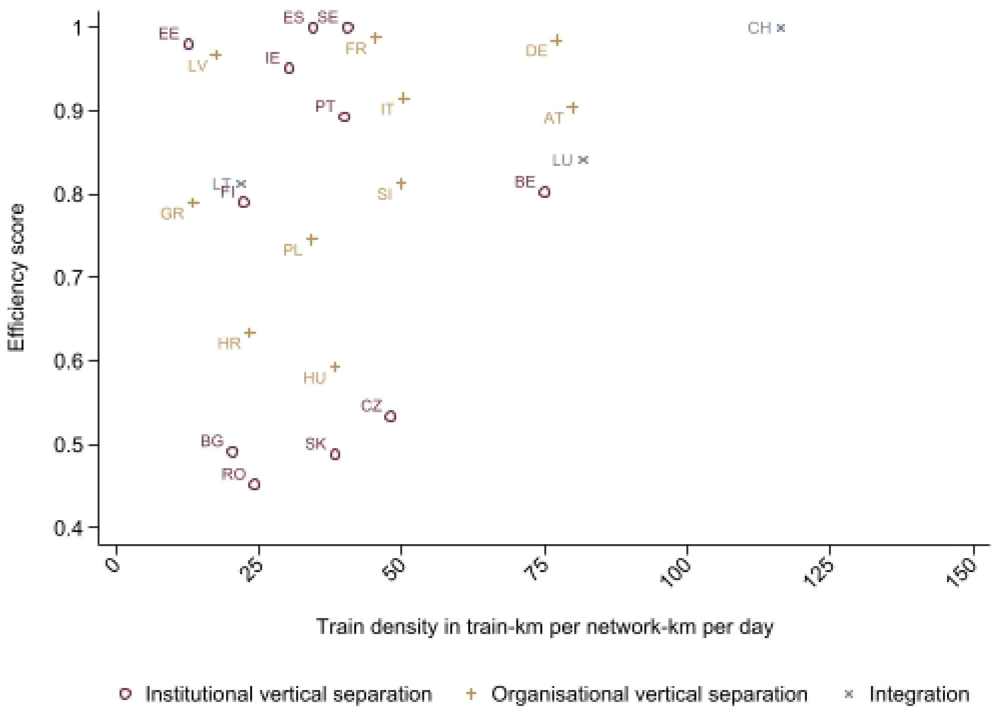
As discussed in Chapter 2, in the past railways in Europe used to be public monopolies organised as vertically integrated companies responsible for both infrastructure management and train operations. Major structural changes started in 1991, when the European Commission presented the first reform proposals with the goal of increasing the competitiveness of the railway sector, improving interoperability of national networks and developing rail transport infrastructure (European Commission, 2019). In the following years, European countries started to restructure their rail systems accordingly, but the implementation of reforms and consequent outcomes still significantly differ between individual EU countries.

To comprehensively assess rail performance in Europe, Figure 9 below presents the average efficiency scores as estimated in Fitzová (2022),[53] together with each Member State's industry organisation and total train density (train-km per network-km per day). The plotted average efficiency scores are bounded between 0 (least efficient) and 1 (most efficient) and serve to construct a ranking of European countries based on the average existing relationship between track length (km), number of employees, passenger and freight fleet and each country's output in terms of passenger and freight volumes during 1999-2017.[54]

[53] Fitzová (2022) estimates each Member State's efficiency score by comparing its performance with the one of other Member States via the Data Envelopment Analysis (DEA) technique (see Chapter 3.2). The analysis was conducted using two types of outputs: passenger-km and tonne-km in the first specification, and passenger train-km and freight train-km in the second specification. The efficiency scores were calculated assuming either constant returns to scale or variable returns to scale. In the present report, an average of all estimated efficiency scores is presented.

[54] Please note that the efficiency scores of Fitzová (2022) are the most recent scores available in the literature, but do not reflect the situation in 2024.

Figure 9: Average efficiency scores during 1999-2017 across European countries



Source: E.CA Economics based on data from Ait Ali and Eliasson (2022), Fitzová (2022) and IRG. Notes: To limit the impact of outliers in the data, the presented efficiency scores are calculated as an average of the different estimations from Fitzová (2022). Average efficiency scores for Denmark, the Netherlands and UK are not available. For Switzerland, the market organisation as defined in Ait Ali and Eliasson (2022) is adopted. Train density values refer to 2017 only, however, train density is a stable measure and does not present strong yearly variations. For instance, the results do not change if values from 2021 are used.

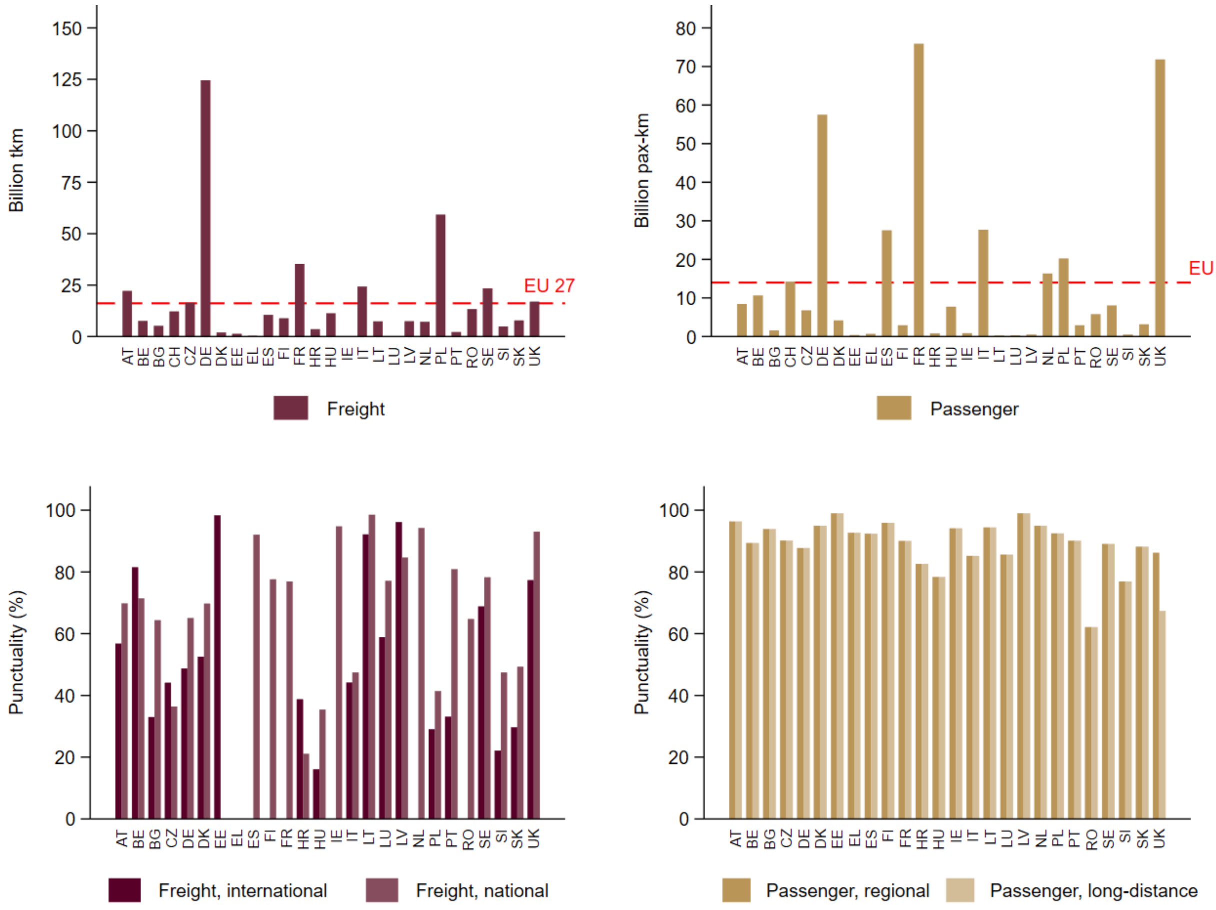
Based on Figure 9 above, European countries with an integrated rail system (Latvia, Lithuania, Luxemburg and Switzerland) present the highest efficiency scores in the sample, with an average efficiency of 0.88. Countries having separated infrastructure from rail operations display an inferior average efficiency score of 0.76, but there are significant differences: Estonia, Finland, Ireland, Sweden, Spain and Portugal fall in the upper end of efficiency scores, while the other countries form a group with the lowest scores in the sample. What they have in common is a relatively low train density. Integrated rail systems have the highest average train-km per network-km per day (73), followed by countries that are organisationally separated (43) and institutionally vertically separated (35). In addition, some countries with high average efficiency scores, such as Belgium (0.80), Finland (0.79) and Spain (0.99), have introduced institutional vertical separation but do not yet have effective competition in their passenger segments (see Table Table 6 in Appendix 3). This seems to indicate that there are other factors promoting the efficiency of their rail services rather than the way their rail industry is organised. Finally, important differences can also be observed when distinguishing between Western and Eastern[55] European countries, as Eastern European countries are associated with a lower degree of efficiency and train density compared to the Western countries.

To further analyse the performance of rail systems across Europe, two Key Performance Indicators (KPIs) are employed, providing valuable insights into each country's volume per segment and quality of services

[55] Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia.

provided. Figure 10 below presents transported freight and passenger volumes in 2021 (upper panels) together with the share of punctual trains per segment[56] in 2019 (bottom panels).

Figure 10: Volume (2021-2022) and punctuality (2019) across European countries



Source: E.CA Economics based on data from Eurostat and Rail Market Monitoring (RMMs). Notes: All freight volumes refer to 2022, except for Belgium (2011), Denmark (2021), Greece (2017), Sweden (2021) and UK (2019). Passenger volumes refer mostly to 2021 or 2022, with the exceptions of Belgium (2007), Hungary (2011), Netherlands (2014), Poland (2017) and UK (2019). Punctuality of freight trains is not available for Greece, while values for international freight trains in Finland, France, Ireland, Netherlands, Spain and Romania are not available.

Based on the top-left panel of Figure 10, one can observe that levels of freight transport in Europe differ significantly among countries. The country with the highest freight volume is Germany, with approximately 125 billion tonne-km transported in 2022, followed by Poland (60 billion tonne-km in 2022) and France (35 billion tonne-km in 2022).

When it comes to passenger transport, France, Germany, Italy, Netherlands, Poland, Spain, Switzerland and UK are the countries with above-average transported passengers in Europe. As indicated in the top-right panel of Figure 10, France appears to be the country with the highest number of passenger-km in

[56] Regional and long-distance passenger trains are classified as punctual if they present a delay of 5 or less minutes. In the case of international and national freight trains, the maximum delay is of 15 minutes. The standardised definition was introduced with the EU Regulation 2015/110, however, its implementation into national law varies from country to country. Therefore, comparison across time and countries can be problematic and caution is advised.

the sample (75 billion passenger-km in 2021), followed by the UK (70 billion passenger-km in 2019) and Germany (60 billion passenger-km in 2021).

Finally, punctuality in rail systems across Europe is explored in the bottom panels of Figure 10, in which the share of punctual freight and passenger trains is presented. As it can be immediately observed, the share of punctual trains in the passenger market is substantially higher than in the freight market. This is because freight operations are characterised by more interdependencies with foreign countries compared to the passenger transport and coordination with other modes of transport for the pre-carriage and onward carriage is usually required. The average share of punctual freight trains in Europe is approximately 40% for international trains and 60% for national trains. Average punctuality in the passenger market is almost 90% for both regional and long-distance trains in Europe. In 2019, the only countries with more than 95% of punctual trains in both segments were Austria, Estonia and Latvia.

4.2 Germany

Before discussing the German railway system in detail, Table 1 below presents an overview of the key aspects characterising the country in terms of history, organisation of the industry and regulation and funding of rail infrastructure based on the sub-chapters presented below.

Table 1: Fact Sheet Germany

Historical and country background	• Deutsche Bahn AG founded in 1994 with rail reform; **goals of the reform were to strengthen rail passenger and freight transport and to relieve the federal budget; measures: restructuring of Deutsche Bahn, separation of responsibilities between State and RUs,** introduction of competition **on the tracks; while reform decreased federal spending and increased efficiency and rail traffic, it led to** long-term underinvestment in network infrastructure **and reduction of network length by almost 6,000km** • **Goals of current government: 25% rail freight modal share and doubling rail passenger numbers by 2030** • **Most populated country in Europe with 83m inhabitants in 2022; one of the highest population densities in Europe** • Largest rail network in Europe with very high train density; **high-speed, freight and other passenger trains run on the same network;** highly dispersed network **to connect many small and medium sized towns** • Passenger traffic increased by >40% and freight traffic by >80% since rail reform; **passenger modal share of 7% and freight modal share of 19% in 2021**
Organisation of the industry	• **Organisational vertical separation** within holding structure since 1994; infrastructure companies: DB InfraGO AG (former DB Netz AG and DB Station & Service AG), DB Energie; RUs: DB Fernverkehr AG, DB Regio AG, DB Cargo AG • **Passenger: open access in long-distance** transport; **franchise** system with mostly competitive tenders **in regional transport**; **freight: open access** (all introduced with rail reform in 1994) • **Market shares DB: 45.2% in freight and 65.4% in passenger transport** in 2021; much lower than incumbent market share in most other European countries
Regulation	• **ERegG** is legal framework regulating in particular access to the network

	• **TACs should cover costs of running and maintaining network infrastructure** plus rate of return; while TAC for passenger services are among higher ones in Europe, freight TACs are the second lowest in Europe • **Two main supervisory bodies: Bundesnetzagentur (BNetzA)** responsible for competition regulation; The federal railway office (**Eisenbahnbundesamt, EBA)** mainly responsible for technical supervision and approval of federal funding and constructional measures
Funding of infrastructure and investment	• **DB InfraGO needs to cover** operating expenditures and **maintenance costs** from TACs and partly pay for investments; **federal funding available only for investments into renewal and expansion** • Funds for renewal of the existing network are established within the multi-annual financing agreement called **Leistungs- und Finanzierungsvereinbarung (LuFV)** between the State and DB InfraGO; major expansions projects are approved and pursued in the **Bundesverkehrswegeplan (BVWP)** • About **EUR 50 billion investment gap in 2016/2017**; increased to around **EUR 90 billion by 2021**; infrastructure is old, prone to failure and over-utilised • State committed itself within **InfraGO project to close investment gap** and to comprehensively renew and enlarge the track infrastructure based on requirement planning derived from target timetable

Source: E.CA Economics based on chapter and sources cited below.

4.2.1 Historical and country background

The history of the German railway starts with the first six kilometres of tracks between Nuremberg and Fürth in 1835. In 1920, German Imperial Railway was established and split into Deutsche Bundesbahn and Deutsche Reichsbahn in 1949. Prior to the German rail reform of 1994, the two German railway companies faced major challenges: The modal share both in passenger and freight transport had been falling, revenues decreasing and deficits accumulating. In 1993, the debt of the two German railway companies reached D-Mark 66 billion (about EUR 34 billion). Personnel costs alone were 50% higher than revenues.[57]

In 1994, with the German rail reform, Deutsche Bundesbahn and Deutsche Reichsbahn merged to form Deutsche Bahn AG (DB). The reform had two major goals: to strengthen passenger and freight rail traffic and to relieve the federal budget. The measures to reach these objectives included the restructuring of Deutsche Bahn, a clear separation of responsibilities between the State and the RUs, the introduction of competition on the tracks and so-called regionalisation (see next chapter). While the reform was successful in introducing competition on the tracks, decreasing federal spending and increasing efficiency and rail traffic post-reform, more recently it led to significant long-term underinvestment in the network infrastructure (see Chapter 4.2.4).

Following the financial rehabilitation and restructuring, Deutsche Bahn started to expand internationally around the year 2000. DB acquired Schenker (2002) and Arriva (2010) during this period. Following the financial crises in 2008/2009 as well as the cancelled stock market launch, Deutsche Bahn re-focused on its core business as well as sustainability. Since 2015 investments into the network infrastructure have been increasing again.

[57] See 25 Jahre Deutsche Bahn AG, available at https://www.deutschebahn.com/resource/blob/6860008/55f4d6392e29e94aca4d2d2095f48e6c/25_J_DB_Broschuere-data.pdf, accessed on 15 November 2023.

Increasing the modal share of rail compared to other modes of transport is back on the political agenda in light of reaching climate targets. The current government has formulated goals regarding the railway sector's output in its coalition agreement: the modal share[58] of rail freight traffic should reach 25% by 2030 while rail passenger traffic should double. To reach these goals, the network infrastructure (DB Netz) and the train stations (DB Station & Service) were combined in one entity "for the common good" and more financial resources will be invested into the network infrastructure. The investment planning will be derived from a target timetable.[59] The State will also take a more active role in governance and steering.

Germany is the most populated country in Europe with 83m inhabitants in 2022. The share of the urban population is around 39%, 41% of the population live in sub-urban areas and towns and 20% live in rural regions. While this split is similar to for example Sweden, Germany is also one of the most densely populated countries in the EU after the Netherlands, Belgium and Luxemburg with a population density of 235 persons/km² compared to 25 persons/km² in Sweden (see Table 13 in Appendix 5 for the data sources). Importantly, Germany has many small and medium-sized towns, in contrast to countries like more centralistic France with Paris as the main hub. This implies that Germany operates a highly dispersed network to connect these cities. One indicator of the special network structure is the number of stations in Germany. In 2018, Germany had almost 7,000 stations compared to 3,000 stations in France and 2,600 stations in the UK, which are the countries with the second and third largest number of stations in Europe (European Commission, 2021).

