The effect of deregulation on the railway sectors in Sub-Saharan Africa

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Abstract

Purpose – Over the last decade, African rail sectors have applied hybrid reform models to catch up with the sub-region's lagging rail performance compared to other regions. With this in mind, this paper aims to study the effect of deregulation on rail transport demand. Following an abundant literature on deregulation in Europe and Asia, this study focuses on structural and regulatory reforms.

Design/methodology/approach – The investigation methodology is in line with the investigations of Mizutani (2019) and Smith, Benedetto, and Nash (2018). This paper uses a seemingly unrelated model (SURE) for general estimation and a random effect least square model for regional block estimation on a panel of 26 countries for 15 years between 2000 and 2015.

Findings – The main results show that structural reforms positively affect passenger transport demand, but negatively affect freight transport demand. The level of competition stimulates demand for freight transport. Privatization of operators positively affects freight transport demand, but has no significant effect on passenger transport demand. The introduction of a regulatory authority has a positive effect on demand for passenger transport, and in certain regional blocs, it affects demand for freight transport, with the existence of corridors shared between several countries.

Originality/value – This study is carried out in the sub-Saharan African sub-region. Indeed, the importance of the rail sector and the dilapidated state of many of its infrastructures should prompt a more abundant literature on the subject of the effectiveness of deregulation movements. We also evaluate the effect of vertical or horizontal separation and the introduction of an independent regulator in the rail sector on overall demand for transport service.

Keywords Deregulation, A seemingly unrelated regression (SURE), Structural reforms, Regulatory authority, Sub-region

Paper type Research paper

1. Introduction

In an economy, rail transport has vital importance for sustainable development (UIC (2020), [1]). This mode of transport can move huge volumes of goods for large numbers of people in an energy-efficient and environmentally friendly way. Additionally, rail is less expensive and more efficient than other means of transport. In fact, rail has a higher transport capacity per dollar invested than other means of transport (UIC, 2017). In a growth dynamic, the rail sector generally contributes to accelerating and intensifying trade flows. On this basis, increased interregional, intra-regional and international trade are all additional factors on which economic growth is based (AfDB, 2015). In many parts of the world, the rail sector is making a comeback after years of decline. The most common market structure in the world's rail

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industries consisted of a public entity in a natural monopoly market. The market is traditionally regulated by the State, especially the responsibility of the ministry in charge of transport. Following several years of underperformance of the sector in developed countries, and bureaucratic management that affected budgetary and financial transparency in infrastructure, European countries have steadily deregulated their rail sectors with structural and regulatory reforms.

Sector restructuring refers to the vertical and horizontal disintegration of the sector. Vertical disintegration involves granting another private or public operator a concession to operate and administer the transport service and/or manage infrastructure facilities. Horizontal disintegration involves setting up a holding company [2] or putting the sector out to tender, and harmonizing the relationship between the services using the structure. Regulatory reforms consist in privatizing operators in the sector and setting up authorities independent of the public authorities to regulate the sector. Unlike the network sector, in the rail sector no standard reform model is established to improve the performance of rail transport (World Bank, 2017). However, at the beginning of the 21st century, the application of various hybrid models of reform had improved the performance of the rail sectors of several countries in the world's sub-regions. However, some regions are still lagging behind, and the situation of their rail sectors is critical.

The state of the rail sector in sub-Saharan Africa is hardly glowing. Almost all of the sub-region's rail networks are offerings of colonization (AU, 2015, [3]). Following independence, public bodies were created to operate the railroads. Compared to the reforms in Europe countries who inspired them, many countries in Africa don't prioritize the rail sector and the deregulation of public utilities does not follow the same steps. The regulatory strategy of African countries habitually follows the history of their colonizer. In contrast with other public utilities, many African countries do not yet have its own regulatory ideology in the rail sector (Olievschi, 2013b). So, the railway networks fell into a spiral of abandonment and degradation (AfDB, 2015). With the exception of South Africa and the countries of North Africa, several countries do not have a railway sector that plays an important role in the transport of goods and citizens compared to other means of transport (roads and rivers in particular). The industrialization of countries and the transport of goods by road cannot sustain the average growth rate of 3.5% in the year of the beginning of the 21st century (World Bank, 2017). Indeed, the network density of railroads is 2.96 km per 1,000 km^2 for the entire continent, compared with 62.7 km per 1,000 km^2 in France (Mbangala, 2007). The concessioning of 14 rail infrastructure in the sub-region between 1995 and 2005 revealed ambiguous performances (Mbangala, 2007). Passenger traffic fell by 1.59% annually for the concessions, and by 0.13% for the public operators. On the other hand, freight traffic increased by 9% for concession operators and 0.44% for public operators.

Over this decade, almost no rail sector has managed to support up to 50% of its infrastructure investments. Only the Sitarail concession financed 57% of its rail investments, and managed to achieve one of the best performances in freight transport than in passenger transport (Mbangala, 2007). This is because the rail networks conceded to the operator cover several territories and facilitate the logistics of transactions involving large quantities of goods between countries. In contrast, very few countries have networks that cross borders, especially in Central Africa (AfDB, 2015). This situation limits the performance of freight and passenger transport.

Over the past decade, a number of countries have deregulated the rail sector in line with economic, social and institutional plans to create a framework in which the rail sector can play an important role in the transportation network sector (Olievschi, 2013b). The reforms implemented by the authorities in charge are endogenous and do not follow a continental or subregional organization as in Western countries (AfDB, 2015). In fact, many countries opt to renegotiate and modify their concession models. By way of illustration, Cameroon uses a holding model with the company Mobirail to limit the impact of the private company Camrail on the sector. Other countries, such as Zambia and Tanzania, are opting to withdraw from the concession model and return the rail sector to vertical and horizontal public ownership. In North Africa, Morocco applies horizontal separation, but retains vertical integration under public ownership. With this in mind, the countries apply various forms of public operator competition. In Senegal, the infrastructure structure is privately owned. As a result, the country has set up a transport sector regulator. Several countries have set up independent regulators for the sector. Regulatory authorities are sometimes responsible for all modes of transport, as in Côte d'Ivoire and Zimbabwe, or are the integrated arm of an authority covering several countries, as in Tanzania. Nevertheless, in several countries, responsibility for regulating the sector remains with the ministry in charge.

Structural and regulatory changes should logically improve the supply situation. On the other hand, many countries still have almost non-existent rail sectors. Indeed, no country in the sub-region carries more than 5,000,000 passengers a year (AfDB, 2015). On average, 936,000 people per kilometer don't use rail service transport in the sub-region (World Bank, 2020a, b). Moreover, only South Africa has reached 200,000,000 tonnes of goods transported by rail in a single year. In the sub-region, excluding South Africa, an average of 3,468,000 tonnes of goods are transported by rail, compared with 14,265,000 tonnes worldwide (World Bank, 2020a, b). Railway companies have functional locomotive fleets ranging from 0 to 100 locomotives in the sub-region (AfDB, 2015). With the exception of South Africa, which has a Park of 3,250 working locomotives (World Bank, 2020a, b). Benin, Congo and Malawi have fewer than 30 locomotives. The Democratic Republic of Congo has 40 locomotives for a population of nearly 96 million. South Africa has over 25% of the Park's locomotives in sub-Saharan Africa.

All these statistics demonstrate the exogenous nature of the effects generated by the various reforms implemented in the rail sectors. The countries of the continent have set themselves the goal of creating a continental African free-trade zone. But given the state of the rail sectors in each country, achieving effective and efficient trade between the various sub-regions is chimerical. Indeed, rail is the most economical and ecological means of transporting huge quantities of goods overland over long distances (UIC, 2020). Consequently, it is of the utmost importance to identify the factors that are driving improved performance in the rail sector in sub-Saharan Africa. The application of various modes of reform does not ensure satisfactory performance indicators, and leads to huge financial losses for countries due to greater use of road transport. In its provisions, this study questions the effect of deregulation actions on the rail sector in sub-Saharan Africa.