The German railway network is the largest in Europe with 38,836 kilometres of lines in 2022 (federal network: 33,400 kilometres) out of which 20,182 are single-track (about 52%) and 21,297 km are electrified (about 55%) (See Table 10 in Appendix 5). The German network is also highly utilised with a train density well-above the European average with 79.3 train-km per network-km per day in 2021 out of which 76% are passenger transport (See Table 12 in Appendix 5). Apart from Germany only two countries, Austria and Switzerland, have an above average train density both for passenger and freight services (see Figure 3). The density of train operations is influenced by various factors, including the frequency of services, the level of urbanisation and the length of rail lines. Regarding passenger transport, Germany places significant emphasis on regional and commuter rail services. The high level of urbanization and population density in certain regions, such as the Rhine-Ruhr metropolitan area, contributes to a dense network of commuter and regional train services, however Germany is also providing frequent and widespread train connectivity even in less densely populated regions. As regards freight, Germany is a key hub for freight rail transport in Europe and its freight rail transport contributes significantly to the overall intensity of train operations. Due to Germany's successful decentralised economic model, cargo trains connect the geographically dispersed German *Mittelstand* firms. Germany is also one of the very few countries in the world that runs high speed trains on the same tracks as freight and other passenger trains and that has such a pronounced mix of freight, regional and long-distance high-speed transport. This represents an enormous challenge in terms of capacity allocation and time scheduling for the entire railway system.

While the freight modal share has been relatively constant over time, varying from about 17% pre-reform to a maximum of 20.2% in 2016 and 19% in 2021, the passenger modal share has been increasing from

[60] Data on pre-reform modal shares in 1993 is based on the Federal Ministry for Digital and Transport "Verkehr in Zahlen" 2000, available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

[60] Data on pre-reform modal shares in 1993 is based on the Federal Ministry for Digital and Transport "Verkehr in Zahlen" 2000, available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

6.5% pre-reform to 9.3% in 2019 (See Table 8 in Appendix 3 for the 2021 modal shares).[60] Prior to the reform in 1994, total network length was around 44,600 km.[61] This is a reduction in network length of almost 6,000 km since the foundation of DB AG, while at the same time passenger traffic increased by more than 40% and freight traffic by more than 80% since 1994.[62]

4.2.2 Organisation of the industry

With the German railway reform in 1994, vertical organizational separation (including accounting separation) between infrastructure management and train service operations was implemented to enable competition in train services. The fully state-owned German incumbent Deutsche Bahn AG[63] was established in 1994 and in 1999 the holding structure was implemented. It now combines different subsidiaries under the umbrella of a holding: DB Fernverkehr AG (long-distance passenger transport), DB Regio AG (regional passenger transport) and DB Cargo AG (freight transport), which are railway undertakings, and the infrastructure companies DB InfraGO (railway infrastructure, passenger stations) and DB Energie GmbH.[64] In addition, DB holds 100% of the stakes in DB Schenker, which is active in national and international non-rail logistic solutions. The network infrastructure manager DB InfraGO is responsible for maintenance and renewal of the track infrastructure, for setting track access charges, allocating capacity and determining the network timetable. The holding company DB AG's main role is to provide an overall strategy for all business areas and central functions such as finances and treasury (within the limits of regulatory unbundling provisions, as far as the infrastructure subsidiaries are concerned). With the railway reform in 1994, competition in train service operations was introduced.

DB AG's train services were separated into regional passenger, long-distance passenger and freight transport. Long-distance passenger and freight traffic do not receive federal funds and therefore must be profitable. Both in freight and long-distance passenger traffic, there is competition on the market, as there is unrestricted open access to the entire network. For unprofitable and subsidised regional rail passenger services, a franchising system was introduced with the goal of achieving a decent level of service at as low subsidies as possible. Since 1996, the federal states (Bundesländer) have been responsible for procuring regional passenger train services[65] which are not commercially viable and for financing them within franchise contracts (so-called regionalisation). The regionalisation funds are based on transfers from the federal budget to the federal states (Regionalisierungsmittel) (Link, 2016).[66] The

[60] Data on pre-reform modal shares in 1993 is based on the Federal Ministry for Digital and Transport "Verkehr in Zahlen" 2000, available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

[61] See Allianz Pro Schiene, https://www.allianz-pro-schiene.de/themen/infrastruktur/schienennetz/, accessed on 14 September 2023.

[62] According to transport data published by the Federal Ministry for Digital and Transport, rail freight transport increased from 70.7 billion tonne-km in 1994 to 129 tonne-km in 2019 (the last pre-Covid year), which is an increase of 82%. Rail passenger transport grew from 65.2 billion passenger-km in 1994 to 102 billion passenger-km in 2019, an increase of 56%. For further information see „Verkehr in Zahlen" 2022/2023 and earlier years available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

[63] DB (2022). Integrierter Bericht 2022, p.37.

[64] See https://ir.deutschebahn.com/de/berichte/tochtergesellschaften/, accessed on 14 September 2023.

[65] Regional passenger train services are legally defined as below 50km distance or less than 60 minutes travel time. Though there are 16 federal states, there are 27 regional authorities responsible for procuring regional passenger transport. Some federal states have up to five different responsible regional authorities.

[66] One problem of the regionalisation approach is the strict distinction between commercial long-distance and subsidised regional services. InterRegio services were neither regional nor long-distance passenger traffic and did not receive any funding via

legal framework allows open tenders and direct awards under very restricted conditions, with a growing share of train-km awarded by competitive tendering. Around 14% of train kilometres in regional services were still directly awarded in 2021 (Bundesnetzagentur, 2022). Thus, a monopoly is granted for these regional passenger transport services (competition for the market) and contract durations typically vary between eight and a maximum of fifteen years allowed by EU regulation.

Typically, the franchise contracts oblige RUs to provide rolling stock with minimum requirements on age, type and furnishing of trains. The majority of tenders even requires the use of new rolling stock due to technical and/or quality considerations. As the contract duration is usually shorter than the lifetime and amortisation of rolling stock over 20 to 30 years, financing solutions (such as buyback guarantees) are often provided to lower RUs' risk. Lower Saxony and Baden-Wuerttemberg even have their own fleet of rolling stock that is made available to RUs.[67] The misalignment between short-term planning and long-term investment in rolling stock is more evident for freight and long-distance passenger transport. Since there is open access both in freight and in long-distance passenger transport, but capacity allocation and the scheduling of the timetables is done on a yearly basis,[68] there is an even bigger discrepancy between long-term investment in rolling stock and short-term allocation of routes.

This might be one of the reasons why there is still little competition in commercial long-distance passenger transport services despite open-access competition. According to Bundesnetzagentur (2023) (BNetzA), there were 346 RUs active in the German market in 2021, which in an international comparison is the highest number of competitors active in the market. The majority of these companies are active in freight transport (163) and regional passenger transport (107), while there are 26 competitors to the incumbent DB in commercial long-distance passenger transport, which is still high compared to other countries.[69] Most traffic in long-distance passenger transport is provided by DB Fernverkehr AG, Flixtrain, SNCF and ÖBB (Bundesnetzagentur, 2023, p. 14).

The market share of the incumbent DB has been constantly decreasing since the introduction of competition on the tracks. In 1994, 99% of the passenger-km and 98.8% of tonne-km in 1995 were provided by DB on the German network.[70] In 2021, DB's market share (in terms of train-km) was 45.2% in freight and 65.4% in passenger transport respectively, which is much lower than the incumbent market share in most other European countries (see Table 8 in Appendix 3). Instead, BNetzA (2023) provides market shares based on passenger-km for passenger transport for 2021 distinguishing long-distance and regional services. The market share of DB was 66% in regional passenger transport and 96% in long-distance passenger transport. This highlights that while competition seems to be effective in freight and regional passenger transport, few competitors managed to successfully enter the long-distance passenger transport segment.

Regionalisierungsmittel post railway reform. This has generated the incentive for DB to abolish these services starting in 2000, which implied the discontinuation of many middle-distance services (Centre on Regulation in Europe, 2016c).

[67] See for example https://www.schienennahverkehr.de/spnv-erklart-wer-finanziert-und-wartet-spnv-fahrzeuge/, accessed on 18 December 2023.

[68] There are exceptions: Under certain conditions, capacity may be reserved under 5-year framework agreements. However, these agreements do not allow for reserving specific train paths, only path contingents within defined bandwidths.

[69] Some rail transport companies are not directly active in passenger or freight transport but for example in supplying construction sights, conducting test runs or are sole shunting service providers.

[70] „Verkehr in Zahlen“ 2004/2005 available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

4.2.3 Regulation

The legal framework underlying the regulation of the German railway sector, in particular the access to the network, is the Eisenbahnregulierungsgesetz (ERegG).[71]

Access to the network infrastructure and service facilities must be granted to RUs in an unbiased, non-discriminatory and transparent way. During the capacity allocation process, all RUs notify their capacity requirements to the infrastructure company DB InfraGO (tracks and service facilities). Given the current status and capacity of the network infrastructure, capacity shortages and hence conflicting capacity demands, happen regularly. In case of conflicting demands, the infrastructure manager applies the legally defined capacity allocation rules which are published in his network statement.[72] Every rejected demand must be notified to and reviewed by the BNetzA and RUs can also complain to the BNetzA about the capacity allocation. According to BNetzA, 87 train path applications were denied for the timetable 2022 and 115 for the timetable 2023. While BNetzA considered none of the rejections for the timetable 2022 to be problematic, one rejection for the timetable 2023 was denied due to an accounting mistake (BNetzA, 2023). Thus, there does not seem to be discrimination between DB-internal and external RUs regarding access to the network infrastructure. However, as already highlighted, capacity allocation and the scheduling of the timetables is done on a yearly basis, while RUs must take long-term investments in rolling-stock. The investment risk is particularly high for entrant RUs who cannot easily employ acquired rolling stock elsewhere.

Track access charges should cover the total costs of running and maintaining the network infrastructure plus a rate of return (weighted average cost of capital, WACC). The exact charging principles and methods but also the yearly actual track access charges for each segment need to be authorised by the BNetzA. The average track access charges in Germany were EUR 4.32 per train-km for passenger services and EUR 0.19 per train-km for freight services in 2021 (see Table 12 in Appendix 5). While track access charges for passenger services are among the higher ones in Europe, freight track access charges are the second lowest in Europe (only Estonia had lower average freight access charges in 2021).

There are two main supervisory bodies in Germany. The Bundesnetzagentur (BNetzA) is responsible for competition regulation. It must especially ensure the non-discriminatory access to the railway infrastructure by examining the network statement, initiating investigations into the capacity allocation procedures both following complaints but also pro-actively and since 2016 verifying and permitting the track access charges. It is also responsible for monitoring the compliance with the unbundling regulations set out in the ERegG. Decisions taken by BNetzA are immediately effective. The federal railway office (Eisenbahnbundesamt, EBA) is mainly responsible for the technical supervision and approval of constructional measures, the issuing and revocation of operating licenses and the approval of federal funds. In particular, it supervises the multi-annual financing agreement (LuVF).

[71] Eisenbahnregulierungsgesetz vom 29. August 2016 (BGBl. I S. 2082), das zuletzt durch Artikel 2 des Gesetzes vom 9. Juni 2021 (BGBl. I S. 1737) geändert worden ist. Available at: https://www.gesetze-im-internet.de/eregg/.

[72] See for example Nutzungsbedingungen Netz der DB Netz AG (NBN 2024) available at https://fahrweg.dbnetze.com/fahrweg-de/kunden/Netzzugang-und-Regulierung/nutzungsbedingungen/NBN/Nutzungsbedingungen-Netz-der-DB-Netz-AG-NBN-2024-10105728#, accessed on 24 November 2023.

4.2.4 Funding of infrastructure and investment

DB InfraGO must maintain and expand the track network. DB InfraGO needs to cover its operating expenditures and maintenance costs from track access charges and partly pay for investments. Federal funding is available only for investments into renewal and expansion (Nash et al, 2013). Since by law the State cannot support maintenance, this leads to the incentive for the infrastructure manager not to maintain the tracks until renewal is necessary and can be financed by the State. Public funding distinguishes between the renewal of existing network infrastructure and new investments and expansion of the network.

Funds for renewal of the existing network are established within the Leistungs- und Finanzierungsvereinbarung (LuFV) between the State and DB infrastructure managers (DB InfraGO, DB Energie) (IMs). The current LuFV III entered into force in January 2020 and covers the period 2020 to 2029. Within the LuFV III, the State grants EUR 63.4 billion of non-refundable lump-sum subsidies in total over the period 2020 to 2029 (i.e. around EUR 6.3 billion per year) for investments into the renewal of the existing infrastructure.[73] The costs of maintenance – at least EUR 22.8 billion - have to be covered by the DB IMs (Monopolkommission, 2023). Instead of evaluating the realisation of single projects, the LuVF contains quality criteria against which the infrastructure companies' quality is evaluated. These include nine quality criteria with explicit quality goals that are monitored by the EBA on a yearly basis, for example the theoretical increased travel time due to necessary speed reductions on deficient network sections or the number of infrastructure defects. Quality goals are formulated as percentage reductions from the levels of the previous year.[74] Even though the age of the infrastructure is included as a quality criterion, there are no explicit quality goals that can be sanctioned related to this criterion. Measures such as delays caused by infrastructure are not part of the quality criteria. If the defined quality goals are not met by the DB IMs, the State can reclaim (part of) its funds. The Monopolkommission criticises that the quality criteria of the LuVF insufficiently describe the quality of the network infrastructure and do not provide incentives to cost-efficiently employ the funds provided (Monopolkommission, 2023).

New investments and expansion of the network are largely financed by the State. Major expansions projects are approved and pursued in the Bundesverkehrswegeplan (BVWP), which is the framework program of the Federal Government for the planning of the transport infrastructure and contains planned investments into roads, railway network and waterways to handle the traffic forecast.[75] The current BVWP is the BVWP 2030 with a total volume of around EUR 270 billion and over 1,000 projects. Out of the overall volume, about 42% (around EUR 112 billion) are railway projects. New investment and expansion projects in the railway sector account for on average EUR 1.8 billion per year over the period 2016 to 2030. The BVWP is updated every 5 to 10 years. The initial stage of the BVWP involves the proposal of projects, in which DB InfraGO participates and provides input based on their network concept and traffic forecast. Proposed projects are evaluated via a cost-benefit analysis conducted by an external expert.

[73] The largest part with around EUR 51.4 billion comes from the federal budget. The rest is financed via dividends of DG AG to the State and funds from the "Bedarfsinvestitionen des Bundes". DB must provide own funds of at least EUR 1.375 billion. See also §2b of the Leistungs- und Finanzierungsvereinbarung III zwischen der Bundesrepublik Deutschland und der DB Netz AG, der DB Station und Service AG, der DB Energie GmbH sowie der Deutschen Bahn AG.

[74] For the detailed explanations on each quality criterium and how it is calculated, see Leistungs- und Finanzierungsvereinbarung III zwischen der Bundesrepublik Deutschland und der DB Netz AG, der DB Station und Service AG, der DB Energie GmbH sowie der Deutschen Bahn AG, Anlagen 13.2.1 to 13.6.

[75] Bundesministerium für Verkehr und digitale Infrastruktur, Bundesverkehrswegeplan 2030, available at: https://bmdv.bund.de/SharedDocs/DE/Publikationen/G/bundesverkehrswegeplan-2030-gesamtplan.pdf?__blob=publicationFile.

According to the guidelines to the cost-benefit analysis[76] published by the Federal Ministry of Digital and Transport, projects entering the BVWP 2030 are evaluated based on the effect on the specific route concerned. Indirect effects on other routes or the entire network in terms of for example capacity and utilization are not considered,[77] but projects can now also be proposed in bundles.[78] A second problem of the current cost-benefit analysis underlying the project evaluation for the BVWP is that resilience is not part of the evaluation criteria. The current criteria assume a network without construction work or disruptions. Measures increasing the resilience of the network by for example building additional sidings are then frequently evaluated negatively based on the current criteria entering the cost-benefit analysis. Not all projects that are evaluated positively are incorporated into the BVWP. The concrete order in which projects included in the BVWP are realised is determined by the Federal Ministry of Digital and Transport after a joint analysis with DB. Which of the projects of the BVWP get realised depends on the federal budget allocated to transport, which is set on a yearly basis.

The BVWP only concerns projects that are necessary to meet the needs for rail freight and long-distance passenger transport. New investments and expansion projects in regional passenger transport can get funding via an annually updated programme of the State and the federal states based on the Gemeindeverkehrsfinanzierungsgesetz (GVFG). Projects can be proposed by the federal states and the State finances up to 90% of the fundable costs, the remaining project funding must be agreed upon between the federal state and the concerned RU in separate contracts. Additionally, investment projects outside of the BVWP can be realised based on special investment programmes financed by the State.

As previously mentioned, one of the goals of the railway reform in 1994 was to relieve the federal budget. As a result, the focus was on cost-cutting and efficiency increasing measures. As explained in Chapter 4.2.1, part of the network was dismantled reducing total track length. The reform also led to serious underinvestment in the network infrastructure while at the same time utilization of the network continuously increased. Annual federal funding of the rail industry was significantly cut from EUR 15,995 million to EUR 9,350 million between 1994 and 2005, reaching its minimum in 2005.[79] An expert assessment for the Federal Ministry of Digital and Transport evaluated the investment gap at about EUR 50 billion for DB Netz and DB Station & Service jointly in 2016/2017.[80] According to DB, this investment gap has increased to around EUR 90 billion by 2021.[81] Consequently, the infrastructure is old, prone to failure and overutilised. Furthermore, the strain is unevenly distributed across the network: the utilisation rate on the 3,500 km of highly utilised network is around 125%.[82] With the focus on cost cutting, resilience and the utilization of hubs has not been sufficiently taken into account in network planning

79 „Verkehr in Zahlen“ 2006/2007, available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

79 „Verkehr in Zahlen“ 2006/2007, available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

79 „Verkehr in Zahlen“ 2006/2007, available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

79 „Verkehr in Zahlen“ 2006/2007, available at https://bmdv.bund.de/SharedDocs/DE/Artikel/G/verkehr-in-zahlen-archiv.html.

80 Dornier Consulting and Mazars (2019), LUFV III 2020 – 2024, Gutachten im Auftrag des Bundesministeriums für Verkehr und Digitale Infrastruktur, available at https://www.eba.bund.de/SharedDocs/Downloads/DE/Finanzierung/LuFV/LuFV_III_Bedarfsermittlung.pdf?__blob=publicationFile&v=4.

81 See for example “Gemeinwohlorientierte Infrastruktur – Weichenstellung für das Schienennetz der Zukunft” available at https://fahrweg.dbnetze.com/resource/blob/12286636/6f78fbcdf53c15ef0263e382e2c6e447/Download-Faktenblatt-Infrago-data.pdf.

82 See for example “Von überlasteter Infrastruktur zum Hochleistungsnetz: DB will Schiene fit für Wachstum und Verkehrsverlagerung machen” of 30 Mai 2022, available at https://www.deutschebahn.com/de/presse/pressestart_zentrales_uebersicht/Von-ueberlasteter-Infrastruktur-zum-Hochleistungsnetz-DB-will-Schiene-fit-fuer-Wachstum-und-Verkehrsverlagerung-machen-7712858, accessed on 13 November 2023. A utilisation rate of 100% is defined as the maximum utilization at which capacity buffers are fully considered. At a utilization rate above 100%, for example delays of one train can impact subsequent trains.

and investment. Given the unsatisfactory state of the network infrastructure and the resulting performance challenges (see next chapter), the State committed itself within the InfraGO project to provide additional funds to close the investment gap and to comprehensively renew and enlarge the track infrastructure based on requirement planning derived from a target timetable. The investment programme includes not only the renewal and enlargement of the highly utilised part of the network, but also the improvement of the overall state of the network, a number of smaller measures to increase the robustness and capacity of the network, measures relating to the digitisation of control systems, the modernisation of train stations and the expansion of the network.[83]

4.2.5 Performance

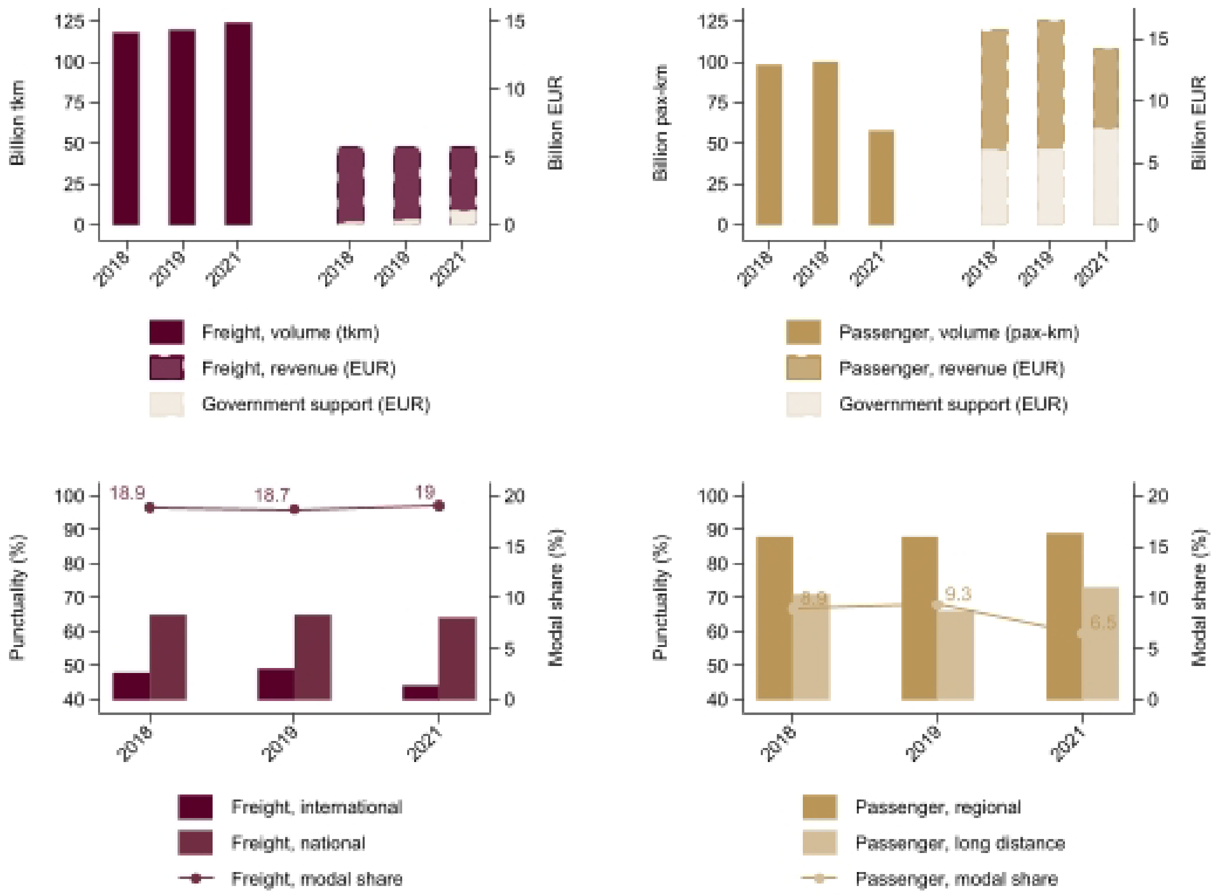
To assess the performance of the German railway system, we employ Key Performance Indicators (KPIs), providing insights into the rail sector's growth, financial situation, inter-modal competition and quality of services over time.

Figure 11 below shows freight and passenger transport volumes together with each segment's income and government support (top panels) during 2018-2021 in Germany. The year 2020 is left out as measures are affected by the COVID-19 pandemic. Additionally, the Figure provides information on the evolution of freight and passenger's modal share and trains' punctuality[84] (bottom panels).

[83] See for example "Gemeinwohlorientierte Infrastruktur – Weichenstellung für das Schienennetz der Zukunft" available at https://fahrweg.dbnetze.com/resource/blob/12286636/6f78fbcdf53c15ef0263e382e2c6e447/Download-Faktenblatt-Infrago-data.pdf.

[84] Regional and long-distance passenger trains are classified as punctual if they have a delay of 5 or less minutes. In the case of international and national freight trains, the maximum delay to be on time is of 15 minutes. The standardised definition was introduced with the EU Regulation 2015/110, however, its implementation into national law varies from country to country. Therefore, comparison across time and countries can be problematic and caution is advised.

Figure 11: Key Performance Indicators in Germany



Source: E.CA Economics based on data from Bundesnetzagentur, Eurostat and Rail Market Monitoring (RMMs). Notes: Only subsidies to regional trains were considered when computing government spending of passenger train operations.

Since the German railway reform in 1994, both freight and passenger volumes have been steadily increasing. In 2021, total rail freight volume reached an all-time high at around 125 billion tonne-km. Passenger traffic volume was around 100 billion passenger-km in 2019, but severely affected by the COVID-19 pandemic in the following years. Germany has by far the highest freight volume among the European countries and the third largest passenger volume behind France and the UK (see Figure 10).

In terms of income, Figure 11 above (upper panel) provides freight and passenger revenues accounting for government support. While government support is low in for-profit rail freight transport, government support is substantial in rail passenger transport. As explained previously long-distance passenger train services are not subsidised while regional train services are procured by the federal states and funded via regionalisation funds. The higher level of government support in 2021 reflects the low ticket revenues in short-term passenger transport during the COVID-19 pandemic.

The lower panel of Figure 11 shows the modal share of freight and passenger rail transport as percentages of total inland transport. The freight modal share has been fairly stable over the past years at around 19%. The current government wants to increase the freight modal share to 25% by 2030. On the contrary, the passenger modal share was around 9% in 2019, but dropped heavily in 2021 in the aftermath of the COVID-19 pandemic.

The increasing utilization of the network given stagnating capacity lead to decreasing quality and dissatisfaction of both RUs and end-customers (Bundesnetzagentur, 2023). Punctuality, defined as the percentage of trains which are at most 5 minutes late, is one indicator of quality of service reflecting the high traffic density on a network infrastructure that requires substantial investment. Punctuality levels have been decreasing in recent years both in rail passenger and freight transport. While in 2021 around 65% of national freight trains were on time, only 44% of international freight trains have been punctual. In passenger transport, punctuality was measured at 89% for regional passenger trains and 73% in long-distance passenger transport. These quality-of-service levels are particularly low in freight transport compared to Sweden, the UK and Austria and punctuality levels in passenger transport are similar to UK punctuality levels (see next chapters). Furthermore, since spring 2022, punctuality levels have further deteriorated to 64% in freight, 66% in long-distance passenger and 81% in regional passenger transport in June 2022 (Bundesnetzagentur, 2023). Note also that these punctuality measures do not include trains that are cancelled altogether. Since substantial maintenance and renewal work on the network is planned for the next years, delays will probably increase even further (Bundesnetzagentur, 2023).

4.3 Sweden

Before analysing the performance of the Swedish railway system, Table 2 below presents an overview of the key aspects characterising the country in terms of history, organisation of the industry, regulation and funding of rail infrastructure.

Table 2: Fact Sheet Sweden

Historical and country background	• Swedish railways were liberalised 35 years ago with the **very first deregulation policy in Europe in 1988**. Today, the Swedish **system** is regarded as **very successful** thanks to the **good balance between private and public involvement** while **competition** is **assured** by a strong vertical separation • The country hosted 10m inhabitants in 2022; one of the **lowest population densities in Europe (**25 inhabitants per square kilometre in 2021) • **High train density** and network **focused on linking urban centres rather than northern regions**; high track utilisation levels are achieved at the expenses of connectivity in the north • **Passenger modal share of 8%** and **freight modal share** of **29%** in 2021
Organisation of the industry	• **Institutional vertical separation** introduced in 1988**:** Trafikverket as infrastructure manager and Transportstyrelsen as regulator; after the reform of 1988, the incumbent operator (SJ) was divided into SJ (passenger), Green Cargo (freight), Jernhunsen (real estate), and EuroMaint and Swemaint (vehicle maintenance) • **Passenger**: **open access** for both **regional** and **long-distance transport** since 2011, but **competitive tendering for subsidised** regional and long-distance **services** (since 1990 and 1993, respectively); f**reight**: **open access** since 1996 • **Market shares of 56% in passenger transport (SJ) and 48% in freight transport (Green Cargo)** in 2021. Sweden is one of the few countries, together with Germany, where the incumbent faces full competition in all three market segments (regional, long-distance and freight)
Regulation	• **TACs** are **set at marginal costs and** are **low by international standards in all market segments**; they display **little differentiation** based on vehicle characteristics **and have consequently poor incentivising properties**

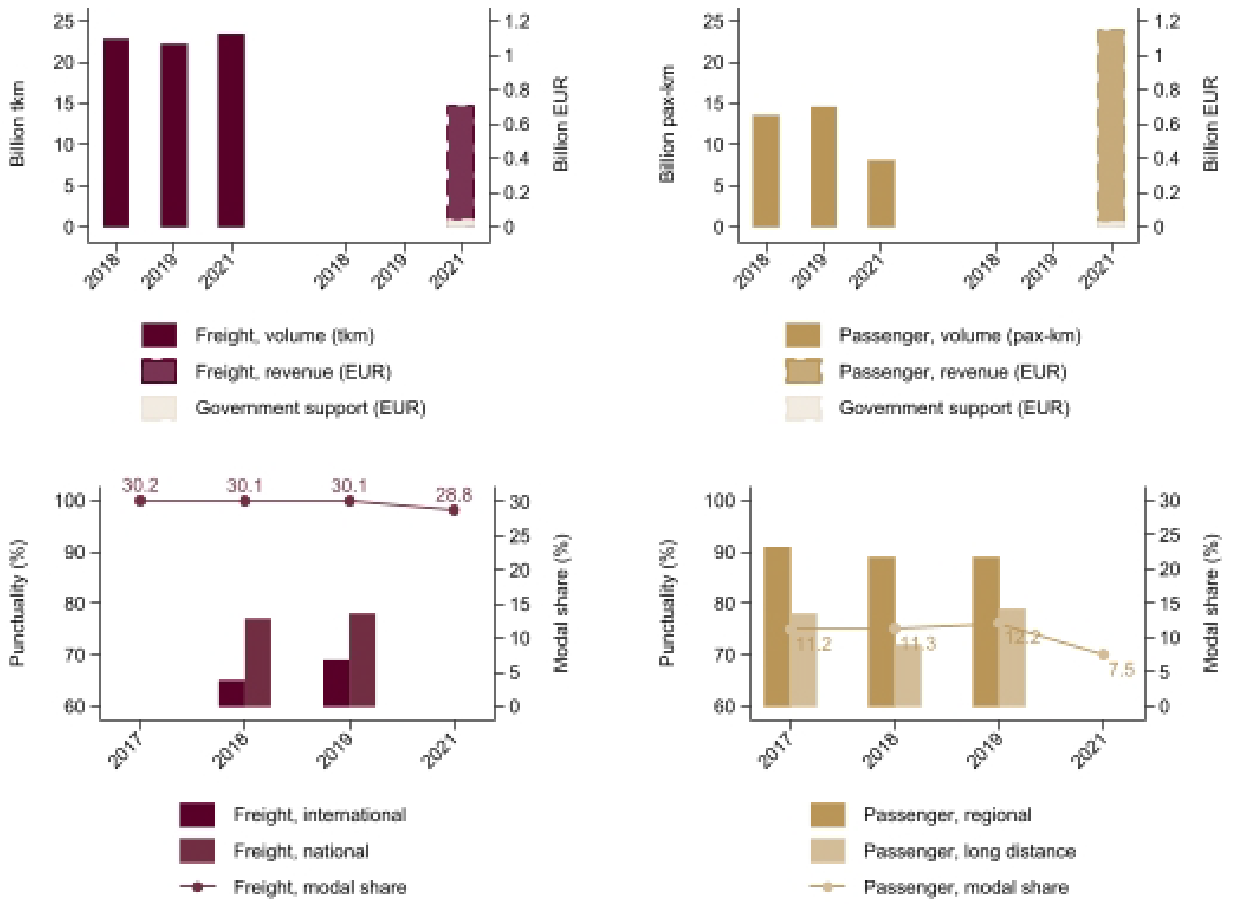
	● This can be explained by the desire to keep rail competitive against road transport but also to compensate for Sweden's geographical disadvantage. In recent year there has been a change in this policy and TACs will be doubled ● The **regulator** Transportstyrelsen is **mainly involved with safety rather than efficiency**
Funding of infrastructure and investment	● **The planning** of transport infrastructure projects is carried out **within 11-year national plans with the goal of strengthening interactions among different modes of transport** ● Government lays down directives while the infrastructure manager prepares the plans; once approved, the plans are based on yearly funding but most of investments are financed by the agencies' own budget (with the exceptions of major transport projects) ● **Rail infrastructure** is **heavily sustained by the national government via subsidies** in view of the environmental and safety benefits that increased volumes and traffic would realise

Source: E.CA Economics based on Alexandersson and Rigas (2013), Andersson et al. (2018), Kurosaki and Alexandersson (2018), Nash et al. (2013), Olsson et al. (2019) and The Williams Rail Review (2018).

Performance

Figure 12 below presents freight and passenger's transport volumes together with each segment's income and government support (top panels) during 2018-2021 in Sweden. Additionally, the Figure provides information on the evolution of freight and passenger's modal share and trains' punctuality (bottom panels). The year 2020 is left out, since measures are affected by the COVID-19 pandemic.

Figure 12: Key Performance Indicators in Sweden



Source: E.CA Economics based on data from Eurostat, IRG and Rail Market Monitoring (RMMs). Notes: Punctuality of international and national freight trains in 2017 and 2021 is not available. Values on government support only include subsidies for track access charges and are, therefore, a lower bound of the state's actual support to both freight and passenger operations.

In 1996, Sweden introduced competition in the market for freight operations but unlike passenger transport, Regional Public Transport Authorities (CPTAs) are not involved in the organisation and management of such operations. Based Figure 12 (top-left panel), in recent years the country has experienced stable freight volumes of around 22 billion tonne-km, with only minor yearly fluctuations.

For the passenger market, subsidised, regional services are provided by means of competitive tendering since 1990 while call for tenders for subsidised inter-regional services begun in 1993. In the spring of 2009, further legislation set out to gradually dismantle the remaining SJ monopoly on (profitable) long-distance passenger services reaching its full effect in December 2011. Finally, in 2012 a new law on public transport allowed for open-access competition everywhere in the passenger market, although competitive tendering persists for subsidised services. After the reforms, passenger-kms doubled, especially at the regional level, thereby indicating a positive contribution of the newly instituted regional transport authorities. In recent years and similarly to Austria, passenger transport increased in the country despite a minor reduction in 2021 probably still related to the COVID-19 pandemic. In terms of income, the government's contribution in support of Sweden's rail system has increased over the years, also considering that low track access charges are not able to cover rail infrastructure's full costs.[85] In addition

[85] Please note that Figure 12 above (upper panels) provides only a lower bound of the state's actual support to rail operations in 2021, which is actually substantially higher than what presented in the Figure.

to the government's support to unprofitable inter-regional passenger operations and rail infrastructure, regional transport authorities are largely involved in the funding of unprofitable regional services.

Figure 12 (bottom panels) presents the evolution of freight and passenger modal shares as percentages of total inland transport occurring in Sweden during 2017-2021. Excluding 2021, the freight modal share in the country has been stable over the years and remains the second highest among Austria, Germany and UK. On the contrary and disregarding the impact of COVID-19, the percentage of passenger transport in Sweden appears to be steadily increasing over time.

In terms of quality of services, the punctuality of national freight trains in Sweden seems to be consistently above 77% in 2018 and 2019 while international freight trains improved their reliability by 4%. The performance of regional passenger trains is stable, with around 90% of trains being at maximum five minutes late. Long-distance passenger operations are less reliable, with an average punctuality of 76% during 2017-2019.

4.4 United Kingdom

Before analysing the performance of UK's railway system[86], Table 3 below presents an overview of the key aspects characterising the country in terms of history, organisation of the industry, regulation and funding of rail infrastructure.