The dilapidated state of the railway sector at the end of the 20th century has led to a large body of literature on rail transport and the railway economy. The studies focus on sectoral indicators of infrastructure efficiency and aggregate demand for services from three perspectives. The first perspective looks at the effect of structural reform of rail infrastructure on sectoral indicators of rail transport. The investigations first assess the effect of vertical infrastructure disintegration on the demand for rail transport services (Laabsch & Sanner, 2012; Mizutani & Uranishi, 2020; Nakamura & Sakai, 2020; Tomeš, 2017). Secondly, studies evaluate the effect of competition on service demand (Lalive & Schmutzler, 2008; Mizutani & Uranishi, 2020; Tomeš, 2017; Van de Velde *et al.*, 2012) and infrastructure efficiency (Asmild, Holvad, Hougaard, & Kronborg, 2009; Smith *et al.*, 2018).

The second perspective analyses the effect of regulatory reforms in the rail sector on performance indicators. Indeed, investigations evaluate the effect of rail sector regulation by an independent state authority on rail transport performance (Laurino, Ramella, & Beria, 2015; Nash, Benedetto, & Smith, 2017; Smith *et al.*, 2018). In addition, other studies analyse the effect of operator privatization on the demand for rail transport service (Mizutani & Uranishi, 2020; Nash, Smith, Crozet, Link, & Nilsson, 2019; Preston & Robins, 2013) and infrastructure efficiency (Holvad, 2020; Lerida-Navarro, Nombela, & Tranchez-Martin, 2019).

The final perspective analyses the effect of institutional organization on rail sector performance. Indeed, investigations focus on the effect of public policies on the performance of the railway sector, including the attractiveness of the country (Bouraima *et al.*, 2023; Lee, Han, Kim, & Lee, 2022; Olievschi, 2013b) urbanization (Alimo *et al.*, 2022) the pricing model (Monchambert & Proost, 2019) and privatization and investment policies with foreign partnerships (Jedwab & Storeygard, 2019; Olievschi, 2013b).

The present study is in line with the first two perspectives, and seeks to complement this literature in sub-Saharan Africa. Indeed, the majority of studies assessing the effect of deregulation of the rail sector on demand for rail transport services are carried out in European, American and Asian countries. This study is carried out in the sub-Saharan African sub-region. Indeed, the importance of the rail sector and the dilapidated state of many of its infrastructure should prompt more abundant literature on the subject of the effectiveness of deregulation movements. Studies carried out in sub-Saharan Africa focus on the issues of privatization, concession and investment programs (AfDB, 2015; Bangura, 2000; Bidiasse, 2017; Jedwab & Storeygard, 2019; Mbangala, 2007; Mwase, 1993; Olievschi, 2013b). The literature neglects the effect of vertical or horizontal separation and the introduction of an independent regulator in the rail sector on the overall demand for transport services. The hybrid aspect of structural and regulatory reform models in sub-Saharan Africa over the last two decades supports our study of several of the continent's countries. Table 1 presents the various reforms evaluated in this research.

The aim of this study is to assess the effect of structural and regulatory reforms on the demand for rail transport. With this in mind, to determine what types of factors are important in the formulation of rail sector reform policy in subregional countries. To achieve this objective, we use a seemingly unrelated regression (SURE) method on data from sub-Saharan African countries. The data used in this study come from the World Bank, the UN, the AfDB and the countries' annual or decennial rail infrastructure reports. The rest of the study is organized as follows: section 2 provides a systematic review of the eclectic literature; section 3 presents the methodology and data and their processing; section 4 analyses the results and section 5 concludes and recommends.

Table 1. Presentation of the reforms of the railway sector evaluated

Structural reform	Vertical unbundling	It is the separation of the management of railway assets between rolling stock and the railway network. Different managers can deal with rolling stock and the railway, taking care of the investment in both segments of the rail sector
	Horizontal unbundling in management	This is horizontal separation in the management of contracts. Indeed, different operators can take care of the freight and passenger market. In addition, to ensure good customer management by a private operator, a holding company is set up in the concession contract. It is a separation of governance by holding companies
	Horizontal unbundling in operators	This is the horizontal separation by the number of operators in the rail sector. Usually, two operators are in the sector respectively for freight or passenger transport
Regulatory reform	Ownership of the operators	It is the property of the operators. Operators can be public, private or have a mix of public-private ownership that is widely touted in the literature to reduce the asymmetry of information
	Share of Ownership	It is the share of the capital of all operators that belongs to private operators. Decision-makers can put railway operators under concession while retaining control over the governance of the entity or entities
	Independent regulatory authority	It is the establishment of an independent regulatory authority in the railway sector in order to limit the office failures of public decision-makers

Source(s): Authors' own work

2. Review of the literature on rail sector deregulation

We briefly present a theoretical analysis and an empirical synthesis of the deregulation of the railway sector through reform. With this in mind, we present this section in two areas: regulatory and structural reforms.

2.1 Deregulation of the rail sector: regulatory reforms

2.1.1 Independent regulation. Railway economics is the study of the economic problems associated with the provision of rail freight and passenger services. Railways provide a utility of place and time for the people and goods transported (Waters, 2007). As a result, it is a service of general interest to the public and arguably requires control by public institutions. The regulation of public service institutions such as transport has developed along two main lines. The first is the traditional economics of regulation (Pigou, 1932; Samuelson, 1954) and the industrial economics of regulation (Guasch, Laffont, & Straub, 2008; Laffont & Tirole, 1993; Tirole, 1991), which encourage the regulation of urban public transport monopolies, respectively by the state and an independent regulatory authority.

The second axis consists of the political economy of regulation (Posner, 1974; Stigler, 1971, 1972) and the institutional current of regulation (Coase, 1960; Williamson, 1989), which opposes regulation by criticizing respectively the independence of the State and the possibility of higher transaction costs compared with the other solutions available. Meyer (1959), argues that rail regulation is obsolete, so that recourse to markets can work. On this basis, the political economy of regulation shows that in the long run the regulator sees the industry as a customer to be protected and served, and the welfare of the industry becomes the focus of the regulator (Buchanan & Tollison, 1972; Tullock, 1972, 1978).

This study is in line with the institutional current of regulation to argue that regulation of the rail sector may not be the solution to improving sector indicators. This situation largely prevails in sub-Saharan Africa with the embryonic state of the railway sectors for which the introduction of regulatory authorities will entail additional transaction costs. In fact, the rail sector is different from the network sectors that require regulation. Consequently, we have the following hypothesis:

(1) The establishment of a regulatory authority does not have a significant effect on the demand for the transport service.

Empirical studies assessing the effect of regulation on rail sectors are almost non-existent, as the investigations cited above have focused on changes in rail organization. Nevertheless, Friebel, Ivaldi, and Vibes (2010), Wetzel (2008) show that independent regulation of the rail sector can lead to a minimization of infrastructure costs. On this basis, an assessment of rail sector regulation in 20 countries around the world by Laurino *et al.* (2015) shows that regulation improves rail transport service in vertically integrated public infrastructure, but the effects are less significant when operators are privatized. Following them, Smith *et al.* (2018) use a rail sector regulation index constructed by a European survey to show that better regulation has a positive effect on the efficiency of the rail sector, which depends on the horizontal, vertical structure and intensity of use of the network. Investigations show that regulation is important to increase the demand for service in a rail sector with a high degree of competition (several operators) and high use of the rail network (Benedetto, Smith, & Nash, 2017; Nash *et al.*, 2017). Gonzalez (2023) shows that the independence of the regulatory authority significantly reduces accidents and defects in the rail system. From this point of view, the regulatory authority will make rail transport safe and attract passengers.

On the other hand, recent studies have shown that independent regulation makes it difficult to harmonize railway policies in European countries and slows down regional integration of the railways (Scialà & Stroffolini, 2024; Tomo, Iacono, Mercurio, Mangia, & Todisco, 2024). The present study will complete the gap in the literature, namely the effect of the presence of a regulatory authority on the demand for rail transport services in Sub-Saharan Africa. In Africa, compared to the telecommunication sector, the introduction of the railway sector regulator doesn't follow the participation of private companies in the sector. The participation of the private sector is organized by the establishment of concession contracts, which are regularly dealt with the supervisory ministry. But some countries like Senegal and South Africa have regulatory authority.