Table 3: Fact Sheet United Kingdom

Historical and country background	• Often regarded as the birthplace of the modern railway system • **One of the first European countries to liberalise its railway market. Dissatisfaction with the cost and performance** of the rail system resulted in calls for a review of the industry and the proposal to move towards a more integrated rail system • **Third most populated country in Europe with 67m inhabitants in 2020**; 60% of total population resides in urban areas such as London, Birmingham, Manchester and Glasgow • **Train density is above the European average (83 train-km per network-km per day)** and is mainly associated with passenger transport (93%) • **Passenger and freight modal share were both 9%** in 2019 but while freight modal share has been declining over time, passenger modal share steadily increased
Organisation of the industry	• **Institutional vertical separation** introduced in 1994 and very first country in Europe to completely privatise its rail system by 1997: after Railtrack's insolvency in 2001, Network Rail became the new infrastructure manager while regulation is in the hands of The Office of Rail and Road (ORR). Finally, the Department for Transport (DfT) is responsible for franchising • After the vertical separation, the incumbent for passenger transport (British Rail) was divided into more than 100 companies and completely privatised; the existing freight operator was dismembered and sold to EWS (DB Schenker) and Freightliner • **Passenger: competitive tendering of domestic passenger services** via net cost contracts since 1997. **Open access operations** are allowed **only if a "not primarily abstractive" test is passed; freight: open access** since 1994

[86] The UK comprises Great Britain and Northern Ireland. The present report details and analyses the position of Great Britain only, as the rail system of Northern Ireland is negligible.

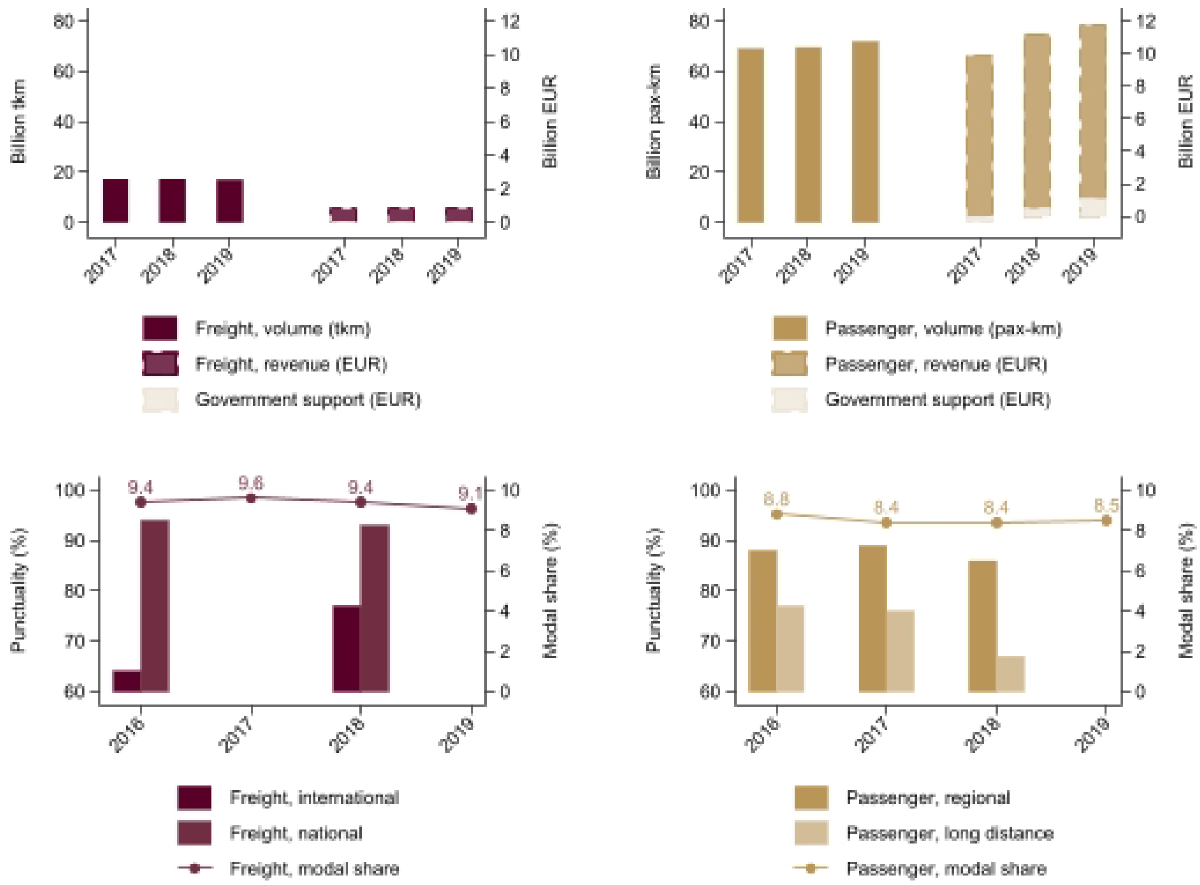
	● **Market shares** of the dominant operator are the lowest among Austria, Germany and Sweden, with **1% in passenger transport** and **7% in freight transport**
Regulation	● The **ORR regulates** Network Rail based on **5-year control periods** in which **quality targets** and **funding** are **decided** ● **ORR uses benchmarking tools (**international/internal econometric models and engineering-based studies) **to set efficiency targets** and revises Network Rail's investment plans to achieve them. **Innovation targets are set separately** based on geographical routes ● In addition to control periods, **"Balanced scorecards" impose targets on Network Rail** to **meet** the **needs of customers.** In case these targets are not met, the ORR may **impose penalties** ● **TACs** are sophisticated and **designed to influence operators' behaviour** (e.g., **performance regime**) in addition to the payment of a fixed charge
Funding of infrastructure and investment	● **Funding** of infrastructure is **determined within 5-year control periods** during which Network Rail plans its activity, including plans for investment; infrastructure enhancements are largely determined by the DfT's funding decisions that are taken outside of the periodic review ● **Network Rail has three main sources of income that are used** to finance its activities, pursue efficiency goals and **fund rail infrastructure**: **TACs**, **government funding** and **other** sources (31%, 43%, and 24% in 2018/2019) ● **Government funding** levels and **investment** in rail infrastructure per capita **grew significantly over time.** Support is also given to franchised passenger services and open-access freight services via subsidies

Source: E.CA Economics based on Centre on Regulation in Europe (2016a), Nash and Smith (2021), Nash and Smith (2020), Nash et al. (2013), and Smith and Nash (2023).

Performance

Figure 13 below presents freight and passenger's transport volumes together with each segment's income and government support (top panels) during 2017-2019 in the UK. Additionally, the Figure provides information on the evolution of freight and passenger's modal share and trains' punctuality (bottom panels). The year 2020 is left out, since measures are affected by the COVID-19 pandemic.

Figure 13: Key Performance Indicators in UK



Source: E.CA Economics based on data from Eurostat, the Office of Rail and Road (ORR) and Rail Market Monitoring (RMMs). Notes: Values referring to each segment's income and level of government support have been converted into Euros using Eurostat's annual exchange rate in 2017, 2018 and 2019. Additionally, income and government support in the UK are recorded from April to March of the following year but have been assigned to the year for which most of the income/government support refers to (e.g. April 2017-March 2018 is assigned to 2017). Punctuality of international and national freight trains in 2017 is not available.

In 1994, UK's freight sector was privatised with complete open-access competition. Since then, freight operations have largely taken place on the same network as passenger services[87], however, unlike passenger transport, freight transport is almost entirely privatised. Rail freight operations in the UK run in response to demand from their commercial customers – if there is no demand, no service will be run – and, as it can be seen in Figure 13 (top-left panel), have a restricted scope. Additionally, the government has a limited role in rail freight aside from setting the safety and regulatory environment. In terms of support, only small subsidies through the Mode Shift Revenue Support Intermodal grant are provided,[88] amounting to less than 1% of total government funding for rail.[89]

On the contrary, since 1997 most passenger operations have been franchised and only limited open-access competition has been allowed. After the reforms, UK has experienced a significant growth in passenger transport and, albeit its non-exclusivity, the introduction of franchising seems to have been an important contributing factor (Centre of European Regulation, 2016a). Between 2017-2019, as it can be seen in

[87] More specifically, as of March 2023 only 8% (1,208 km) of the country's total network is open exclusively for freight traffic.

[88] Such limited subsidies have the goal of encouraging the movement of bulk and intermodal freight by rail (and water) on routes where road haulage detains a financial advantage.

[89] The subsidies amounted to 16, 15, and 14 million Euros in 2017, 2018, and 2019, respectively.

Figure 13 (top-right panel), passenger-kms have been growing in the country and are the second highest among Austria, Germany and Sweden. As shown in Figure 13 (top-right panel), net government support[90] to franchised operators has also been increasing over time, as most franchises were no longer profitable as they once had been,[91] switching from 374 million Euros in 2017 to circa 1.1 billion Euros in 2019.

In terms of inter-modal competition, Figure 13 (bottom panels) presents the evolution of rail's modal share of inland freight and passenger transport from 2016 to 2019. As it can be seen, both rail modal shares have been largely constant over time,[92] except for small yearly fluctuations and are the lowest among Austria, Germany and Sweden. Punctuality, on the other hand, has seen substantial improvements for international freight trains, which switched from 64% of punctual trains in 2016 to 77% in 2018. On the contrary, punctuality for long-distance passenger trains seems to have deteriorated over the years, with a 10% reduction compared to 2016.

In the UK, the infrastructure was separated from rail operations and regulated by an independent regulator with strong powers and resources; the entire rail sector was privatised; and competition was introduced for both freight and passenger services in the form of competition in the market and competition for the market. As a result, there is still considerable dissatisfaction with the performance of the industry for a number of reasons.

First, much of the dissatisfaction is linked to the fact that, far from reducing costs, the post-reform period has seen significant cost increases, particularly in infrastructure but also in operations. McNulty (2011) attributes these cost increases largely to misaligned incentives between the infrastructure manager and train operators. Such misalignments were not fully addressed by contracts (TACs or performance regimes) and McNulty strongly advocated for alliances between the two sides, involving not just the merging of management teams but the full sharing of cost and revenue risk. Another source of dissatisfaction was the financial failure of several franchises. Whereas the problem with earlier franchises had been over-optimistic forecasts of the scope for cost reductions, more recently the problem has been over-optimistic forecasts of future revenues. Following the loss of traffic due to the COVID-19 pandemic, all franchises became unprofitable and the government was forced to take emergency measures. Thirdly, the country experienced dissatisfaction with the complicated nature of its pricing structure, which was often subject to anomalies and caused confusion. Finally, there is dissatisfaction with the way the timetabling process works, which does not produce attractive or reliable timetables in terms of train spacing and availability of connections. In addition, Network Rail was criticised for over-selling the number of paths in relation to what could be run reliably and for finalising timetables with too little time to fully check what was feasible (Smith and Nash, 2023).

These findings eventually led to calls for a review of the industry (the Williams Review) which in turn proposed a move to a more integrated railway in the Williams-Shapps Plan for Rail (2021).

[90] Net government funding accounts for funding given to franchised operators and payments made back to the government by franchised operators as per their contract agreements.

[91] In recent years, operator expenditure has increased at a faster rate compared to operator income, as cost inflation continued but passenger numbers fell below the initial expectations of many operators when they bid for the franchise. As a result, operators' profitability and government's costs have been affected.

[92] Average values of 9.4% and 8.5% for freight and passenger rail transport, respectively, during 2016-2019.

4.5 Austria

Before analysing the performance of Austria's railway system, Table 4 below presents an overview of the key aspects characterising the country in terms of history, organisation of the industry, regulation and funding of rail infrastructure.

Table 4: Fact Sheet Austria

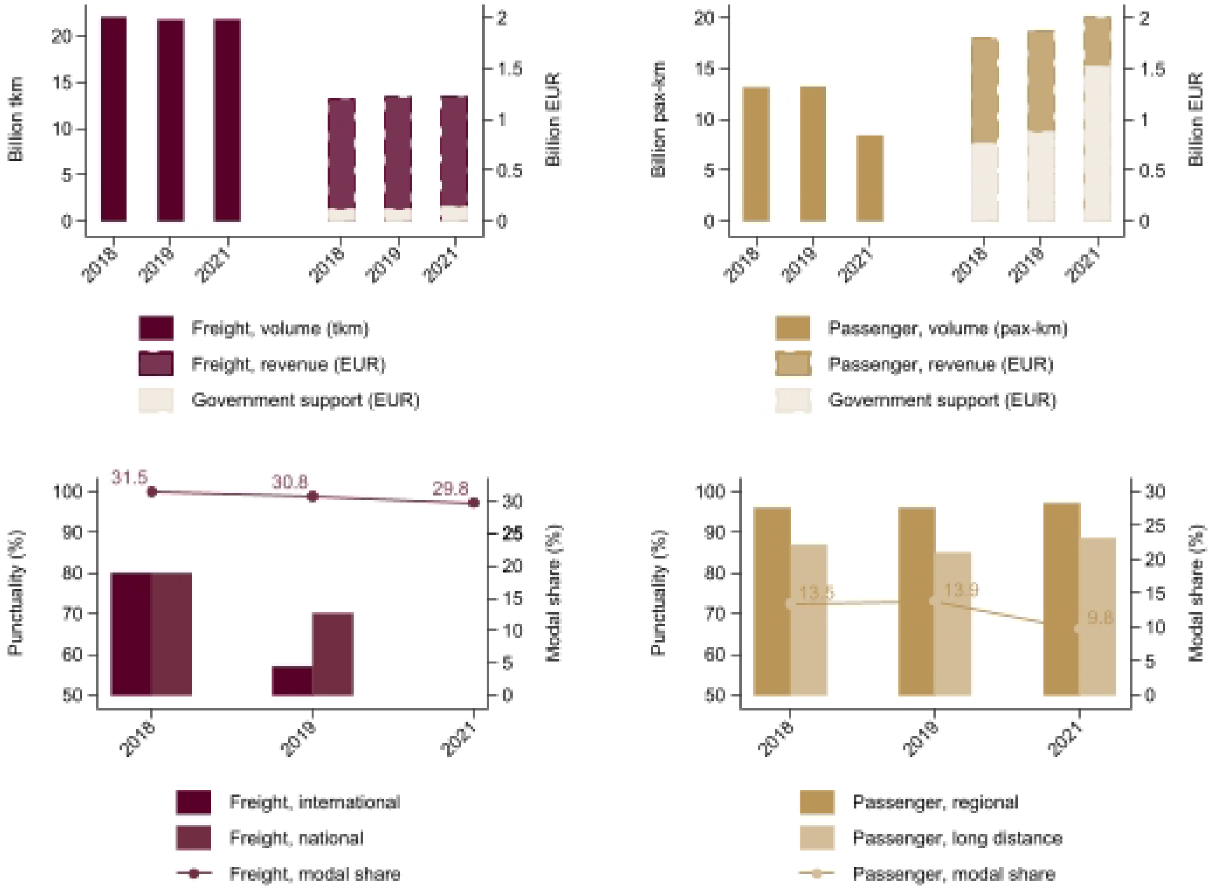
Historical and country background	• Austria's Federal Railways are amongst **the most successful in Europe** • **Lowest populated country among Germany, Sweden, and UK (9m inhabitants) in 2022**; most densely populated areas are urban areas in the Eastern part of the country (e.g., Wien) while the Western side is characterised by the Alpine regions • **Train density in 2022 was the highest among Germany, Sweden, and the UK** (85 train-km per network-km per day) with **average passenger and freight modal shares above 30% and 10%**, respectively, between 2018 and 2021
Organisation of the industry	• **Organisational vertical separation** with holding structure since 1992: ÖBB-Infrastruktur AG as the infrastructure manager and Schienen-Control as the regulator; RUs: ÖBB-Personenverkehr AG (passenger) and Rail Cargo Österreich AG (freight) • **Passenger: open access in long-distance transport** (concretely, since 2011 with the entry of Westbahn) **and cross-country transport** (concretely, since 2017 with entry of Regiojet) while **direct award of PSO contracts** takes place for **regional** transport; **freight: open access** since 1998, concretely since 2001 • **In 2021 the market shares of ÖBB were 87% and 68% in passenger and freight transport**, respectively; highest among Germany, Sweden, and UK
Regulation	• **ÖBB-Infrastruktur's costs do not have to be entirely financed with TACs (differently from Germany);** the Federal **Government provides** an **operating cost subsidy** reducing the residual cost amount to be covered by the market surcharges. The operating subsidy is **governed by a 6-year subsidy contract between ÖBB-Infrastruktur and the government** and is conditional on TACs not being able to cover the Schienen-Control's expenses • **TACs** are composed of (i) **costs related to train-operations directly caused by infrastructure users** and (ii) **segment-specific market surcharges**. Differently from the UK, Austria and Sweden calculate TACs based on billion train-km
Funding of infrastructure and investment	• **ÖBB-Infrastruktur and the government engage in two 6-year contracts (revised annually) based on the Framework Plan**; the Framework Plan is a **presentation of projects** and **investments**, including **maintenance** expenses, that are planned **for the next 6 years**. The Plan is prepared by ÖBB-Infrastruktur and BMK and approved by the government • The **first contract** relates to **subsidies** in support of rail operations while the **second contract** governs subsidies for **maintenance**, **planning**, and **construction** of rail infrastructure • **Maintenance and replacement projects are funded via subsidies**, **new construction and expansion projects** are funded by raising funds on the **capital market** via the Austrian Federal Financing Agency (ÖBFA) since 2016. For **repayment**, the government grants ÖBB-Infrastruktur an **annual subsidy** based on its net investment volume which is, however, **paid over 30-50 years** • Long-term rail planning also includes a **Target Network Plan**, which encompasses network investments and expansions for the next 15-20 years.

Source: E.CA Economics based on ÖBB-Holding AG (2022) and Schienen-Control (2022).

Performance

Figure 14 below presents freight and passenger's transport volumes together with each segment's income and government support (top panels) during 2018-2021 in Austria. Additionally, the Figure provides information on the evolution of freight and passenger's modal share and trains' punctuality (bottom panels). The year 2020 is left out, since measures are affected by the COVID-19 pandemic.

Figure 14: Key Performance Indicators in Austria



Source: E.CA Economics based on data from Eurostat, Schienen-Control and Rail Market Monitoring (RMMs). Notes: Punctuality of international and national freight trains in 2021 is not available.