2.1.2 Operator ownership. The independence, benevolence and efficiency of the State raised by the political economy of regulation raise several questions about the office automation derivatives of public administration. The current of public choice is opposed to public efficiency and the British experiments led to the vertical disintegration of rail transport infrastructure. Indeed, several studies promote the privatization of operators. But it should be recognized that public ownership can take various forms with varying degrees of public control versus managerial autonomy (Waters, 2007). Later, with the popularization of concession operations that ensure management autonomy, the consideration of the agency theory in the concession relationship of the public transport sectors denounces several perceptible limits of privatization (Tirole, 1991). Particularly in the particular case of sub-Saharan Africa, our main limitations are the opportunistic behaviour of operators and the non-compliance of the parties to the concession contract (Bidiasse, 2017; Blanc & Gouirand, 2007; Olievschi, 2013a). With this in mind, we have the following hypothesis:

(2) The privatization of railway operators has a positive effect on the demand for transport services.

Some investigations have assessed the effect of the privatization of operators on the demand for rail transport services. Preston and Robins (2013) show that the privatization of operators has a positive effect on the demand for transport services with the use of a simple linear regression. Following them, Mizutani (2020) shows that privatization positively affects the demand for freight transport, but it is rather public ownership that positively affects the demand for passenger service. Several studies show the positive effect of the privatization of operators on the demand for rail transport services (Resor & Laird, 2013; Tomeš & Jandová, 2017; Wellings, 2014) and infrastructure efficiency (Holvad, 2020; Laurino *et al.*, 2015; Lerida-Navarro *et al.*, 2019). But the opportunistic behaviour of private operators justifies some investigations finding that private ownership has a negative effect on passenger transport demand (Fitzova, 2022). Private companies are operators that rationally maximize their profits, but not necessarily their service costs (Kamaruddin, 2023). Private sector operators help secure investment for the rail sector (Mizutani, 2024).

2.2 Deregulation of the rail sector: structural reforms.

2.2.1 Vertical and horizontal unbundling. Following the opportunistic behaviour of the concessionaire, the incentive regulation proposed to make the market of the incumbent operator questionable with the opening of the market. Indeed, the concessionaire threatens the incumbent operator with the possible entry of a designed (Baumol, Panzar, & Willig, 1982). According to Baumol (2000), potential competition should be what would incentivize a hypothetical efficient railway to invade the market, that is-at-say by making the assumption that the market is contestable. This analysis led to the creation of holding companies to encourage incumbent rail transport operators to perform better. With the increase in logistics needs in countries, the vertically integrated monopoly market in the rail sector is being challenged.

Monopoly operators favour their own service providers. Indeed, the railway sectors benefit from being disintegrated or unbundled to avoid the opportunistic behaviour of operators who prefer to serve their interests (Newbery, 2006). Competition between sectors leads to better accessibility to transport services and in the long term to a reduction in prices following a reduction in infrastructure costs (Baumol *et al.*, 2002). In addition, competition improves the well-being of the consumer. However, depending on the size of the network and the level of economic activity of the State, the degree of vertical separation and competition must be taken into account so as not to render the reforms ineffective (Waters, 2007). Vertical or horizontal separation depends on several constraints of the railway sector, but the theory does not deny its benefits to the railway sector. To this end, we have the following hypotheses:

(1) The disintegration of the railway infrastructure has a positive effect on the demand for transport services.

(2) Competition in rail service has a positive effect on the demand for transport services.

Structural reforms in the rail sector compared to regulatory reforms are subject to great empirical literature. The infrastructure of the railway sector has been the subject of several studies during the period of development of rail transport services in developed countries. The results of the effect of *vertical and horizontal separation* are ambiguous. Indeed, some studies find that *vertical separation* of rail infrastructure has a positive effect on the demand for transport services. Several quantitative analyses that use econometric methods (Nash, 1997; Tomeš & Jandová, 2017; Van de Velde *et al.*, 2012) and case studies (Bošković & Bugarinović, 2015; Laurino *et al.*, 2015) show that vertical separation has a positive effect on the demand for transport services. With the use of a fixed-effect linear regression in the data of the railway sectors of European countries, Mizutani (2020) shows that vertical integration decreases the demand for passenger service. Furthermore Asmild *et al.* (2009), Cantos, Pastor, and Serrano (2010) and Smith *et al.* (2018) show that vertical separation improves the efficiency of the railway infrastructure. In contrast, other investigations show that vertical separation does not influence the overall demand for the transport service.

The quantitative approach of Laabsch and Sanner (2012) which uses econometric methods, shows that the vertical separation of the railway infrastructure has no significant impact on the demand for passenger transport services, unlike a vertically integrated sector, which achieves better results. In the same vein, studies show that vertical separation has no significant effect on the efficiency of the railway industry. For example, we have the studies of Laabsch and Sanner (2012), Wetzel (2008). Álvarez-SanJaime, Cantos-Sánchez, Moner-Colonques, and Sempere-Monerris (2024) show that vertical separation and specialization of operators by type of transport (freight and passenger transport) lead to greater efficiency in the provision of services and make it possible to fight against market powers. A long-term effect of vertical separation on rail transport supply is conditioned by market deconcentration (Cantos-Sánchez, Moner-Colonques, & Sempere-Monerris, 2023). Indeed, the vertical separation of the sector without competition in the market will reduce the service offer in the short term.

Horizontal separation, which is to a lesser extent considered by the integration of a holding company or the competitive bidding of the incumbent operator to a large extent in the railway sector, has great literature with ambiguous results. Indeed Mizutani (2015) shows that the holding model does not have a significant effect on the efficiency of the rail sector. Following him, Smith *et al.* (2018) partially oppose this result and shows that a holding company is preferable to a complete separation of the infrastructure. Indeed, their studies show that the holding company has a better effect on the demand for overall rail transport service. Fitzova (2022) confirms this finding and suggests that a holding company model has some advantages over full vertical separation in terms of efficiency, but these can be offset by reduced competition. The structure of the holding company increases the total costs of the service (Nakamura & Mizutani, 2023). Separation of freight and passenger transport increases efficiency in the rail sector (Cantos-Sánchez *et al.*, 2023; Alsaedi, 2023). Competition in freight is beneficial, while competition in passenger transport depends on the level of competition. The benefits of competition may outweigh the costs of vertical separation when competition is more widespread. Nevertheless, work that opposes competition in the sector recognizes that it lowers infrastructure costs. Indeed, opening the market for railway services to competition can, in principle, yield substantial social benefits, partly because operators get more incentives to become more cost-efficient and more responsive to consumer demand (Ait Ali & Eliasson, 2022).

In contrast, econometric studies argue that horizontal separation has a positive effect on the efficiency of the rail sector (Cantos *et al.*, 2010; Ivaldi & Vibes, 2008) and the overall demand for rail transportation service (Lalive & Schmutzler, 2008; Mizutani & Uranishi, 2020; Tomeš & Jandová, 2017; Van de Velde *et al.*, 2012). Some studies show that the entry model has an impact on the profitability of the rail system (Nakamura & Mizutani, 2023; Nakamura & Sakai, 2020). As a result, studies emphasize the degree of competition in the sector. This is because a small number of competitors can create a high degree of competition. The effects of horizontal separation depend on how competition is introduced. Indeed Cantos *et al.* (2012) and Friebel *et al.* (2010) insist on policies for the sequential implementation of vertical and horizontal restructuring reforms and on the implementation of reforms that combine vertical and horizontal restructuring to promote an increase in rail transport sectoral indicators. To summarize this literature, we present Table 2, which helps us to show the difference of the effects of each reform in the railway sector by the variety of experiences in Europe, the USA and other countries.

The literature on railway sector reforms highlights three observations. The first to note is that there are fewer investigations into regulatory reforms than those into structural reforms. Indeed, structural reforms have been the most applied in the sector and it is following the British experience that several countries have conceded to the sector while keeping shares in the board of directors. The second is the variety of methods used to analyse the effect of reforms on the demand for transport services in the rail sector. The last observation is a lack of literature in the African and South American regions, which have the least efficient railway sectors. In this study, the ability to propose a reform model to improve the demand for rail transport service is relevant to the development prospects of African economies.

3. Methodology

In this section we present the specification of the empirical model with the estimation method and the description of the data used in this study.

3.1 Description of data and variables

The data used in this study are collected from 26 countries in sub-Saharan Africa over 16 years (2000–2015) presented in Table 3. They come from a variety of sources: the World Bank, the UN, the AfDB and the national reports of the railway sector. The non-availability of transport data does not allow the whole panel to be completed. Some railway sectors in the sub-region (7) have been withdrawn from the 33 countries with a rail network due to a lack of data or by the recent construction of the rail transport service. The railway sectors of Togo and Mauritius are illustrative in this respect. The status of data availability is presented by country and by regional block in Table 2. In the various databases, where data were lacking, we supplemented with the national and continental reports and communications of the railway sectors. The various indicators of deregulation were collected in reports and communications from national and continental sectors and global databases.

The variables of the study and their different measures are presented in Table 4. Passenger rail transport demand is measured in passengers per kilometre and freight transport demand in tonnes per kilometre (Lerida-Navarro *et al.*, 2019; Mizutani & Uranishi, 2020). The non-availability of data on the total coverage of the panel does not allow for data on the number of employees in the rail sector. Nevertheless, the variables of interest were reported by the B.A.D. (2015). This report is very useful in corroborating the data collected on the situation of the railway sectors in the sub-region.

The reforms evaluated are measured differently depending on their applicability. Vertical separation and the establishment of an independent regulatory authority are binary. The

Table 2. Synthesis of studies on railway reforms

Authors	Article type	Reform	Results	Recommendation
USA and developed countries				
Laurino *et al.* (2015)	A comparative analysis of regulatory practices in developed countries	Structural reforms	The efficacy of structural reform depends on the transport system, political context, economic situation, business and regulatory environment	Countries have to improve the level of transport sector regulation to develop the profitability of reforms in railway infrastructure
Grimm and Pittman (2018)	A comparative analysis of regulatory practices in USA	Regulatory and Structural reform	Structural reform impacts rail mergers. The recent US deregulation process expanded competitive access, and the antitrust exemption removal expanded competitive access	States' regulator has to improve competition policy issues in North America, including vertical competitive effects in North American rail mergers and integration of competitive access neighbouring countries
Rowangould (2013)	Case study	Privatization reform	The public funds are aimed at increasing freight rail capacity with the goal of diverting some goods currently moved by truck to rail. While the benefits of moving goods by rail are relatively clear, it is unclear if public decision makers can effectively identify strategic rail investments that will achieve their policy goals	Many flaws and challenges affecting the benefit estimates that public funding decisions rely on. Various regulatory reforms and policy interventions may offer more effective and reliable outcomes to private operators
Kamaruddin (2023)	An econometric analysis by a Tobit model on Japan rail firms	Privatization reforms	private firms are profit-maximizing entities but not necessarily cost-efficiency maximizers. Fifth, measuring all the performance dimensions and interpreting the results relative to each other is essential	To privatize operators but also improve the quality of institutions in the country to develop the quality of regulation
Shin (2024)	An econometric analysis by a Cobb–Douglas production function on annual financial statement	Regulatory and structural reform	the rail industry became less competitive with regulatory reform, even if the rail industry had an increasing labour productivity trend. There was a strong negative correlation between the market concentration index and labour productivity	The regulator has to improve the level of competition with an incentive strategy despite the abolishment of before and after the abolishment of the Interstate Commerce Commission (ICC)

(*continued*)

Table 2. Continued

Authors	Article type	Reform	Results	Recommendation
Nakamura and Mizutani (2023)	An econometric analysis by a translog cost function with data on large Japanese private railway companies	Structural reform	Public ownership can reduce costs for companies whose financial administration is in a crisis situation, while a holding company structure increases total costs	State ownership is profitable for the rail sector but the State has to invest in infrastructure efficiency and development
Europe				
Wetzel (2008)	An econometric analysis by a multioutput distance function model on railway operators	independent regulator	The establishment of an independent regulator has a positive effect on technical efficiency, but a negative on the right access of operator	The establishment of an independent regulator is better with the implementation of other structural reforms to improve access rights
Friebel *et al.* (2010)	An econometric analysis by a frontier model on railway operators	independent regulator and vertical separation	The introduction of multiple reforms in a package has negative effects, while sequential reforms improve efficiency	Introducing an independent regulator must be applied before the competition's deregulation process
Smith *et al.* (2018)	An econometric analysis by a frontier model on railway operators	Regulatory and structural reform	the cost-reducing benefits of regulatory reform depend on the degree of (actual or desired) market openness, vertical structure, and the intensity of network usage	The establishment of an independent regulator is better with the implementation of other structural reforms to improve the benefits of railway operators
Benedetto *et al.* (2017)	Qualitative analysis and observation of the regulatory context	Regulatory reform	European rail regulators, in general, exhibit many of the features of ideal regulation; in particular around key features, such as independence, resourcing, longevity and expertise, transparency and, in turn, stability and predictability	regulators must play a greater role in regulating the efficiency and quality of infrastructure managers, and potentially becoming more involved in the designing stages of passenger market opening
Tomo *et al.* (2024)	Qualitative analysis and observation of the regulatory context	Regulatory reform	Governance and organizational aspects of Regulatory Authorities are critical to ensuring that regulatory tasks are appropriately accomplished	The introduction of common legislation may lead to coercive isomorphism, but specific features characterizing the different national contexts may mitigate the pressures, resulting in differences among Regulatory Authorities in terms of governance, management and organization

(*continued*)

Table 2. Continued

Authors	Article type	Reform	Results	Recommendation
Mizutani (2024)	An econometric analysis with the pooled OLS, the fixed effects, and the random effects models and the fixed effects model	Regulatory and structural reform	the competitiveness of passenger railways has a positive relationship with investment	Strong economic conditions and the competitive situation in passenger rail are important for investment than regulatory reforms
Álvarez-SanJaime *et al.* (2024)	An econometric analysis with three stage least squares (3SLS)	Regulatory and structural reform	Vertically separated and specialized in passenger services operators display the strongest improvements in efficiency levels, while integrated incumbents facing competition show the lowest market power indexes	Regulators have to improve the level of competition management and insure investment of operators
Preston and Robins (2013)	An econometric analysis and extrapolating methods of the demand for passenger rail services	Privatization reform	Since privatization, rail demand has grown strongly but our analysis indicates that transitional disruptions suppressed demand by around 9% over some prolonged period	Countries have to privatize their operators because the reforms have had advantages in terms of lower fares and better service levels than otherwise would have been the case of public ownership
Africa and developing countries				
Bidiasse (2017)	Regulatory process analysis in Cameroon	Regulatory reform	The regulatory by the State lead to decrease the level of investment in the sector with non-compliance with contract clauses by the stakeholders	States have to improve the quality of contract by ensuring the compliance of stakeholders and their responsibilities in the sector, like investment, selling, rail development and pricing
Havenga, De Bod, Simpson, Swarts, and Witthöft (2021)	Case study	Regulatory reform	Various regulatory policy challenges have resulted in a strong engineering ethos to overcome technical challenges, such as high-speed bogies, seamless welding and moving frogs	The state has to secure and protect the subsidy with regulations limiting road transport service provision. Additionally, they have to disintegrate the network, which became unaffordable and uncompetitive in its current form

(*continued*)

Table 2. Continued

Authors	Article type	Reform	Results	Recommendation
Buthphorm, Sukhotu, and Hengsadeekul (2024)	An econometric analysis by a SEM (structural equation modelling)	Structural reform	Rail infrastructure, mode choice, and technology have a great effect on the expansion of rail freight transport in Thailand. The rail freight transport system, rail performance, and Thailand's rail infrastructure development strategy were significant direct predictors of rail freight expansion	Developing countries have to increase the level of competition in the sector