After the reforms, rail freight in Austria became fully open access and today is characterised by lively competition. As Figure 14 (top-left panel) shows, freight traffic is responsible for the largest share of total gross tonne-kms in the network (consistently above 20 billion tonne-kms during 2018-2021) and, despite the strong growth of the passenger segment, this balance of power remained the same in the last few years (Schienen-Control, 2022). To achieve a high share of rail freight traffic as desired by the Austrian transport policy, the Federal Government provides active financial support to various forms of rail freight transport[93] which cannot be offered at competitive prices without a sufficient degree of public support. Based on Figure 14 (top-left panel), in the last years this amount of aid has been gradually increasing over time, switching from 111 million euros in 2018 to 140 million euros in 2021. Approximately half of these subsidies are destined to single wagon freight operations (Schienen-Control report, 2022).

[93] Namely, Single Wagon Transport, national and international Unaccompanied Combined Transport, and national and international Rolling Road (RoLa).

Passenger traffic in Austria presents some open-access competition on selected routes, especially for long-distance and cross-country operations, but is mostly governed by the direct award of public service contracts. In the country, passenger traffic is considered to be the strongest market segment (Schienen-Control, 2022). Nonetheless, (top-right panel) above indicates a stagnated growth of the segment at around 13 billion passenger-kms, which further reduced to circa 8,5 billion following the COVID-19 pandemic. Public financial support has been increasing over time, also including the provision of emergency measures and contracts in response to the pandemic. Additionally, the Austrian Federal Government actively supports rail operations and the investment in rail infrastructure.

Figure 14 (bottom panels) also presents the evolution of rail's modal share of inland freight and passenger transport from 2018 to 2021. Despite both modal shares being slowly declining over time, the percentages of rail freight and passenger transport in the country are the highest among Germany, Sweden and UK. In terms of quality, passenger rail services appear to be extremely reliable, with a share of punctual trains consistently above 90% and 95% for long-distance and regional trains, respectively. In 2019, punctuality of freight trains reduced by 23% for international trains and by 10% for national trains compared to the year before.

4.6 Conclusions

Compared to Germany, rail systems in Sweden and the UK are characterised by a different organisational structure, regulatory frameworks and outcomes in terms of competition and performance. In Sweden, institutional vertical separation and government subsidies in support of unprofitable transport services contributed to the achievement of considerable gains in labour productivity and improvements in the modal share of rail. To the contrary, in the UK, the separation of infrastructure from train operations together with privatisation, the introduction of competition in the market and the establishment of a regulator with strong powers failed to control for costs and led to dissatisfaction over the performance of the rail industry. Similar to Germany, Austria implemented organisational vertical separation. However, the Austrian railway system achieves a superior quality of rail services and a higher modal share for both passenger and freight transport than Germany.

According to Smith et al. (2018), economic regulation can impact productive efficiency by directly influencing the infrastructure manager's operations or indirectly, via the promotion of competition in the rail system. The direct approach is particularly strong in the UK where the Office of Rail and Road monitors and influences Network Rail's performance by setting efficiency targets and track access charges. This is also the case for Germany, characterised by a price cap regulation of track access charges accounting for expected productivity increases. The indirect approach seems to have been adopted in Sweden, with low track access charges thanks to state subsidies that encourage both competition and rail modal share, given the country's focus on environmental and safety benefits. While regulation in Sweden appears to have been effective in achieving high passenger and freight volumes, the UK has experienced large unit cost increases and deteriorating rather than improving efficiency, despite the regulator's focus on promoting Network Rail's performance as described above. Among the factors contributing to these developments, the Office of Rail and Road underlined the extreme fragmentation in the industry and the consequent difficulties in achieving efficient coordination among the parties (e.g. timetable process). Additionally, infrastructure and operations' related costs increased due to the misalignment of incentives between Network Rail and train operators,[94] which could not be fully solved by UK's track access charges

[94] The incentives of Network Rail and train operators are almost completely different. Train operators have limited incentives to manage rolling stock leasing costs and track access charges costs, while the overall system of incentives appears to have a bias

and performance regimes. Smith et al. (2018) underline that for countries characterised by a high train density such as Austria, Germany and UK, an integrated rail industry minimises cost. On the contrary, the development of rail in Sweden is intrinsically advantaged by the country's geographical characteristics.

Together with the different forms of vertical separation, Austria, Germany, Sweden and the UK gradually introduced competition on the tracks but with different modalities and outcomes. In Sweden, competition mostly takes place in the form of competitive tendering and, despite the rail system being expensive in terms of subsidies, proved being effective in controlling costs. Overall, the success of the Swedish rail system is often attributed to its balance and transparency, which are fundamental also considering the substantial public subsidies that are needed for the system to properly function. More specifically, the public sector is balanced by private sector competition, the use of competitive tendering is balanced by open-access competition and the role of regions is balanced with that of the central government.

On the contrary, competitive tendering is one of the drivers of the dissatisfaction with the rail system in the UK. Despite the UK enjoying lively competition and a low degree of dominance of the incumbent operators, substantial cost increases in both rail infrastructure and franchised passenger services occurred. Typically, the introduction of competitive tendering combined with the introduction of private operation should reduce unit costs of around 20-30% (Smith and Nash, 2023). However, the extreme fragmentation in the country's rail industry and failed franchises which had to be taken over by the government prevented the UK from achieving such reductions. In addition, franchises in the UK are adopted by means of riskier net cost contracts and are larger compared to other European countries.

Differently from Germany, Sweden and UK, Austria hosts the most dominant incumbent operators in both the freight and passenger market. At the same time, the country's quality of services is among the highest in Europe and general satisfaction characterises its rail system. The Austrian rail financing model is one of the most important factors allowing such superior performance. An optimal financing model is crucial for sustaining, expanding and improving the quality and the performance of rail. Rail financing in Austria is characterised by simplicity, a long-term perspective, adequate funding per capita and orientation towards the end-customer. Additionally, part of the Federal Government's financial burden is shifted into the future as incurred costs can be repaid over 30 years. Sweden's rail financing is also characterised by long-term planning, but it is the government that lays down directives and prioritises investment objectives while the infrastructure manager prepares and proposes the plans. As of today, there are important examples of projects with negative rates-of-return that have been approved and initiated despite their poor sector contribution but because of their important political image.

Finally, rail financing in the UK is characterised by 5-year control plans and the embedment of specific efficiency targets and cost reductions into the financial settlements with the goal of incentivising Network Rail's performance for the following control period. Nevertheless, the country experienced higher costs of rail infrastructure and a general deterioration of efficiency in recent years. The Office of Rail and Road identified the inability to coordinate and plan renewal projects together with the presence of too centrally planned efficiency targets as the responsible factors.

Overall, the choice of the organisational structure of the industry in not the sole determinant of the quality and performance of the railway sector and there exists different policy mixes between vertical organisational structure, competition on the tracks and regulation through which similar outcomes can

towards capital expenditure rather than making better use of the existing capacity (McNulty, 2011). Additionally, some franchises in the UK are short but train operators remain responsible for choosing rolling stock. As a consequence, there is little incentive to invest and innovate, as train operators will want a rolling stock that performs well from the start of the franchise regardless of long-term costs and benefits (Centre on Regulation in Europe, 2019).

be achieved. Additionally, the costs and benefits of each country's rail system also strongly depend on the country-specific environment and historic development of the network.

Summary

- Austria, Germany, Sweden and the UK have different environments, histories and network developments. This affects the way their rail systems are organised and regulated, and the resulting performance.

- In Germany, increasing utilisation of the rail network combined with stagnating capacity has led to a decline in service quality, resulting in growing dissatisfaction among both RUs and customers. Conversely, Sweden has a high share of rail in both passenger and freight transport, with a particularly high level of service quality in the former segment and an improving one in the latter segment. In the UK, where passenger transport dominates the market, modal share and punctuality have declined over time. In addition, misaligned incentives, failed franchises, a complicated pricing structure and the timetabling process have led to significant cost increases and widespread dissatisfaction. Meanwhile, Austria stands out with the highest rail modal share of the four countries and an exceptional quality of rail passenger services, but the country also has high government spending.

- The choice of organisational structure of the industry is not the only determinant of the quality and performance of the railway sector and there are different policy mixes between vertical organisational structure, competition on the tracks and regulation that can achieve similar outcomes.

- For example, while Sweden has successfully implemented a regulatory system that promotes efficiency through competition, the UK's direct focus on Network Rail's efficiency has led to large increases in unit costs and dissatisfaction due to misaligned incentives and extreme fragmentation within the industry. Germany, like the UK, promotes efficiency directly through the regulator, but the outcome is different from the UK.

- In terms of competition, Sweden's competitive tendering has proved effective in controlling costs and achieving a successful balance between public and private involvement. On the other hand, competitive tendering in the UK resulted in higher costs and in failed franchises. Unlike the other three countries, Austria has very dominant incumbent operators, yet the quality of the country's rail services is among the highest in Europe. This is largely due to Austria's optimal funding model, which is characterised by simplicity, a long-term perspective, adequate per-capita funding and a focus on the end-customer.

5 Cross-industry comparison

Rail transport is not the only regulated network industry whose vertical organisation is subject to debate. In fact, sector-specific legislation and regulation govern many traditional network industries. This chapter will compare railways to telecommunications and electricity industries. Such a comparison can be telling, because these network industries share core properties and their regulation faces similar trade-offs. Yet, comparisons can also be misleading when sector-specific particularities are ignored. Thus, we do not aim for a holistic comparison of the industries. Instead, we focus on specific features of the named industries and discuss what can be learned for the regulation and organisation of railway.

5.1 Telecommunication

Regulatory regimes that require vertically integrated firms to share hard-to-replicate infrastructures – such as the "last-mile" connections in telecommunications networks, railway tracks, or electricity transmission lines – create potential incentive problems, as vertically integrated firms may be induced to discriminate against upstream or downstream competitors. For example, telecommunications network operators might discriminate against competing service providers or railway track owners might discriminate against competing RUs.

There are two main regulatory solutions to prevent such discrimination: rules requiring equal treatment or "non-discriminatory access" to bottleneck facilities or vertical separation. Regulations requiring non-discriminatory access are subject to the limitations inherent in all such principal-agent relationships. Regulators typically have incomplete information, monitoring and policing compliance is costly and the results are likely to be imperfect. An alternative option, one which in theory eliminates all the incentives for discrimination is to require vertical separation. Indeed, most of the proposals for vertical separation in telecommunications have been primarily motivated by perceived problems in implementing mandatory access regimes, which force telecommunications incumbents to lease portions of their "last mile" networks to competitors at regulated prices.

By its very nature, mandated vertical separation involves a regulatory decision to alter the market structure that has developed through market forces. To the extent market forces generate efficient outcomes (i.e. there are no market failures, such as natural monopolies), such naturally developed structures might be optimal. Indeed, in telecommunications markets, it is commonplace for network infrastructures to be owned and operated by the same firms that provide retail services directly to subscribers.

According to economic theory such efficiencies are highest in industries where there are significant and asset-specific sunk costs and where there are high levels of complexity or uncertainty (see Chapter 3.3. above). All these characteristics well describe both the telecommunications and railway industries. To the extent mandated vertical separation disrupts or reduces efficiencies of vertical integration, it may reduce the investment incentives, thereby reducing economic welfare and harming consumers in the long-term. Concerns about the potential for such disruptions have led most regulators in the telecommunications sector to back away from mandatory full separation.[95]

[95] Crandall et al. (2010).

Even when regulators force vertically integrated incumbents to lease access to their networks to retail competitors at binding maximum prices, incumbents may have incentives to engage in non-price discrimination in favour of their own retail services. Such non-price discrimination could take several forms, like providing competitors with slower installation times or providing them with services of lower quality. In this context, the challenge for regulators is to devise mechanisms for detecting and policing potential discrimination. In principle, regulators have again the same two choices: They can impose behavioural rules on incumbents, requiring them to meet various regulatory metrics for providing service on a non-discriminatory basis, backed up by some form of case-by-case enforcement mechanism and penalties; or they can attempt to alter incumbents' incentives by imposing some form of mandatory separation.

In this context, the primary argument for mandated separation is that it eliminates (or at the very least substantially reduces) the incentive of the incumbent network operator to engage in non-price discrimination in favour of its own retail operations. Simply put, in the absence of mandatory separation, the incumbent maximises the joint profits of its upstream network operations and its downstream retail affiliate. Such joint profit maximization may entail raising the costs of its upstream facilities to its downstream rivals (and thus deterring or slowing their entry), even at the cost of reduced sales and thus reduced profits, in its upstream division. If the upstream unit can be forced to maximize profits independent of the interests of its retail affiliate – as, at least in theory, would be the case of full vertical separation - it will no longer have any incentives to discriminate.

However, vertical separation also gets rid of all vertical efficiencies related to common ownership of assets. It is unlikely that a regulator could fully take over that role and restore the efficiencies. Therefore, the focus on the regulation in telecommunications was strong anti-discrimination regulation (which in the end required strong cost-plus regulation of prices).

Most notably, the telecommunications reform was generally envisioned as enabling entrants a "stepping stone" on the "investment ladder": the new competitors (entrants) would begin with building their customer base by offering own services based on the "unbundled offers" using open access to the incumbent's infrastructure. Ultimately, in the next step, they would lead to investments in the form of innovative new services and technologies based on rolling out their own, new, next-generation infrastructure. Thus, the ultimate goal of the reform was long-term: to foster innovation and competition across different technologies (e.g. cable, fibre, mobile, etc.).

Technological progress has been quite successful in resolving the problem of the "last mile" bottleneck. Currently alternative technologies such as fibre, TV cable or wireless offer "last mile access" to the same customers as traditional DSL used to do in the past. Therefore, there is some degree of competition between technologies, with different technologies having different incumbents. Therefore, the problem of lack of intra-brand competition has been to a large extent resolved through inter-modal competition between technologies.

In contrast, in the railway industry the entry of a new type of infrastructure is generally not envisioned, because it has always faced strong inter-modal competition. Instead, the idea of the vertical separation in the railway industry seems to be mostly driven by an attempt to reduce the prices (through increased horizontal competition) and perhaps providing better incentive for maintenance of the rail infrastructure.

The analogy to the telecom sector suggests that vertical separation of the railway industry is not necessary to achieve the stated objectives of the reforms. A limit of the comparison of the sectors is that coordination of service operations in the rail industry appear to be much more complex, than functioning of the downstream retail sector in telecommunications. This makes potential efficiencies of vertical integration more substantial in the railway industry, as discussed in more depth in Chapter 3.3 above.

5.2 Electricity

Historically, electricity sectors in most countries were organised on the basis of vertically integrated monopolies (either state-owned or privately-owned but regulated) encompassing functions such as energy generation, transmission, distribution and retailing. However, a paradigm shift towards market-based organisation and privatisation, combined with increased dissatisfaction with the performance of such vertically integrated firms resulted in changes to the traditional model. The electricity sector has been largely reorganised through vertical separation and some vertical levels (such as generation and retailing) have been opened for competition, while traditional bottlenecks elements (such as transmission and distribution) have retained their monopoly character. Nonetheless, they have been subject to regulation and other measures intended to foster efficiencies and constrain market power.

Most relevant for our analysis of railways was the separation of electricity generation and retailing activities. It was commonly believed that the development of well-functioning markets (both real-time spot markets and forward wholesale electricity markets) would support competitive entry of both retailers and generators. It was believed that liquid spot, future and other derivative markets would enable industry participants to effectively manage price risks, countervail against residual market power (especially in oligopolistic generation) and provide investors with the revenue security required to support long-term investments in electricity generation.

However, the experience in reformed electricity sectors has fallen short of these expectations. Even in the presence of relatively liquid wholesale contract markets, contract durations are generally no more than three years, much shorter than the period required to secure long-term investments. Additionally, divergences in the contracting preferences of generators and retailers have led to “hit and run” retail entry and hold-up problems.

Electricity generators face relatively high entry costs and therefore require long-term contracts to support their investments. In contrast, retailers face relatively low entry costs and prefer short-term contracts. If wholesale prices fall during the life of the long-term fixed price contract, it creates a risk of being undercut by new entrants or bypassed by large industrial customers. Therefore, a retailer who holds such a contract faces strong incentives to renegotiate it, to rescind it or otherwise even face bankruptcy. Anticipating such hold-up risks, generators will under-invest.

Contract duration is not the only mismatch between retailers and generators. Other types of mismatches may also arise. For example, industrial customers may have different load profiles (e.g. seasonal or daily demand variations) which do not align well with generators’ supply profiles that can depend on technology and factors such as weather (e.g. sun and wind conditions). Such mismatches in supply and demand uncertainty can cause a misalignment of contracting preferences. For example, retailers or industrial customers may require supply security, whereas generators with uncertain supply (e.g. renewable sources like wind or sun) may prefer supply contracts without penalties in the event of non-supply.

To summarise, the misalignments in preferences and in contract characteristics on the supply and the demand side can reduce the overall efficiency of the market, in particular leading to the underinvestment on the generation side. The under-investment in generation is likely to cascade also to other vertical layers, e.g. transmission and distribution. Vertical integration is a likely natural solution to solve most of these problems.

Thus, one of the key insights from the electricity industry is that vertical integration allows to internalise the wholesale price risks and the risks of market power abuse. If the vertically integrated firm can balance between its generation and retail load, then it does not face incentives to exert market power over wholesale prices. Any extra profits it secures at the wholesale level translates into reduced retail-level profits, because the wholesale price is an input cost to its own retail arm. On the other hand, a non-integrated generator, or an integrated generator with unbalanced generation and load, faces incentives to increase wholesale prices.

In other words, through self-generation integrated generators have a natural hedge against changes in wholesale prices. Thus, they can substantially reduce their wholesale price risks. By internalising wholesale electricity price risks to the firm, integrated generators are not as exposed as non-integrated generators to investment-distorting regulations such as wholesale price caps.

A similar misalignment of contract duration and incentives is also present in the railway industry. The services, both in passenger and freight transport, are usually contracted for periods much shorter than the depreciation period of sunk investments. This misalignment of durations and incentives naturally creates some hold-up risks and other market imperfections or failures that make the investments riskier and thus lead to underinvestment. Vertical integration is likely to lead to better alignment of the incentives at different levels of the vertical chains and thus better-long-term efficiency.