Source(s): Authors' own work

Table 3. Countries in the railway sectors selected for this study

No	Country	Data coverage	No	Country	Data coverage
Central Africa			*West Africa*		
1	Gabon	2000–2015	14	Benin	2000–2013
2	Cameroon	2000–2015	15	Burkina Faso	2000–2012
3	Congo, Dem. Rep	2000–2015	16	Ivory Coast	2000–2012
4	Congo, Rep	2000–2012	17	Ghana	2000–2015
Southern Africa			18	Mali	2000–2012
5	Angola	2000–2013	19	Mauritania	2000–2015
6	Botswana	2000–2012	20	Nigeria	2000–2015
7	Eswatini	2000–2013	21	Senegal	2000–2015
8	Madagascar	2000–2012	*East Africa*		
9	Malawi	2000–2015	22	Ethiopia	2000–2015
10	Mozambique	2000–2015	23	Kenya	2000–2015
11	South Africa	2000–2015	24	Sudan	2000–2012
12	Zambia	2000–2012	25	Tanzania	2000–2012
13	Zimbabwe	2000–2015	26	Uganda	2000–2015

Note(s): Total: 382 observations for 26 countries
Source(s): Authors' own work

variable for these two reforms takes the value 1 when the sector is vertically separated or regulated by an independent authority, and 0 otherwise. Regulatory reform of the share of capital under private ownership is measured on a scale of 0 to 1. Regulatory reform of private sector ownership and horizontal structural reform are measured on a scale of 1 to 3. Horizontal structural and organizational reform involves a holding company which allows governance to be separated without distorting the horizontal integration of the operator. The presence of this unbundling policy in SSA countries allows us to take it into account between total horizontal integration and horizontal separation as (Nakamura & Mizutani, 2023). Regulatory reform of ownership takes into account the mixed presence of public and private operators. The ownership mix of operators is advantageous for network sectors in terms of information symmetry (Perrot, 1997). The structural reform of the number of operators is linear, as it takes into account the number of operators in the rail sector. The main purpose of this reform is to assess the effect of the devolution of rail markets. The two horizontal unbundling reforms are

Table 4. Presentation of variables and their measures

Type	Code	Wording	Measure	VIF [1/VIF]
Variables explained	DTFP	Passenger rail demand	Linear P/km	–
	DTFF	Demand for rail freight transport	Linear T/km	–
Variables of interest	RSSV	Structural reform: vertical separation	0 – not separated 1 – Vertical separation	1.87 [0.5346]
	RSSH1	Structural reform: horizontal separation	0 – not separated 1 – Separated by holding company 2 – Horizontal separation	2.36 [0.4237]
	RSSH2	Structural reform: horizontal separation – number of operators	Linear	3.82 [0.2621]
	RRPP1	Regulatory reform: privatization of the operator – presence of a private operator	0 – public property 1 – Pub/private property 2 – Private property	1.97 [0.5072]
	RRP02	Regulatory reform: operator privatization – private sector participation rate	Between 0 and 1	2.33 [0.4300]
	RRAR	Regulatory Reform: Regulatory Authority	0 – no regulatory authority 1 – Regulatory Authority	1.69 [0.5910]
Control variables	LOCOM	Numbers of locomotives	Linear	3.07 [0.3254]
	RND	Rail network density	Linear	1.44 [0.6967]
	RPR	Rural population rate	Between 0 and 0.5	2.50 [0.3993]
	GDPC	Gross domestic product per capita	Linear	2.73 [0.3661]

Note(s): Mean VIF (Variance inflation factor): 2.38
Source(s): Authors' own work

not identical, as the first evaluates the existing horizontal separation, but the second evaluates the degree of unbundling. The two variables differ and their correlation is less than 80%.

The transport demand variables (freight, passenger), the number of locomotives and GDP per capita are put in logarithmic form. As the density of the rail network is strongly correlated with the number of locomotives, we divide it by the total population of the country. The variance inflation test is performed and the results are presented in Table 3. The descriptive statistics, the different data sources and the multicollinearity coefficients of the variables are presented in Appendix 1. The multicollinearity coefficients and the results of the variance inflation test show that there is no correlation between the different variables in the study.

3.2 Estimation model specification

The study's empirical model is in line with work in the literature (Mizutani & Uranishi, 2020; Smith *et al.*, 2018). The model is developed on the basis of a global demand function for sub-Saharan rail transport and to study how structural and regulatory deregulation affects demand for freight and passenger rail services. The fundamental demand theory of transport economics formulates that the quantity of rail transport (Q) is affected by the price of the service (P) and the level of people's income (Y). The literature has questioned the geographical effect of rail on transport demand. In addition to geographical conditions, quality of service and operator management are implicated in the performance of rail sectors (Baumol & Willig, 1999; Quandt & Baumol, 1966). This is the set of service conditions and constraints (N). Equation (1) shows the rail transport service demand function. Other endogenous or endogenous factors (O) can affect transport demand. In this study, we cannot unfortunately use the price of service because of the unavailability of data for some countries of the panel. Just a few numbers of countries have data on the price of transport, especially where prices are regulated. Many studies in the literature faced the difficulty of collecting data on prices in the railway sector and don't use them (Laurino *et al.*, 2015; Nash *et al.*, 2017, 2019; Smith *et al.*, 2018; Mizutani & Uranishi, 2020).

$$Q = f(Y, P, N, \mathrm{D}, O) \tag{1}$$

The aim of deregulation (D) is to affect the performance and service quality of rail operators. With this in mind, following the literature, we consider that deregulation can affect service demand (Nash *et al.*, 2017). Equation 2 is the empirical model specification for this analysis. The vector DTF_t is composed of the quantity of passengers ($DTFP$) and freight ($DTFF$) demand. The RS vector$_n$ represents structural reforms and the RR vector$_m$ represents regulatory reforms, as shown in Table 2. Control variables representing service constraints ($LOCOM$, NRD and RPR) and population income levels ($GDPC$). The unavailability of data on the price of the service does not allow us to consider the pricing of the service.

$$DTF_t = \alpha_0 + \sum \alpha_n RS_n + \sum \alpha_m RR_m + b_1 LOCOM + b_2 RND + b_3 RPR + b_4 GDPC \tag{2}$$

The empirical model is estimated using the method of seemingly unrelated regressions (SURE) in accordance with the study by Smith *et al.* (2018). This choice is justified by three facts about empirical systems. The first is to facilitate interpretation. Indeed, each variable is divided by the sample means using a system of equations with rail and freight demand that can simultaneously influence each other (Smith *et al.*, 2018). This study aims to model seemingly unrelated regression on panel data using dummy variables (Pratama *et al.*, 2023). The traditional OLS method can be applied independently to each regression equation as estimation tools. Although each equation in Equation (2) does not directly interact with each other, it is impossible in practice to collect or measure all possible variables that affect the service offering. In other words, although these equations are apparently unrelated, they actually have unobserved properties in common and should be treated as a group for the estimation of their parameters. The interpretive advantage of using SURE to estimate the supply of transport service is that it allows each regression model to take advantage of the information contained in the other regression equations by accounting for the correlated errors between the different equations caused by unobserved characteristics (Tiong, Ma, & Palmqvist, 2023; Washington, Karlaftis, Mannering, & Anastasopoulos, 2020).

Secondly, this specificity makes it possible to gain efficiency in estimation by combining information on different equations (Fiebig, 2001; Srivastava & Maekawa, 1995). With multivariate longitudinal data, time series data, or repeated measurements, the M responses contained in Y are generally correlated with population data. M response in this study are dependent variables, especially the demand for passenger and freight transport by rail. M contained in Y are generally correlated because of regional specificities. In addition, in analyses of economic data or data from the social sciences, it is not uncommon for prior information on the phenomenon under study to allow the analyst to specify a system of M regression equations. The error terms in these equations can therefore have the same characteristics, resulting in contemporary correlations between the equations. The explanation of the supply of the railway sector in different geographical locations implies that the answers M contained in Y are correlated. The subgroup's M responses are characterized by unobserved heterogeneity with the level Skewes and Kurtosis test in the Appendix. A system of 2 or more regression equations (one equation for each answer) in which some rectifiers contained in X are absent from some regression equations corrects for unobserved heterogeneity (Parsaeian, 2024). This is especially true for multivariate economic data that refer to general theories (e.g. investment equations, production functions) or applications dealing with the explanation of a certain economic activity (i.e. production functions).

The final motivation is to impose and/or test restrictions that involve parameters in different equations. Indeed, the significance of the Breusch–Pagan independence test of estimation makes it possible to ensure that there are no restrictions. This test of cross-sectional dependence based on Sargan's difference test for over-identifying restrictions in a dynamic panel data model, but again assuming homoskedasticity within each cross section and under a slope homogeneity assumption. To ensure the robustness of these results, we estimate regressions using the ordinary least squares method on samples of countries in the different subregional blocks of sub-Saharan Africa (Central, Southern, Western and Eastern). The results of Skewes and Kurtosis for the dependent's variables show the existence of endogeneity of the demand of rail transport service. Indeed, the asymmetry coefficient of Skewes is 2.282 and 6.79 respectively for passenger and freight transport. On the other hand, the distribution's concentration coefficient of Kurtosis is 10.421 and 49.272 respectively for passenger and freight transport. These values mean that many African countries have rail service demand least than the mean continental level. We have, therefore, African countries with a high and a least level of rails demand transport compared to the mean level in the continent. This endogeneity leads us to apply a subregional estimation. The reduction in the individual dimension (number of countries) justifies the use of this estimation model. This estimate will corroborate the results of the general model despite the hybrid deregulation models of the rail sector in the different regional blocs.

4. Study results and interpretations

We present the results of the study in two axes. The first axis presents the results of the general model estimation using seemingly unrelated regressions (SURE). The second axis presents the results of the estimation specific to the railway sectors of the regional blocks with the use of random-effects ordinary least squares.

4.1 General model estimation

The results of the general estimation are presented in Tables 5 and 6 for passenger and freight rail transport demand, respectively. Horizontal separation of the rail sector positively affects passenger demand, but has an inverse effect on freight demand. This result is in line with the study by Mizutani and Uranishi (2020).

Indeed, structural deregulation has a different effect on demand for passenger and freight transport. Nevertheless, we find that vertical separation linked to the number of operators in the sector positively affects demand for freight transport. So, the application of a holding company mainly improves demand for passenger transport and has a negative effect on demand for freight transport. This result corroborates the results of Nakamura and Sakai (2020) on the entry model for new operators and the management of competition. In Africa, with the least level of technology development, public ownership cannot reduce costs for companies whose worst financial administration led to expensive rail transport prices. On the other hand, vertical separation has no significant effect on passenger demand, but has an inverse relationship with freight demand. Vertical separation in SSA usually results in the concession of the incumbent railroad operator to a foreign private company. This company favours the transport of goods for export, which maximizes its profits, while neglecting domestic trade and passenger transport. But in accordance with the work of Cantos-Sánchez *et al.* (2023), vertical separation leads to better operator efficiency in highly incentivizing environments. Operators who manage rolling stock and infrastructure must respect contracts and commitments for

Table 5. Results of the general estimate for passenger transport demand

Variables	L(DTFP) Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
RSSV	0.603***	0.287*	–	–	–	–
	(0.206)	(0.157)	–	–	–	–
RSSH1	0.350**	0.358**	–	0.350**	–	–
	(0.143)	(0.145)	–	(0.146)	–	–
RSSH2	0.0957	0.162	–	0.177	–	–
	(0.198)	(0.194)	–	(0.195)	–	–
RRPO1	−0.0333	–	0.0412	–	0.0650	–
	(0.0967)	–	(0.0944)	–	(0.0953)	–
RRP02	−0.921***	–	−0.585**	–	−0.670**	–
	(0.299)	–	(0.283)	–	(0.285)	–
RRAR	0.166	–	0.695***	–	–	0.734***
	(0.256)	–	(0.223)	–	–	(0.223)
L(LOCOM)	0.286***	0.256***	0.327***	0.264***	0.412***	0.296***
	(0.0673)	(0.0653)	(0.0636)	(0.0655)	(0.0582)	(0.0622)
RND	65.07	60.09	65.63	62.87	71.59	53.44
	(64.94)	(65.14)	(66.01)	(65.41)	(66.81)	(65.52)
RPR	−0.0471***	−0.0412***	−0.0491***	−0.0411***	−0.0507***	−0.045***
	(0.00736)	(0.00714)	(0.00734)	(0.00717)	(0.00741)	(0.00706)
L(GDPC)	−0.590***	−0.617***	−0.632***	−0.624***	−0.607***	−0.649***
	(0.119)	(0.121)	(0.118)	(0.121)	(0.119)	(0.118)
Constant	11.08***	10.87***	12.15***	11.05***	11.91***	12.03***
	(1.200)	(1.217)	(1.178)	(1.218)	(1.190)	(1.182)
Observations	382	382	382	382	382	382
R-squared	0.274	0.246	0.237	0.240	0.217	0.227
B–P test°	6.762***	7.495***	8.195***	8.438***	11.926***	7.172***

Note(s): °Breusch–Pagan of independence test
Standard errors in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source(s): Authors' own work

investments that can improve the quality of services. According to Bidiasse (2017), some African countries do not ensure that stakeholders respect contracts and their responsibilities in the sector. So, rail sector equipment is becoming old and useless for operators in many countries, while the population is spending too much money on transport between rural areas and towns.

Regulatory reforms have mixed effects on transport demand. The privatization of operators has a positive impact on freight transport demand. This result corroborates works in the literature (Mizutani & Uranishi, 2020; Tomeš & Jandová, 2017; Wellings, 2014). We find that the rate of capital privatization of the rail sector has a positive relationship with the demand for freight transport and an inverse relationship with passenger transport. Indeed, when the sector is safer controlled by a private operator, the latter rationally carries out these activities in his personal interest by favouring the transport of goods to the detriment of passenger transport, which gives less profit. This assertion is consistent with the analysis of (Kamaruddin, 2023) which justifies that the private interest of operators can influence the offer of rail transport services in terms of price and quality. To mitigate this situation, the public sector needs to maintain significant shares in the sector's capital to protect internal trade and rail travellers. The work of Bidiasse (2017) explains various difficulties with the agency model and the roughness of concession contracts to improve the transport service. Mizutani and Uranishi (2020) demonstrate that the impact of public ownership on protecting consumers of the service is very important, especially in the rail sector, which is efficient for the transport and external traffic of goods. With this in mind, the application of a regulatory authority can be a solution to

Table 6. Results of the general estimate for freight transport demand

Variables	L(DTFF) Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
RSSV	0.443***	0.269**	–	–	–	–
	(0.168)	(0.128)	–	–	–	–
RSSH1	−0.583***	−0.587***	–	−0.594***	–	–
	(0.116)	(0.119)	–	(0.119)	–	–
RSSH2	1.406***	1.480***	–	1.494***	–	–
	(0.162)	(0.159)	–	(0.160)	–	–
RRPO1	−0.298***	–	−0.269***	–	−0.239***	–
	(0.0790)	–	(0.0828)	–	(0.0847)	–
RRP02	0.244	–	0.549**	–	0.439*	–
	(0.244)	–	(0.248)	–	(0.253)	–
RRAR	0.205	–	0.893***	–	–	0.836***
	(0.209)	–	(0.196)	–	–	(0.197)
L(LOCOM)	0.262***	0.285***	0.387***	0.292***	0.496***	0.417***
	(0.0550)	(0.0534)	(0.0558)	(0.0536)	(0.0518)	(0.0549)
RND	137.9***	171.8***	81.52	174.4***	89.18	112.7*
	(53.05)	(53.29)	(57.87)	(53.59)	(59.41)	(57.88)
RPR	−0.00254	−0.00573	0.00462	−0.00567	0.00251	−0.000391
	(0.00601)	(0.00584)	(0.00643)	(0.00588)	(0.00659)	(0.00623)
L(GDPC)	0.498***	0.518***	0.691***	0.511***	0.722***	0.725***
	(0.0974)	(0.0990)	(0.103)	(0.0995)	(0.106)	(0.104)
Constant	1.932**	1.726*	0.761	1.894*	0.457	0.612
	(0.980)	(0.996)	(1.033)	(0.998)	(1.058)	(1.044)
Observations	382	382	382	382	382	382
R-squared	0.274	0.246	0.237	0.240	0.217	0.227
B–P test°	6.762***	7.495***	8.195***	8.438***	11.926***	7.172***

Note(s): °Breusch–Pagan of independence test
Standard errors in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source(s): Authors' own work

this problem. In this sense, the establishment of a regulatory authority has a significantly positive effect on the demand for passenger and freight transport (Laurino *et al.*, 2015; Smith *et al.*, 2018). On the other hand, it significantly affects transport demand only in the model that does not consider the other reforms. Taking into account the regulatory environment as a whole, the activity of a regulatory authority may not influence the service offer, particularly because of the weakness of incentive mechanisms. Regulatory environments have a great influence on the services offered in the rail sector (Gonzalez, 2023; Scialà & Stroffolini, 2024; Tomo *et al.*, 2024).