The misalignment of incentives in the railway sector might be even stronger than in the electricity sector because the products offered in the electricity sector are more homogeneous, so that the utilization of transmission infrastructure requires less coordination. In the case of the railway sector, different modes of transport (freight, regional passenger and long-distance passenger) largely use the same infrastructure, so there is need to coordinate them with each other. Also, coordination between rolling stock and rail infrastructure is required (e.g. in terms of implementation of ETCS). It seems that all these coordination issues could be resolved more easily and efficiently in a vertically integrated structure.

These consideration raises important questions about the optimal degree of competition in both upstream and downstream markets. Cut-throat competition in the downstream market might be considered a useful tool in reducing the prices to end-customers. However, the experience in the electricity sector suggests that such competition might result in distortion of the market at the upstream level, where long-term investments are required. Indeed, recent reports suggest that Germany’s electricity power grids need multi-billion euros of investment in the coming decades. So, while the outcome of vertical separation might seem to be beneficial to the end-users in the short term, in a longer time perspective this does not need to be the case.

Summary

- The telecommunication industry is an example of a network industry that is vertically integrated, i.e. the infrastructure operator is also active in the service markets. Regulation focusses on cost-plus regulation of access prices to eliminate discrimination. It has been successful in opening and maintaining access to the bottleneck infrastructure to competitors. This has led to a relatively competitive structure and positive outcomes in the end-customer markets.

- The electricity sector is an example of a network industry that has been vertically separated. Some levels, such as generation and retailing, have been opened for competition. The traditional network elements, such as transmission and distribution, have retained their monopoly character. The existence of liquid wholesale, retail and derivative markets ensures fair pricing and efficient allocation of electricity in the spot markets. However, the industry suffers from underinvestment in transmission infrastructure.

6 Conclusions

This chapter presents the general policy insights (Chapter 6.16.2) and more specific take aways (Chapter 6.2), which were derived from the detailed review of the relevant economic literature, industry statistics, the cross-country and the cross-industry comparison. We finish with comments on the most common pitfalls in the political debate (Chapter 6.3).

6.1 Policy insights

This study offers three policy insights:

Policy insight I – Railway policy across Europe shares common long-term goals

The commonly shared, long-term goals of railway policy are achieving the best end-user (passengers and freight shippers) experience (output & availability, speed, punctuality/resilience, service) under the side constraint of a high modal share of rail and production at lowest costs (low prices, low funding). These goals are part of various broader initiatives such as the European Union's Sustainable and Smart Mobility Strategy or the Fourth Railway Package, which aim to further integrate and modernise the European rail sector. However, some of these objectives are in opposition to each other and thus require a careful balancing of trade-offs. For example, the policy objectives of decreasing costs to relieve the federal budget and fostering investment into a high quality and innovative future network are unlikely to be reached at the same time.

Policy insight II – There is no one single policy solution

While European Union directives guide railway policy harmonization across member states to common long-term goals, individual countries retain autonomy in shaping their specific approaches and policies. National railway policies can vary significantly among individual European countries due to differences in historical development and condition of their existing railway networks, geographic (e.g. topography) and demographic (e.g. population density or urbanization) considerations, economic structures and political priorities. In terms of policies, countries differ with respect to their modal shift priorities, focus on new infrastructure investment or modernisation of the existing infrastructure (e.g. electrification, automation or digital signalling) and can have different approaches to competition and open access. Finally, differences in factors such as workforce structure and labour relations, budgetary prudence, adoption of advanced new technologies and the level of international cooperation with neighbouring countries also play a major role in determining optimal policy and action.

As a result, different forms of horizontal and vertical organisational market structure can reach the same long-term goals. This conclusion can be drawn from comparing efficiency scores, which measure the productive efficiency of the railway system across countries based on their existing relationship between track length (km), number of employees, passenger and freight fleet and each country’s output in terms of passenger and freight volumes. Figure 9 in Chapter 4.1 shows for the period 1999-2017 that countries like Spain, Sweden and Estonia reached a high average efficiency score with an institutionally vertically separated market model, while Germany, France and Latvia reached a comparably high efficiency score with a model of organizational vertical separation. Switzerland also reached a top efficiency score based on a fully integrated model.

A more specific cross-country comparison of various institutional settings further supports this point: The choice of the organisational structure of the industry is not the sole determinant of the quality and performance of the railway sector and there exist different policy mixes between vertical organisational structure, competition on the tracks, type of funding and regulation through which similar outcomes can be achieved. For instance, the Swedish rail system in particular requires the active support of the government and of regional authorities to properly function (e.g. track access charges being well below full costs and the necessity for support in regional and long-distance rail services). In this respect, in Sweden institutional vertical separation has been effective in increasing transparency and in achieving a better balance between the national and regional governments. Competitive tendering in Sweden was successful in limiting the costs associated with rail and in attracting high passenger and freight volumes, while rail financing allows for long-term planning. On the contrary, institutional vertical separation in UK resulted in general dissatisfaction with the railway system as UK's high degree of fragmentation, dense network and misaligned incentives between infrastructure manager and RUs discourage coordination and reduce service quality. The situation was exacerbated by failed franchises which had to be taken over by the government and by a centralised infrastructure manager lacking local knowledge to implement the imposed efficiency targets. Finally, Austria, where the railway industry is organisationally vertically separated as in Germany, was able to achieve a high degree of service quality and customer satisfaction. The reason is its adequate funding model backed by a strong political cross-party commitment, which is oriented towards the end-customer and that successfully fosters long-term planning and coordination within the industry.

Policy insight III – Holistic approach is required (*Systemgedanke)*

Given the rail system's inherent conflicts between long-term investment and short-term end-customer needs, its operational linkages between the different business segments and the interaction of many stakeholders / competitors, there is a need for ***Systemgedanke***, i.e., a holistic view of the system which takes all the diverse aspects into account and internalises externalities and conflicts. In particular, the fact that in Germany the same railway network is used by all three segments (freight, regional and long-distance passenger) poses a huge coordination challenge. Furthermore, the delineation line between the natural monopoly segments like network infrastructure changes with innovation and improved business operations. For instance, ETCS brings some of the infrastructure investments into the rolling stock. Train technologies such as Automated Train Operation (ATO) or Digital Automatic Coupling (DAC) reduce capacity consumption of the railway infrastructure.

Such a holistic view intrinsically exists in a vertically integrated industry. Economic theory predicts that vertical integration can be (at least a partial) solution to address possible coordination failures and contracting problems. In particular, since innovation and improved operating processes require strong coordination between the infrastructure and train service sides of the system and technical developments and investments are needed on both sides, they can be undertaken easier in a vertically integrated system.

6.2 Economic trade-offs

There are many important trade-offs and factors determining the desired optimal vertical organisational structure of the rail industry, which can be derived from the academic literature and are summarised in the following take-aways:

Take-away 1 – Infrastructure managers and the train service operators have different incentives

The infrastructure manager seeks for a high degree of economic and operational predictability, attempts to avoid disruptions on its network and keeps it maintained. Train service operators attempt to serve their customer needs and benefit from larger infrastructure, more available capacity and a more predictable (in case of passenger transport) and more flexible (in case of freight transport) track allocation processes. In a vertically integrated organisational market structure, the joint interest of train service operator and infrastructure provider is pursued. In a vertically separated market organisation, a different institution has to ensure that the infrastructure provider recognises train service operators' interests. Otherwise, the opposing incentives can lead to overutilisation of existing infrastructure by train service operators (as they try to compete for new end-customers) or insufficient investment in infrastructure by its manager (as it faces uncertainty if the investment is going to attract new train service operators acting in shorter time frames).

Take-away 2 – High train density favours vertical integration

The optimal vertical organisational market structure differs depending, *inter alia,* on train density and on the characteristics of the available infrastructure. In countries with low train density, vertical separation between train service operations and infrastructure management may minimise total cost, while in countries with high train density a vertically integrated operator may allow cost minimisation. As can be seen in Figure 9 in Chapter 4.1, no country with a train density above 50 train-km per network-km per day opted for an institutionally vertically separated model and Germany is well above this train density threshold.

Take-away 3 – Shared infrastructure favours vertical integration

Similarly, countries with dedicated infrastructure for different types of transport (e.g. freight versus passenger or long distance versus regional) inherently face fewer coordination problems. Therefore, they can more easily opt for institutional vertical separation. For example, this is the case in Spain, which has developed a dedicated network of high-speed rail lines (Alta Velocidad Española, AVE) connecting major cities for trains operating at higher speeds (exceeding 300km/h) and which are separate from conventional railway lines. In contrast to that, rail infrastructure in Germany is generally shared among all types of train services (with only few exceptions), which speaks in favour of a vertically integrated model, which according to economic theory helps to solve coordination and contracting problems and minimise costs.

Take-away 4 – Vertical separation may harm investment incentives

Vertical separation is likely to create divergence of investment incentives between different levels of the vertical chain and various stakeholders. For example, a manager of a separated infrastructure does not benefit from an increase in the quality of infrastructure directly (the benefit in terms of higher prices ends up with the train service operator), so the incentive to invest in quality is reduced compared to an integrated system. This effect tends to increase with the degree of competition, fragmentation and heterogeneity in the downstream markets. An example: a fragmented market structure for rail operations does not favour standardisation, which reduces overall costs and increases efficiency of the system. The organisation of the market should be designed in such a way that the downstream service operators and the upstream network operator have incentives that are aligned as much as possible, while providing a reasonable level of horizontal competition at the service level.

Take-away 5 – Different vertical systems require different regulation

Different forms of vertical organisational market structure require different forms of regulation. In a vertically integrated market model and with horizontal competition, there is a need for strong regulation to assure non-discriminatory access for competitors to the incumbent's infrastructure. In contrast, in a vertically separated market model, there is a need to expose the infrastructure operator to the end-customer perspective to induce the *Systemgedanke* and promote cost efficiency. Some regulation of prices and quality is necessary in both systems. There is a need for strong regulation in both systems, but regulatory priorities will differ across systems. Under vertical separation, the regulator needs to facilitate the *Systemgedanke* and the examples of other countries show that it is a very difficult task.

Take-away 6 – Infrastructure requires some form of government funding

Budgetary prudence by the state implies lower state funding for the railway infrastructure and operations. As there must be a funding source, this requires i) higher efficiency in providing these services, ii) higher prices (or lower quality) for end-customer or iii) a reduced coverage of rail services. In countries where efficiency gains have been by-and-large exploited, higher prices and reduced coverage imply a lower competitiveness of the rail sector. As the rail industry stays in inter-modal competition to other modes of transport, this may result in a lower modal share in the long run.

6.3 Pitfalls in the political debate in Germany

The political debate on the topic of railways is often on the search for quick and easy solutions, which results in severe oversimplifications. Ignoring more balanced and nuanced considerations can lead to some pitfalls and mistakes.

Pitfall I: Vertical separation is not a simple cure for malfunctioning services

The literature shows that vertical separation comes with some benefits if considered in isolation, but must be assessed against the background of the specific railway system at hand. Given the high idiosyncratic constellation in different countries, there is no robust empirical evidence, though, for vertical separation being good or bad *per se*.

In the policy debate, when "vertical separation" is proposed as a policy instrument, what is actually meant is a mixture of instruments, i.e., vertical separation combined with an introduction or increase of horizontal competition and with additional regulation. Such a policy mix might or might not work - its success depends on a country's fundamentals, market environment and how it is implemented. It would be wrong to assume that vertical separation in itself will provide a cure.

Pitfall II: Competition is a tool, not a goal in itself

Competition in train services is a useful tool that can induce cost efficiency and price competition beneficial to the end-users in the short-term. On the other hand, promoting competition should be viewed as a tool to achieve other objectives, e.g economic efficiency, and not as a goal in itself.

A call for "more competition" comes with very different nuances depending on the business segment and the broader market environment, e.g. the share of other modes of transport. Nobody questions that more competition is generally beneficial. However, if more competition in the train services leads to lower infrastructure investment, it can weaken railways in inter-modal competition and reduce the rail modal share in the long-term. In case of shared infrastructure, unrestricted open-access competition in one segment can quickly exhaust capacity available for other segments, while tender competition can be more easily fit within existing capacity constraints. Because of the natural monopoly characteristics of the market, some form of regulation will be required. A call for "more competition" through vertical separation requires taking all those nuances into account.

Pitfall III: Regulation can also fail

Regulating the rail industry is a complex task with many dimensions. In this context it must be recognised that regulators can fail just as markets can. Typical regulatory failures include regulatory capture when interacting with a vertical integrated operator, regulatory inefficiency related to an authority mentality ("*Behördenmentalität*") and missing business knowhow/end-customer perspective in a vertically separated market organisation. Both vertically integrated and vertically separated systems allow for horizontal competition in train services and both require some form of regulation. In an institutionally vertically separated system, some tasks (e.g. those related to *Systemgedanke*) must be regulated and transferred to the administration. Even if a vertically separated system does not require more regulation, nonetheless it creates new regulatory tasks for the administration. It is an open question whether these tasks are better handled by a regulator/ministry or by the vertically integrated incumbent with the relevant industry know-how.

Pitfall IV: Vertical integration does not prevent or eliminate competition

Horizontal competition in train services can be achieved in various forms of vertical market structure: in both vertically integrated and vertically separated markets. It is natural to think that vertical separation promotes competition, because it removes the infrastructure incumbent entirely out of the service markets.

However, intense horizontal competition in train services is possible also when the infrastructure incumbent is allowed to operate in the service markets. If the indiscriminatory access rights to the bottleneck infrastructure are granted, monitored and enforced, there are generally no obstacles to ensure fair and intense service competition. European regulation of the rail sector prescribes at least accounting separation between the infrastructure and train services of the incumbent. Given the successive introduction of competition on the tracks in all segments, the different railway packages also include provisions regarding the capacity allocation and track access. In Germany, the infrastructure incumbent's share in train services has been decreasing over the last 20 years and horizontal competition in Germany is more intense than in most other European countries (see Figure 7) without institutional vertical separation.

This is confirmed also by the experience from other regulated industries. Telecommunications is an example of an industry where the infrastructure operator has been generally allowed to also operate directly in the services market and where the non-discriminatory access regulation and enforcement has generally fulfilled its role by opening and maintaining access to bottleneck infrastructure for competitors. This has led to a relatively competitive structure and positive outcomes in the end-customer markets. Electricity, on the other hand, is an example of an industry, where there is substantial separation of generation, transmission and distribution assets. While the existence of liquid wholesale, retail and derivative markets ensures fair pricing and efficient allocation of electricity in the spot markets, the industry suffers from underinvestment in (naturally monopolistic) transmission infrastructure. These examples illustrate that horizontal competition is possible in various forms of vertical market structure, also without institutional vertical separation.

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Appendix 2 Literature Overview

Table 5 provides an overview of the theoretical and empirical literature discussed in Chapter 3.

Table 5: Selection of most relevant and recent academic literature studying the effect of vertical separation

Author	Type of study	Methodology	Data	Definition of vertical separation	Main results
Impact of vertical separation on efficiency/productivity					
Fitzová (2022)	empirical	one-step DEA; two-step DEA with tobit regression in second step; one-step SFA	1999 - 2017; 28 European countries	institutional and organisational separation	negative impact of institutional separation on productive efficiency compared to organisational separation; benefits from increased competition must however be considered at the same time.
Lerida - Navarro et al. (2019)	empirical	two-step DEA with tobit regression in second step; SFA	2002 - 2011; 27 European railway systems	Kirchner liberalization index	weak positive link between liberalisation and productive efficiency.
Cantos - Sanchez et al. (2012)	empirical	two-step DEA with tobit regression in second step; two-step SFA with tobit regression in second step; One-step SFA	2001 - 2008; 23 European countries	institutional separation	no statistically significant relationship between institutional separation and productive efficiency compared to base group including vertically integrated and accounting and organisational separation
Cantos et al. (2010)	empirical	two-step DEA with tobit regression in second step; two step Malmquist Index with OLS regression in second step	1985 - 2005; 16 European railway systems	institutional separation	positive relationship between vertical separation and productivity growth, technical change and efficiency change compared to base group including vertically integrated and accounting and organisational separation.
Impact of vertical separation on modal share					

Author	Type of study	Methodology	Data	Definition of vertical separation	Main results
Tomes (2017)	empirical	regression of modal share	1995 – 2013; 27 European countries	institutional separation	weakly negative effect of institutional separation on the modal share of rail passenger and freight transport compared to base group including vertically integrated and accounting and organisational separation.
Laabsch and Sanner (2012)	empirical	regression of modal share	1994-2009; 9 European countries	institutional separation	negative effect of institutional separation on passenger modal share, mostly insignificant effects on freight modal share.
Van de Velde et al. (2012)	empirical	regression of modal share	1994-2010; 26 OECD countries in Europe and East Asia	institutional and organisational separation	no significant effect of organizational or institutional separation on national freight modal share. no difference in passenger modal share between organisational and institutional separation when passenger transport market is open to competition.
Impact of regulation on efficiency in different organisational market structures					
Smith et al. (2018)	empirical	Translog cost function and cost shares estimation: single output (model 1), multi-output (model 2), two separate outputs (model 3)	2002–2010; 17 European railways	institutional and organisational separation, integration	strong regulatory regimes lead to cost reductions and increased system efficiency. Yet, according to the authors' preferred model specifications, a robust regulator contributes to cost efficiencies only when coupled with vertical separation rather than organisational vertical separation. Therefore, institutional vertical separation *and* strong regulation are essential for achieving cost reductions.
Impact of train density on efficiency in different organisational market structures					

Author	Type of study	Methodology	Data	Definition of vertical separation	Main results
Mizutani (2020)	theoretical	total cost parameter-based model	n/a	institutional and organisational separation, integration	for low levels of train density, vertical separation is the optimal organisational structure. In the mid-range, an intermediate form of vertical separation (e.g. organisational vertical separation) is optimal. For countries with high train density, vertical integration minimises cost.
Mizutani et al. (2015)	empirical	seemingly unrelated regression (SUR) method by the translog total cost function and input share equations	1994 – 2010; 33 European and East Asian railways	institutional and organisational separation, integration	the optimal organisational structure depends on the intensity and type of traffic running on the network. The train density break-even point is 62.72, beyond which vertical integration is the most efficient organisational structure. A High freight share is even increasing the cost of vertical separation.
Wheat and Smith (2015)	empirical	hedonic translog cost function and cost share equations	2000 -2010; Panel data of 28 total reported costs (TOCs) in Britain	institutional vertical separation	passenger rail services in Britain exhibit constant or even decreasing returns to scale but increasing returns to density. The unit cost of operations (without infrastructure) decreases with higher train density: operating more trains at higher frequency can reduce the cost of operations per passenger.
Mizutani and Uranishi (2013)	empirical	translog total cost function: single output (model 1), multi-output (model 2)	1994 – 2007; 23 European and East Asian OECD countries (30 railway organisations)	institutional vertical separation and horizontal separation	vertical separation reduces costs, but the interaction between vertical separation and train density increases costs. This because total costs are higher in vertically integrated organisations compared to vertically separated ones, but the cost difference diminishes with higher train density.