The number of locomotives in the railway sector naturally has a significantly positive effect on the overall demand for transport (AfDB, 2015; Cantos *et al.*, 2012; Lerida-Navarro *et al.*, 2019; Mizutani, 2019; Mizutani & Uranishi, 2020; UIC, 2017). On the other hand, network density relative to the population has a mixed effect on transportation demand. Indeed, the distance of rail negatively affects the demand for passenger transport, but does not have a significant effect on the demand for freight transport. Operators negotiate contracts with industrial and oil companies to transport natural resources (AfDB, 2015). In some sub-Saharan African countries, some rail networks are used exclusively for the transport of natural resources and products for export. The Democratic Republic of the Congo and Eswatini are illustrative. As a result, several rail networks have become obsolete and unusable for transporting populations, as the operator or the state has decided to abandon it for reasons of productivity or specific to the nation (Olievschi, 2013b). But a large transportation network improves the demand for long-distance passenger rail transportation at minimal costs.

The income level of the population has a mixed effect on the general demand for transport. Indeed, GDP per capita has a positive relationship with the demand for freight transport (Mizutani & Uranishi, 2020). Naturally, in the countries with the least wealth, people will move towards the world of transport that minimizes the costs per kilometer to transport goods. But in some cases, for the demand for freight transport, the private operator (concessionaire) prices and contracts the transport of goods and services to make a profit. Therefore, the service is offered to the highest bidder. In contrast, GDP per capita has an inverse relationship with passenger transport demand (Mizutani, 2020; Smith *et al.*, 2018). In the country with a large market size, rail transport for passengers is not favoured by consumers, as the rolling stock is outdated and characterized by poor quality of service. For intercity transport, for example, users in some countries prefer to travel by road, to the detriment of the rail network (World Bank, 2020a, b). Very few countries in the sub-region, such as South Africa, are implementing policies to transition from road to rail transport (Havenga *et al.*, 2021). The rate of the rural population is a significant variable in the demand for transport (Mizutani, 2019). The rail sector is important for rural people (Tovar, 2019).

4.2 Model estimation specific to regional block rail sectors

The estimation results are presented in Table 7. Following Hausman tests, which have results that vary between fixed and random effects, we have opted to use random-effect regressions so as not to omit certain variables from the results. In comparison with the results of the general estimation model, we interpret the results that were not robust and corroborate the most relevant ones.

In the Central African bloc, we find that the vertical separation of the rail sector negatively affects demand for freight and passenger transport. In Cameroon, Bidiasse (2017) demonstrated that the quality of concession contracts does not ensure the quality of service. On the other hand, private sector ownership leads to greater demand for transport. This situation is compounded by the low performance of the public operator in the Republic of Congo. It is important to note that only Gabon has introduced a rail sector regulator, but the variable concerned remains significant within the regional bloc. This situation supports the analyses that defend the effect of rail sector regulation on consumer protection and better rail use (Friebel *et al.*, 2010; Nash *et al.*, 2017; Nash *et al.*, 2019). In fact, the number of locomotives has a significantly positive effect only on demand for freight transport, but a negative effect on demand for passenger transport. This situation confirms the theorists of the political economy of regulation on the inability of state regulation in regional bloc countries to protect consumers. Regulatory authorities are important in the rail sector to encourage operators to be efficient in allocating and offering their services.

In the Southern African bloc, horizontal separation has a positive effect on demand for passenger transport. In fact, the rail sector applies a specific separation by granting operators the exclusive right to transport passengers to a single operator (the incumbent) and goods to another operator (the new operator). Several studies in the literature have defended the effectiveness of this model, which is widely used in European countries (Baumol *et al.*, 2002; Cantos *et al.*, 2010; Guasch *et al.*, 2008; Holvad, 2020; Mizutani, 2020; Nash *et al.*, 2019; Tomeš & Jandová, 2017). This explains the positive effect of the number of operators on the demand for freight transport. Vertical separation, on the other hand, has a negative effect on freight transport. In fact, some rail sectors are unbundled horizontally because operators specialize in transporting mining resources for companies (Lamarque & Nugent, 2022). In contrast to the Central African bloc, regulation negatively affects the demand for passenger transport. Indeed, in Southern Africa, the regulators are regional [4]. Regulation has conflicts of interest with regulatory authorities at the national level (Scialà & Stroffolini, 2024). Indeed, national regulatory authorities promote the integration of trade in goods between countries. Havenga *et al.* (2021) show that national regulatory policies in South Africa are implementing policies for the transition from road to rail transport. In addition, several

Table 7. Results of the estimation specific to the railway sectors of the regional blocs

Country block	Central Africa		Southern Africa		West Africa		East Africa	
Variables	DTFP	DTFF	DTFP	DTFF	DTFP	DTFF	DTFP	DTFF
RSSV	−0.821*	−1.004***	0.310	−0.196	−0.279	−0.100	0.355	−0.0390
	(0.483)	(0.355)	(0.343)	(0.219)	(0.455)	(0.381)	(0.539)	(0.112)
RSSH1	0.272	0.0769	0.589***	−0.310**	0.644	−0.837**	2.402***	−1.269***
	(0.196)	(0.144)	(0.212)	(0.136)	(0.396)	(0.332)	(0.479)	(0.0993)
RSSH2	−0.590	0.204	0.270	0.935***	0.279	1.196**	−0.0849	1.850***
	(0.478)	(0.352)	(0.186)	(0.119)	(0.697)	(0.584)	(1.170)	(0.242)
RRPO1	0.107	0.310	0.245	−0.130	−0.152	1.407***	0.176	−0.125*
	(0.276)	(0.203)	(0.164)	(0.105)	(0.279)	(0.233)	(0.340)	(0.0705)
RRP02	1.341***	0.926***	−1.690***	−0.302	−1.068	−2.396***	3.021**	1.649***
	(0.307)	(0.226)	(0.452)	(0.289)	(0.805)	(0.675)	(1.226)	(0.254)
RRAR	0.841**	0.0868	−0.882***	−0.0598	0.557	1.143*	−0.170	0.0563
	(0.356)	(0.262)	(0.316)	(0.202)	(0.705)	(0.590)	(1.114)	(0.231)
L(LOCOM)	−0.709*	0.618**	0.720***	0.839***	0.303**	−0.584***	0.352**	0.0717**
	(0.392)	(0.288)	(0.132)	(0.0846)	(0.131)	(0.110)	(0.144)	(0.0298)
RND	254.5	−3.757	42.50	19.88	508.4	−631.2**	217.7	78.40*
	(248.1)	(182.6)	(54.14)	(34.61)	(364.0)	(305.0)	(221.6)	(45.91)
RPR	0.109***	−0.00557	−0.0565***	−0.000451	−0.082***	−0.0933***	−0.101*	0.00518
	(0.0304)	(0.0224)	(0.0109)	(0.00698)	(0.0265)	(0.0222)	(0.0544)	(0.0113)
L(GDPC)	0.737**	0.412*	−1.123***	0.628***	−0.485	−0.855***	−0.233*	0.162
	(0.295)	(0.217)	(0.145)	(0.0926)	(0.333)	(0.279)	(0.494)	(0.102)
Constant	−1.204	1.544	13.38***	−0.515	12.87***	19.11***	9.592	4.836***
	(3.098)	(2.280)	(1.674)	(1.070)	(3.586)	(3.004)	(7.571)	(1.568)
Observations	61	61	131	131	116	116	74	74
Country	0.632	0.748	0.652	0.915	0.407	0.457	0.624	0.924
B–P test°	43.780***		4.208**		33.740***		27.060***	
Hausman Test	26,435***	18,351***	3,131***	2,315***	12,435***	10,110***	9,992***	11,775***
	RE	RE	RE	RE	RE	RE	RE	RE

Note(s): °Breusch–Pagan of independence test
Standard errors in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source(s): Authors' own work

countries share common networks that facilitate the transport of freight and, to a certain extent, passengers [5].