Author	Type of study	Methodology	Data	Definition of vertical separation	Main results
Impact of competition on efficiency in different organisational market structures					
Cantos - Sanchez et al. (2023)	theoretical and empirical	two stage game model and its simulation using a numerical example	2019; passenger rail market in Spain	institutional vertical separation, integration	with downstream competition, vertical integration lowers market power and yields modest consumer and social welfare gains compared to separation. Larger economies of scale result in lower prices and access fees, which enhance consumer surplus and industry profits although Lerner indices go up.
Fitzová (2022)	empirical	one-step DEA; two-step DEA with tobit regression in second step; one-step SFA	1999 - 2017; 28 European countries	institutional and organisational separation	directly, vertical separation reduces economic efficiency, as it increases transaction costs and the misalignment of incentives. Indirectly, vertical separation can increase competition. If competition is low, vertical separation reduces efficiency. With higher competition, vertical separation may start generating economic efficiency (although the estimated coefficients are not statistically significant). There is no immediate and direct evidence for a positive effect of vertical separation on efficiency.

Author	Type of study	Methodology	Data	Definition of vertical separation	Main results
Bergantino et al. (2015)	empirical	descriptive and regression analyses	2009 – 2013; railways and airlines service data at the connection level in Italy	n/a	intra-modal competition: entry resulted in larger utilisation of infrastructure and not in aggressive price competition. Intra-modal competition (high speed rail – airline): entry stimulated competition with airlines in terms of pricing and modal share. The Italian case is an example of well-functioning downstream competition in the presence of organisational vertical separation.

Source: E.CA Economics.

Appendix 3 Market structure across countries

For each European country, Table 6 provides information on whether the rail system is vertically and/or horizontally separated (as defined in Chapter 3.2) and the year of introduction, if applicable. Additionally, the Table details the type of existing competition in the three main segments of both passenger and freight transport, including the year of first entry into each market. Finally, the name of each country's infrastructure manager and regulator, together with their legal status, is included.

Competition for long-distance ("ld"), regional ("reg."), and international ("int.") passenger and freight transport are provided. Abbreviations for the type of competition indicate: (i) "OA" - open access ("competition *in* the market"), (ii) "Dir. PSO" - directly awarded Public Service Obligation (PSO) (the government or relevant authority directly awarding a service contract to a specific rail operator without a competitive tendering process), (iii) "failed tenders" - failed PSO tenders (unsuccessful attempt to award a PSO contract via competitive tendering or earlier termination of the tender), (iv) "Comp. tenders" - competitively tendered PSO ("competition *for* the market") and (v) "Mon." - legal monopoly (national legislation granting exclusive rights to a unique train operator for the provision of specific rail services). Observations that are marked as "." are missing while "n/a" identifies either the absence of horizontal separation or the absence of entrants into the market. Observations marked with "*" indicate that the year is not segment-specific and refers to the first entrant in the general freight/passenger market. Observations marked with "**" indicate that the year refers to the formal introduction of a specific type of competition and not entry.

Table 6: Vertical and horizonal separation, competition, and regulation across European countries

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	Horizontal	Segment	Type	Since	Name	Legal status	Name	Legal status
AT	Organisational separation (2004)	n/a	Freight (all)	OA	2001*	ÖBB-Infra	Subsidiary of the holding company	Schienen-Control	State-owned
			Passenger, ld Passenger, reg. Passenger, int.	OA, Dir. PSO OA, Dir. PSO OA, Dir. PSO	2011 . 2017				

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	Horizontal	Segment	Type	Since	Name	Legal status	Name	Legal status
BE	Institutional separation (2014)	n/a	Freight (all)	OA	2002	Infrabel	Subsidiary of the holding company	Regul	Government agency
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO Dir. PSO	n/a n/a 2010				
BG	Institutional separation (2002)	n/a	Freight (all)	OA	2005	.	.	IaJa	.
			Passenger, ld Passenger, reg. Passenger, int.	Comp. tenders Comp. tenders OA	n/a n/a n/a				
CH	Integration (2009)	n/a	Freight (all)	OA	1999*	Trasse	Non-profit company	BAV	Independent commission
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO Dir. PSO	. . .				
CZ		n/a	Freight (all)	OA	1995	SZDC	State-owned	TIAA	Government agency
			Passenger, ld Passenger, reg. Passenger, int.	OA, Dir. PSO, Comp. tenders OA, Dir. PSO, Comp. tenders OA, Dir. PSO	. 2011 .				
DE	Organisational separation (2000)	n/a	Freight, ld Freight, reg. Freight, int.	OA, Dir. PSO OA, Dir. PSO OA	1995*	DB Netz	Subsidiary of the holding company	BNetzA	Government agency

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	Horizontal	Segment	Type	Since	Name	Legal status	Name	Legal status
			Passenger, ld Passenger, reg. Passenger, int.	OA OA, Dir. PSO, Comp. tenders OA, Dir. PSO, Comp. tenders	2000 1997 .				
DK	Institutional separation (1998)	2001	Freight (all)	OA	1997	.	.	Rail Market Regulatory Agency	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO Comp. tenders	2003*				
EE	Institutional separation (2012)	1997	Freight (all)	OA	1999	.	.	Estonian Competitio n Authority	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO, failed PSO Dir. PSO, failed PSO n/a	2006*				
ES	Institutional separation (2005)	n/a	Freight (all)	OA	2007*	Adif	State-owned	CNMC	Parliamentary agency
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO, Comp. tenders, Mon. Mon OA	n/a n/a n/a				
FI	Institutional separation (1995)	n/a	Freight, ld Freight, reg. Freight, int.	OA, Dir. PSO OA, Dir. PSO OA	. 2012 .	.	.		.

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	Horizontal	Segment	Type	Since	Name	Legal status	Name	Legal status
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO, Mon. Dir. PSO n/a	n/a n/a n/a			The Finnish Transport Safety Agency	
FR	Organisational separation (2015)	n/a	Freight, ld Freight, reg. Freight, int.	OA OA OA, Dir. PSO	. . 2005	SNCF Reisenau	Subsidiary of the holding company	ARAF	Government agency
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO, Mon. Dir. PSO OA, Dir. PSO	. 2022 2011				
GR	Organisational separation (2007)	n/a	Freight (all)	OA	2015	.	.	RAS	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO n/a	n/a n/a n/a				
HR	Organisational separation (2006)	n/a	Freight (all)	OA	2014*	.	.	Rail Market Regulatory Agency	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO n/a	. . .				
HU		2008	Freight (all)	OA	2004	MAV Start	.		.

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	Horizontal	Segment	Type	Since	Name	Legal status	Name	Legal status
	Organisational separation (2008)		Passenger (all)	Dir. PSO	2007			National Transport Authority	
IE	Institutional separation (2013)	n/a	Freight (all)	OA	.	.	.	CRR	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO, Comp. tenders Dir. PSO, Comp. tenders Comp. tenders	. . .				
IT	Organisational separation (2000)	n/a	Freight, ld Freight, reg. Freight, int.	OA, Comp. tenders OA, Comp. tenders OA	2001*	RFI	Subsidiary of the holding company	ART	Parliamentary agency
			Passenger, ld Passenger, reg. Passenger, int.	OA Dir. PSO, failed PSO, Comp. tenders OA	2009 2009 .				
LT	Integration	n/a	Freight (all)	OA	.	.	.	RRT	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO n/a	. . .				
LV		2008	Freight (all)	OA	2003*	.	.	SRA, PUC	.

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	Horizontal	Segment	Type	Since	Name	Legal status	Name	Legal status
	Organisational separation (2010)		Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO OA	2001*				
LU	Integration	n/a	Freight (all)	OA	.	.	.	ILR	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSO n/a	. . .				
NL	Institutional separation (2002)	2001	Freight, ld Freight, reg. Freight, int.	OA OA .	1998*	ProRail	Government agency	ACM	Government agency
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO, Mon. Dir. PSO, Comp. tenders OA	2000*				
PL	Organisational separation (2001)	n/a	Freight (all)	OA	2003*	PKP	.	UTK	.
			Passenger, ld Passenger, reg. Passenger, int.	OA, Dir. PSO OA, Dir. PSO, Comp. tenders OA, Dir. PSO	2004*				
PT		n/a	Freight (all)	OA	2008*	IP	.	AMT	.

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	Horizontal	Segment	Type	Since	Name	Legal status	Name	Legal status
	Institutional separation (1997)		Passenger, ld Passenger, reg. Passenger, int.	OA, Mon. OA, Comp. tenders OA	. . .				
RO	Institutional separation (1998)	1998	Freight (all)	OA	2001*	.	.	Consiliul feroviar	.
			Passenger, ld Passenger, reg. Passenger, int.	OA, Dir. PSO Dir. PSO, Comp. tenders Comp. tenders	2005*				
SE	Institutional separation (1995)	2002	Freight (all)	OA	1996**	Trafiverket	Government agency	Transportstyrelsen	Government agency
			Passenger, ld Passenger, reg. Passenger, int.	OA, Comp. tenders OA, Comp. tenders OA, Dir. PSO, Comp. tenders	2011** 2011** 2011**				
SI	Organisational separation (2014)	n/a	Freight, ld Freight, reg. Freight, int.	OA OA .	2009	.	.	AKOS	.
			Passenger, ld Passenger, reg. Passenger, int.	Dir. PSO Dir. PSo n/a	n/a n/a n/a				
SK		2005	Freight (all)	OA	2006*	.	.		.

Country	Separation		Competition			Infrastructure Manager		Regulator	
	Vertical	**Horizontal**	**Segment**	**Type**	**Since**	**Name**	**Legal status**	**Name**	**Legal status**
	Institutional separation (2002)		Passenger, ld Passenger, reg. Passenger, int.	OA, Dir. PSO, failed tenders Failed tenders, Comp. tenders n/a	2012*			Transport Authority	
UK	Institutional separation (1994)	1996	Freight (all)	OA	1994**	Network Rail	State-owned	ORR	Parliamentary agency
			Passenger (all)	OA, failed tenders, Comp. tenders	1997**				

Source: E.CA Economics based on information from several sources: Ait Ali and Eliasson (2022), Alexandersson and Rigas (2023), Bundesnetzagentur, Bougette et al. (2021), Competition Committee, (2020), Dolinayova et al. (2022), European Commission (2023), Finger and Montero (2020), Fitzová (2022), Guillen (2022), Montero and Melero (2022), Rail Market Monitoring (IRG), Sanchis et al. (2023), Tomes (2022), Tomes et al. (2020), and Tomes et al. (2018).

Appendix 4 Key performance indicators across countries

Table 7 contains freight and passenger volumes together with RUs' revenues in both market segments over time for each European country. While freight volume is measured in million-tonne-km per year, passenger volume is measured in million passenger-km ("pax-km"). RUs' revenues are in Euros per tonne-km and passenger-km for freight and passenger transport, respectively, and include subsidies from the State. Observations that are marked as "." are missing.

Table 7: Volume and revenue of freight and passenger transport across European countries

Country	Freight volume (million tonne-km)*			Passenger volume (million pax-km)*			Revenue of RUs (EUR per tonne-km)**			Revenue of RUs (EUR per pax-km)**		
	2019	2021	2022	2019	2021	2022	2018	2019	2021	2018	2019	2021
AT	21,736	21,779	22,121	13,252	8,447	12,855	0.05 €	0.05 €	0.05 €	0.15 €	0.15 €	0.24 €
BE	.	.	.	.	.	.	0.04 €	0.02 €	0.02 €	0.20 €	0.20 €	0.20 €
BG	3,902	4,657	5,239	1,520	1,203	1,600	0.03 €	0.03 €	0.03 €	0.08 €	0.08 €	0.10 €
CH	11,673	12,023	12,135	21,559	14,223	19,201	.	.	.	.	.	.
CZ	16,180	16,326	16,368	10,856	6,752	9,394	.	.	.	.	.	0.15 €
DE	119,470	123,935	124,553	100,252	57,518	92,313	0.04 €	0.04 €	0.04 €	0.16 €	0.16 €	0.25 €
DK	2,525	1,986	2,211	6,174	4,181	6,376	.	.	.	.	.	.
EE	2,155	2,124	1,286	392	290	382	0.02 €	0.03 €	0.05 €	0.09 €	0.11 €	0.15 €
ES	10,710	10,299	10,566	28,847	17,002	27,489	0.03 €	0.03 €	0.03 €	0.13 €	0.13 €	0.17 €
FI	10,271	10,750	8,844	4,924	2,903	12,556	0.03 €	0.03 €	0.03 €	0.09 €	0.09 €	0.10 €

Country	Freight volume (million tonne-km)*			Passenger volume (million pax-km)*			Revenue of RUs (EUR per tonne-km)**			Revenue of RUs (EUR per pax-km)**		
	2019	2021	2022	2019	2021	2022	2018	2019	2021	2018	2019	2021
FR	33,671	35,751	35,282	96,540	75,854	102,814	0.03 €	.	0.03 €	0.15 €	0.15 €	0.17 €
GR	.	.	.	1,252	653	1,117	0.03 €	0.03 €	0.03 €	0.10 €	0.09 €	0.14 €
HR	2,911	3,172	3,529	724	538	812	0.03 €	0.03 €	0.03 €	0.13 €	0.13 €	0.16 €
HU	10,625	11,347	11,351	7,752	5,435	7,817	0.03 €	0.04 €	0.04 €	0.03 €	0.03 €	0.16 €
IE	72	70	81	2,399	870	1,748	.	0.02 €	0.05 €	.	0.14 €	0.37 €
IT	21,309	24,262	24,330	56,586	27,693	46,498	0.03 €	0.03 €	0.03 €	0.12 €	0.12 €	0.18 €
LT	16,181	14,566	7,375	359	287	382	0.02 €	0.03 €	0.03 €	0.06 €	0.12 €	0.17 €
LU	191	176	167	463	304	389	0.10 €	0.10 €	0.11 €	0.46 €	0.47 €	0.76 €
LV	15,019	7,367	7,410	643	361	541	0.02 €	0.02 €	0.02 €	0.12 €	0.10 €	0.12 €
NL	7,080	7,188	7,176	19,353	10,853	17,105	0.03 €	.	0.03 €	0.14 €	0.15 €	0.27 €
PL	54,584	54,387	59,306	21,974	15,746	23,527	0.03 €	0.04 €	0.03 €	0.07 €	0.06 €	0.09 €
PT	2,478	1,881	2,190	5,055	2,912	4,419	0.03 €	0.03 €	0.04 €	0.06 €	0.07 €	0.10 €
RO	13,312	13,625	13,324	5,906	4,271	5,795	0.03 €	0.04 €	0.04 €	0.10 €	0.09 €	0.12 €
SE	22,222	23,449	23,161	14,617	8,027	12,879	0.03 €	0.03 €	0.03 €	0.10 €	0.11 €	0.14 €

Country	Freight volume (million tonne-km)*			Passenger volume (million pax-km)*			Revenue of RUs (EUR per tonne-km)**			Revenue of RUs (EUR per pax-km)**		
	2019	2021	2022	2019	2021	2022	2018	2019	2021	2018	2019	2021
SI	5,292	4,937	4,928	572	504	645	0.04 €	.	0.04 €	0.16 €	.	0.23 €
SK	8,134	8,190	7,838	3,957	1,969	3,168	.	.	.	.	.	.
UK	16,884	.	.	71,823	.	.	0.05 €	0.05 €	.	0.18 €	0.20 €	0.81 €

Source: E.CA Economics based on Eurostat and IRG Reports. Notes: Values marked with “*” are based on Eurostat data while values marked with “**” are based on IRG Reports.

For each European country, Table 8 presents the modal share of rail freight and passenger transport together with the national incumbent’s market share and the HHI (train-km) in both market segments over time. For each of the two market segments, the modal share is defined as the percentage of rail transport with respect to the total inland transport taking place in the country. Total passenger transport includes passenger cars, buses and coaches, rail, air and maritime passenger-km while total freight transport considers air, maritime, road, rail and inland waterways tonne-km. Market Shares are based on the total train-km of the specific country. Please note that a low market share for the national incumbent does not indicate a competitive market. An example can be Greece where a foreign incumbent, Ferrovie dello Stato Italiane, has now a market share above 95%. Therefore, the HHI-Values give a broader view on the level of competition in the specific country. But the HHI-value does not differentiate between Competition for the market and competition in the market. Observations that are marked as “.” are missing.

Table 8: Modal share of freight and passenger transport, market shares and HHIs across European countries

Country	Freight modal share (%) *			Passenger modal share (%) *			Market share national incumbent based on freight-train-km **			Market share national incumbent based on pax-train-km **			HHI freight based on train-km**	HHI passenger based on train-km**
	2018	2019	2021	2018	2019	2021	2018	2019	2021	2018	2019	2021	2018	2018
AT	32%	31%	30%	14%	14%	10%	71%	70%	68%	84%	85%	87%	5,133	7,152

Country	Freight modal share (%) *			Passenger modal share (%) *			Market share national incumbent based on freight-train-km **			Market share national incumbent based on pax-train-km **			HHI freight based on train-km**	HHI passenger based on train-km**
	2018	2019	2021	2018	2019	2021	2018	2019	2021	2018	2019	2021	2018	2018
BE	12%	12%	12%	8%	8%	6%	71%	71%	59%	96%	96%	98%	5,193	9,882
BG	19%	21%	20%	2%	2%	2%	51%	55%	50%	100%	100%	100%	.	.
CH	35%	34%	34%	19%	20%	15%	77%	74%	71%	72%	72%	70%	4,971	6,548
CZ	28%	26%	23%	10%	10%	7%	66%	62%	59%	92%	91%	84%	4,418	8,930
DE	19%	19%	19%	9%	9%	7%	49%	47%	45%	71%	70%	65%	2,256	4,091
DK	12%	12%	9%	8%	8%	6%	0%	0%	0%	68%	65%	58%	.	.
EE	46%	42%	40%	3%	2%	2%	0%	0%	0%	97%	97%	100%	9,567	10,000
ES	5%	5%	4%	7%	7%	5%	64%	63%	61%	100%	100%	99%	4,411	10,000
FI	29%	27%	27%	6%	6%	4%	98%	98%	97%	100%	100%	100%	9,677	10,000
FR	11%	10%	11%	10%	10%	9%	70%	71%	66%	100%	100%	100%	3,522	9,571
GR	2%	3%	3%	1%	1%	1%	100%	99%	0%	95%	95%	.	9,942	9,846
HR	21%	23%	24%	3%	2%	2%	68%	62%	56%	100%	100%	100%	4,862	10,000
HU	27%	26%	26%	9%	8%	6%	46%	45%	41%	94%	94%	94%	2,420	8,805

Country	Freight modal share (%) *			Passenger modal share (%) *			Market share national incumbent based on freight-train-km **			Market share national incumbent based on pax-train-km **			HHI freight based on train-km**	HHI passenger based on train-km**
	2018	2019	2021	2018	2019	2021	2018	2019	2021	2018	2019	2021	2018	2018
IE	1%	1%	1%	3%	3%	1%	.	100%	100%	.	100%	100%	.	.
IT	13%	12%	13%	6%	6%	4%	54%	51%	47%	89%	88%	91%	2,946	6,046
LT	68%	67%	63%	1%	1%	1%	100%	100%	100%	100%	100%	100%	10,000	10,000
LU	8%	7%	7%	5%	5%	4%	100%	100%	100%	100%	100%	100%	10,000	10,000
LV	76%	74%	53%	3%	3%	2%	72%	74%	74%	94%	94%	99%	5,652	9,784
NL	6%	6%	6%	11%	11%	8%	0%	0%	0%	83%	82%	82%	3,140	7,060
PL	27%	24%	22%	7%	8%	6%	56%	52%	47%	40%	39%	38%	2,898	2,844
PT	14%	13%	11%	4%	5%	3%	0%	0%	0%	94%	94%	92%	7,626	8,974
RO	29%	27%	25%	4%	4%	3%	36%	28%	20%	82%	82%	77%	1,980	6,805
SE	30%	30%	29%	11%	12%	8%	54%	49%	48%	55%	55%	56%	3,494	4,751
SI	35%	36%	34%	2%	2%	2%	86%	90%	82%	100%	100%	100%	7,507	10,000
SK	33%	31%	32%	10%	10%	6%	70%	68%	65%	93%	93%	98%	.	.
UK	9%	9%	.	8%	9%	.	4%	4%	7%	1%	1%	1%	2,632	702

Source: E.CA Economics based on Eurostat and IRG Reports. Notes: Values marked with "*" are based on Eurostat data while values marked with "**" are based on IRG Reports.

Table 9 presents the share of punctual trains in freight (international/national) and passenger (long-distance/short distance) transport for each European country over time. Freight trains are categorised as delayed if they are 15 minutes or more behind the schedule while the threshold is over 5 minutes for passenger services. Both definitions are measured for all stops of a train. Observations that are marked as "." are missing. Please note that such standardised definition of punctuality was introduced by the EU Regulation 2015/2010 but its implementation into national laws did not occur at the same time for all countries. Therefore, comparison across countries and time might be problematic and caution in interpretation is advised.

Table 9: Punctuality pf passenger services (long and short distance) and freight services (international and national) across European countries

Country	Punctuality long-distance (%)			Punctuality short distance (%)			Punctuality international (%)		Punctuality national (%)	
	2017	2018	2019	2017	2018	2019	2018	2019	2018	2019
AT	86%	87%	96%	96%	96%	96%	80%	57%	80%	70%
BE	86%	85%	89%	91%	89%	89%	80%	81%	71%	71%
BG	86%	85%	94%	95%	94%	94%	42%	33%	86%	64%
CZ	81%	77%	90%	91%	90%	90%	39%	44%	35%	36%
DE	71%	71%	88%	89%	88%	88%	48%	49%	65%	65%
DK	89%	87%	95%	95%	95%	95%	45%	53%	76%	70%
EE	.	.	99%	95%	99%	99%	.	98%	.	0%
ES	.	89%	92%	.	92%	92%	.	0%	90%	92%
FI	82%	79%	96%	96%	96%	96%	.	0%	77%	78%

Country	Punctuality long-distance (%)			Punctuality short distance (%)			Punctuality international (%)		Punctuality national (%)	
	2017	2018	2019	2017	2018	2019	2018	2019	2018	2019
FR	84%	76%	90%	89%	90%	90%	55%	0%	71%	77%
GR	65%	35%	93%	73%	93%	93%	.	0%	.	0%
HR	64%	56%	83%	88%	83%	83%	39%	39%	22%	21%
HU	66%	65%	78%	82%	78%	78%	22%	16%	40%	35%
IE	85%	84%	94%	91%	94%	94%	.	0%	96%	95%
IT	62%	53%	85%	87%	85%	85%	41%	44%	54%	47%
LV	97%	98%	99%	99%	99%	99%	87%	96%	87%	85%
LT	97%	96%	94%	96%	94%	94%	99%	92%	99%	99%
LU	72%	71%	86%	84%	86%	86%	51%	59%	58%	77%
NL	97%	92%	95%	94%	95%	95%	93%	0%	93%	94%
PL	83%	82%	92%	94%	92%	92%	29%	29%	40%	41%
PT	53%	53%	90%	91%	90%	90%	43%	33%	43%	81%
RO	89%	59%	62%	64%	62%	62%	.	0%	63%	65%
SE	78%	72%	89%	91%	89%	89%	65%	69%	77%	78%

Country	Punctuality long-distance (%)			Punctuality short distance (%)			Punctuality international (%)		Punctuality national (%)	
	2017	2018	2019	2017	2018	2019	2018	2019	2018	2019
SI	55%	49%	77%	77%	77%	77%	21%	22%	40%	47%
SK	80%	77%	88%	91%	88%	88%	31%	30%	46%	49%
UK	76%	67%	.	89%	86%	.	77%	.	93%	.

Source: E.CA Economics based on RMM Report.

Appendix 5 Infrastructure across countries

Table 10 contains total network km, electrified network km and single-tracked network km. While total network-km are indicative of the length of all lines, electrified network-km refer only to network-km which are electrified. Finally, single-tracked network-km are network-km which have only one track. Overall, a network can be separated into four categories: minimum double-tracked and electrified, single-tracked and electrified, minimum double-tracked and non-electrified, single-tracked and non-electrified. Observations that are marked as "." are missing.

Table 10: Total, electrified, and single-tracked network-km across European countries

Country	Total network-km			Electrified network-km			Single-tracked network-km		
	2019	2021	2022	2019	2021	2022	2019	2021	2022
AT	5,615	5,603	5,575	3,976	4,003	4,015	3,411	3,365	3,339
BE	3,614	3,612	3,619	3,100	3,127	3,185	695	689	686
BG	4,030	4,031	4,029	2,869	3,001	3,005	3,040	3,036	3,034
CH	5,302	5,332	5,332	5,293	5,323	5,323	3,226	3,221	3,198
CZ	9,562	9,523	9,521	3,231	3,234	3,234	7,538	7,490	7,453
DE	39,068	38,783	38,836	20,920	21,166	21,297	20,413	20,204	20,182
DK	2,536	2,485	2,448	730	803	802	1,524	1,441	1,413
EE	1,167	1,167	1,175	138	225	140	1,065	1,065	1,065
ES	16,006	16,280	16,468	10,252	10,428	10,669	10,002	10,012	10,146

Country	Total network-km			Electrified network-km			Single-tracked network-km		
	2019	2021	2022	2019	2021	2022	2019	2021	2022
FI	5,923	5,918	5,918	3,331	3,359	3,428	5,231	5,226	5,205
FR	28,350	27,924	27,812	16,703	16,690	16,759	10,944	10,649	10,550
GR	2,280	2,339	1,990	731	731	738	1,651	1,639	1,292
HR	2,617	2,617	2,617	970	994	995	2,342	2,342	2,342
HU	7,743	7,889	7,907	3,111	3,221	3,221	6,522	6,574	6,592
IE	2,045	2,045	2,045	53	53	53	1,579	1,579	1,579
IT	16,779	16,832	16,829	12,016	12,160	12,184	9,058	9,100	9,098
LT	1,911	1,911	1,919	152	152	152	1,449	1,442	1,452
LU	263	271	271	254	262	262	111	111	111
LV	1,860	1,859	1,865	251	251	251	1,493	1,493	1,498
NL	3,040	3,041	3,041	2,224	2,264	2,265	900	897	897
PL	19,359	19,287	19,355	11,982	12,101	12,138	10,584	10,381	10,459
PT	2,526	2,527	2,527	1,696	1,791	1,791	1,916	1,917	1,917
RO	10,759	10,764	10,615	4,029	4,035	4,032	7,704	7,699	7,601

Country	Total network-km			Electrified network-km			Single-tracked network-km		
	2019	2021	2022	2019	2021	2022	2019	2021	2022
SE	10,899	10,912	10,914	8,185	8,186	8,185	8,850	8,854	8,856
SI	1,209	1,209	1,208	610	610	605	879	879	883
SK	3,629	3,626	3,626	1,587	1,585	1,585	2,612	2,614	2,611
UK	16,346	16,316	.	6,158	6,151	.	.	.	.

Source: E.CA Economics based on Eurostat.

Table 5 presents maintenance and renewal expenditure (EUR per train-km) and infrastructure investment per capita across European countries and time. Investment per capita includes spending for new infrastructure and the upgrade of existing infrastructure. Observations that are marked as "." are missing.

Table 11: Maintenance and investment in infrastructure across European countries

Country	Maintenance and renewal (EUR per train-km)			Investment in infrastructure (EUR per capita)		
	2016	2018	2020	2016	2018	2020
AT	7.31 €	7.10 €	7.35 €	127 €	149 €	178 €
BE	9.86 €	8.05 €	8.80 €	39 €	29 €	41 €
BG	2.97 €	3.08 €	3.66 €	25 €	10 €	14 €
CZ	.	5.88 €	5.49 €	64 €	59 €	101 €
DE	4.42 €	4.69 €	6.02 €	37 €	43 €	46 €

Country	Maintenance and renewal (EUR per train-km)			Investment in infrastructure (EUR per capita)		
	2016	2018	2020	2016	2018	2020
DK	5.73 €	5.08 €	4.41 €	66 €	91 €	136 €
EE	10.15 €	10.99 €	15.22 €	.	.	.
ES	3.09 €	3.88 €	4.81 €	34 €	34 €	42 €
FI	7.60 €	9.07 €	9.47 €	26 €	13 €	22 €
FR	11.25 €	12.49 €	15.08 €	32 €	28 €	17 €
GR	1.62 €	0.78 €	0.83 €	28 €	15 €	4 €
HR	5.23 €	7.19 €	7.23 €	6 €	10 €	17 €
HU	2.35 €	2.53 €	3.18 €	6 €	2 €	6 €
IE	.	.	14.00 €	1 €	3 €	7 €
IT	4.03 €	2.62 €	2.61 €	52 €	66 €	62 €
LT	10.94 €	7.71 €	8.23 €	12 €	13 €	47 €
LU	29.63 €	33.20 €	11.26 €	453 €	277 €	343 €
LV	12.18 €	13.78 €	15.68 €	1 €	.	.
NL	6.00 €	8.04 €	8.06 €	48 €	36 €	37 €

Country	Maintenance and renewal (EUR per train-km)			Investment in infrastructure (EUR per capita)		
	2016	2018	2020	2016	2018	2020
PO	2.83 €	2.59 €	3.58 €	31 €	44 €	53 €
PT	1.87 €	2.22 €	3.09 €	3 €	7 €	14 €
RO	1.76 €	.	- €	10 €	.	- €
SE	4.83 €	4.88 €	5.78 €	114 €	97 €	157 €
SI	6.52 €	7.36 €	9.19 €	23 €	58 €	80 €
SK	4.53 €	4.84 €	3.81 €	5 €	28 €	19 €
UK	9.39 €	9.00 €	.	64 €	57 €	.

Source: E.CA Economics based on data from IRG.

Table 12 presents track access charges ("TAC") and train density of freight and passenger transport across European countries and time. Track access charges are defined as the value of Euros per freight or passenger train-km a RU is paying to access a country's rail network. Train density is defined as the number of train-km per network-km per day. Observations that are marked as "." are missing.

Table 12: Track access charges and train density for freight and passenger transport across European countries

Country	TAC per passenger-train-km (EUR)	TAC per freight-train-km (EUR)	Freight train density (train-km per network-km per day)			Passenger train density (train-km per network-km per day)		
	2021	2021	2018	2019	2021	2018	2019	2021
AT	2.30 €	.	25	25	25	55	58	60

Country	TAC per passenger-train-km (EUR)	TAC per freight-train-km (EUR)	Freight train density (train-km per network-km per day)			Passenger train density (train-km per network-km per day)		
	2021	2021	2018	2019	2021	2018	2019	2021
BE	4.40 €	2.38 €	10	10	9	66	66	66
BG	0.56 €	1.39 €	5	6	6	14	14	14
CH	5.08 €	4.89 €	.	15	14	.	104	106
CZ	0.57 €	1.78 €	11	11	11	39	39	39
DE	4.32 €	0.19 €	19	19	19	59	60	61
DK	0.90 €	3.55 €	4	4	3	86	89	99
EE	.	0.09 €	3	3	3	10	11	11
ES	6.65 €	0.22 €	4	5	4	30	30	23
FI	0.44 €	2.17 €	7	7	7	16	17	15
FR	9.17 €	1.29 €	6	6	6	37	37	36
GR	2.07 €	2.30 €	1	1	1	12	12	9
HR	0.54 €	1.09 €	6	7	7	16	16	14
HU	1.25 €	2.25 €	8	7	7	31	31	32
IE	4.40 €	9.46 €	.	0	0	.	30	26

Country	TAC per passenger-train-km (EUR)	TAC per freight-train-km (EUR)	Freight train density (train-km per network-km per day)			Passenger train density (train-km per network-km per day)		
	2021	2021	2018	2019	2021	2018	2019	2021
IT	2.73 €	0.67 €	7	7	8	48	49	45
LT	0.54 €	17.40 €	14	14	13	9	10	8
LU	2.39 €	2.27 €	5	5	4	76	76	75
LV	1.03 €	11.15 €	12	10	5	7	7	7
NL	1.97 €	4.44 €	10	10	9	136	137	136
PL	1.35 €	2.84 €	12	12	12	23	24	25
PT	1.97 €	1.35 €	7	7	6	33	32	31
RO	2.07 €	3.12 €	6	6	6	17	17	16
SE	0.83 €	0.90 €	9	9	9	31	32	30
SI	0.59 €	0.85 €	25	24	25	23	23	24
SK	1.49 €	1.42 €	12	11	12	27	28	26
UK	7€	2€	.	6	6	.	94	77

Source: E.CA Economics based on data from the IRG Report.

Table 13 presents the demographic characteristics of European countries in 2022 and 2021. For the precise definition of urban, sub-urban, and rural areas please consult the EU Regulation 2019/2181. Population density is defined as inhabitants per square kilometre. Observations that are marked as "." are missing.

Table 13: Demographic characteristics across European countries

Country	Total population	Population density (inhabitants per square km)	Population in urban areas (%)	Population in rural areas (%)	Population in sub-urban areas (%)
	2022	2021	2021	2021	2021
AT	8,978,929	108	31%	39%	30%
BE	11,617,623	379	30%	15%	55%
BG	6,838,937	63	44%	31%	24%
CH	8,738,791	217	30%	18%	52%
CZ	10,516,707	139	31%	37%	33%
DE	83,237,124	235	39%	20%	41%
DK	5,873,420	139	37%	32%	31%
EE	1,331,796	31	44%	36%	20%
ES	47,432,893	94	56%	13%	31%
FI	5,548,241	18	40%	28%	33%
FR	67,871,925	107	37%	34%	29%

Country	Total population	Population density (inhabitants per square km)	Population in urban areas (%)	Population in rural areas (%)	Population in sub-urban areas (%)
	2022	**2021**	**2021**	**2021**	**2021**
GR	10,459,782	82	38%	31%	31%
HR	3,862,305	72	32%	36%	32%
HU	9,689,010	107	32%	32%	36%
IE	5,060,004	73	35%	39%	26%
IT	59,030,133	200	36%	18%	46%
LT	2,805,998	45	42%	44%	14%
LU	645,397	244	19%	34%	47%
LV	1,875,757	30	43%	35%	22%
NL	17,590,672	510	56%	11%	33%
PL	37,654,247	123	35%	37%	28%
PT	10,352,042	113	47%	24%	29%
RO	19,042,455	82	30%	42%	28%
SE	10,452,326	25	40%	19%	41%
SI	2,107,180	104	19%	45%	36%

Country	Total population	Population density (inhabitants per square km)	Population in urban areas (%)	Population in rural areas (%)	Population in sub-urban areas (%)
	2022	**2021**	**2021**	**2021**	**2021**
SK	5,434,712	112	22%	45%	33%
UK	67,025,542	275	60%	12%	30%

Source: E.CA Economics based on Eurostat. Notes: Total population and population density in the UK refer to 2020, while values for the share of population living in urban/rural/sub-urban areas refer to 2018.

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E.CA Economics is working on central topics in the field of competition policy and regulation. These include case-related work on European competition matters, e.g. merger, antitrust or state aid cases, economic analysis within regulatory procedures and studies for international organizations on competition policy issues. E.CA Economics applies rigorous economic thinking with a unique combination of creativity and robustness, in order to meet the highest quality standards of international clients.

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