In the West African bloc, the privatization of the operator and the mix of ownership are improving the demand for freight transport, with a large wave of service concessions to foreign companies. This is particularly the case in Senegal and Côte d'Ivoire. The presence of a regulatory authority has a positive effect on demand for freight transport. Countries have shared corridors and concessions that are negotiated jointly with the two sectors. Senegal and Mali on the one hand (Transrail concession) and the Sitarail concession in Burkina Faso and Côte d'Ivoire on the other are illustrative of this. The number of operators has a positive impact on freight transport demand. West Africa is strongly characterized by integrated policies; the rail sector has varying levels of development in the different countries. Regulation of the sector protects domestic trade, which is stimulated between the countries with which it shares the corridor. Alimo *et al.* (2022) shows in the same vein that operators have more freight wagons than passenger wagons between two guys in West Africa. The Senegalese regulatory authority is illustrative in this respect with an increase in freight transport in neighbouring countries compared to passenger transport over the last decade (AfDB, 2015). Mizutani (2019) corroborates this maxim of the positive effect of the sharing of a corridor between countries on corroborates this maxim of the positive effect of corridor sharing between countries on national rail transport demand in general, but this study is limited to an effect on freight transport demand in the West African bloc. Rail deregulation reforms have no significant effect on passenger demand. The private sector's share of the sector has a negative impact on demand for transport. Operators are rational in transporting goods and services as a result of market contracts between countries in the sub-region (Cissokho, 2022). This neoliberal policy has led to the construction of railways to exploit resources in some countries in the sub-region.

In the East African bloc, the positive effect of the number of operators on freight transport demand corroborates the situation in the West African bloc. On the other hand, the private sector's share of the capital has a positive effect on overall demand for transport. The quality of institutions in the sub-region makes it possible to put in place incentive mechanisms for operators to comply with contractual clauses. The quality of contractual regulation in the countries of the sub-region is favourable for the sub-region's network sectors (Lamarque, 2022; World Bank, 2020a, b). Rail transport is good enough to ensure integration between countries in terms of both goods and passengers. In fact, in the sub-region, Sudan, Uganda and Kenya trade with many of the other countries in the regional bloc by rail (AfDB, 2015). Many travellers in the regional bloc can go from one country to another by rail. Private companies holding concessions for the networks can make a profit from the demand for both passenger and freight transport (World Bank, 2020a, b). People living in rural areas use rail transport as a means of transporting themselves and their goods across dry areas (Lamarque, 2022). In fact, the population rate in rural areas has a negative effect on the general demand for rail transport. Rail transport is used by people in urban areas to travel from one country to another.

5. Study conclusions

Over the past decade, African railway sectors have applied hybrid reform models to catch up with other regions in the performance of the sub-region's railways. With this in mind, this paper aims to study the effect of deregulation on the demand for rail transportation. Following abundant literature in Europe and Asia on deregulation, this study focuses on structural and regulatory reforms. The contribution of this study is first, the use of the share of private ownership of capital in the sector and the number of operators as variables that measure the reform of the railway sector. We evaluate regulatory and structural reforms in sub-Saharan countries, with African rail sectors lag behind those of developed countries. Second, we apply a regional block estimate to capture the effect of deregulation on rail sectors that may share the same corridors. In accordance with the work of Mizutani (2019) and Smith *et al.* (2018), we use an apparently unrelated (SURE) model for the general estimate and a random effect least square model for regional block estimation.

From the general estimate, we find that the horizontal separation reform has a positive effect on passenger transport demand and the opposite effect on freight transport demand. The number of operators in the sector significantly affects demand for freight transport. The vertical separation reform has a positive effect on demand for passenger and freight transport. With regard to regulatory reforms, private sector participation in the capital of operators has a significant positive effect on demand for freight transport. It has the opposite effect on demand for passenger transport. Privatization or mixed ownership has a negative effect on demand for freight transport. The coexistence of private and public operators can lead to conflicts of interest, to the detriment of demand for freight transport and an increase in passenger transport. The introduction of a regulatory authority in the rail sector has a positive effect on demand for passenger and freight transport. Regulators are committed to protecting consumer interests, but regulatory environments and weak incentive capacities can limit their influence in the sector. The number of locomotives, the population rate in rural areas and GDP per capita are significant variables in the demand for general rail transport.

Furthermore, the estimate by regional block shows that, depending on the presence of shared corridors between countries, regulation of the rail network significantly affects demand for passenger or freight transport. In regional blocks with shared networks, the presence of the regulator affects demand for freight transport, and in the opposite case, as in Central Africa, it affects demand for passenger transport. In the same vein, GDP per capita negatively affects passenger transport demand in the Southern and East African regional blocs. Consequently, in Southern and Eastern Africa, the poorest countries or those with a high population density use transport as a means of transport compared with the Central and West African regional blocs.

We recommend that the railway sector establish rail regulators and emphasize their level of independence from operators. Regulatory operators help to decrease the price of transport services with incentive strategies. In many African countries, transport costs increase with many constraints, especially the increase of fuel prices. An independent regulatory authority will protect the interests of the consumer and domestic or sub-regional trade. In addition, public institutions must promote the construction of shared corridors between countries to stimulate trade and the movement of people between countries and consequently increase the demand for freight and passenger transport. The East African regional bloc is illustrative in this respect despite the poor state of infrastructure. Many regional blocs have not shared corridors between countries and the rail sector is developing slowly. Various projects in the rail sector are not prioritized than other sectors, like telecommunication.

The increase in the density of rail networks will in the long term reduce the investment deficit with the benefits under the constraint of good management and regulation of the sector. From this point of view, the establishment of holding companies is an advantage in controlling the activity of operators. On this basis, institutions must give responsibility for passenger transport to an operator, preferably publicly owned, and progressively introduce competition in the rail sector, in particular for the transport of goods. However, it is also favourable for African's rail sector to mix public and private owned operators. Both have advantages for customers in terms of price and cost. The vertical separation linked to concessions is not bad for the sector, but regulatory institutions must set up contracts that can maintain the level of performance of the sector in the long term. Regulators have the responsibility of applying incentive strategies to encourage operators to make an effort on the transport service offering. Nevertheless, on this point, the new wave of concessions since 2005 has perfectly made it possible to restrict certain opportunistic behaviours of certain operators. One of the limitations of this study is the absence of limited data in 2015 and does not allow us to assess the long-term impact of these new waves of reforms. Therefore, a future study can complete the coverage of the data and better perceive the effect of these reforms. In addition, other studies can be carried out to assess the impact of a single mode of reform on the performance of the railway sectors, in particular the quality of service or production efficiency.

Notes

1. International Union of Railways.
2. The holding company models in rails sector are various but they always apply to protect costumer from the company and sometimes insure the presence of local employer in foreign companies.
3. African Union.
4. TAZARA is an entity that regulates the railway sector in Zambia and Tanzania with a network that is common to both countries for trade.
5. The dilapidated state of the infrastructure does not ensure the quality of transport for passengers.

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Table A1. Descriptive statistics, Pairwise multicollinearity coefficient and variable data source

Variable	DTFP	DTFF	RSSV	RSSH1	RSSH2	RRPO1	RRP02	RRAR	LOCOM	RND	RPR	GDPC
Obs	382	382	382	382	382	382	382	382	382	382	382	382
Mean	1020.233	56500.186	0.586	1.647	1.387	0.927	0.24	0.191	180.762	2344.932	60.983	1634.48
Std. Dev	1272.171	34,2000	0.493	0.806	0.657	0.999	0.362	0.394	649.103	4080.938	16.526	1954.735
Min	0	26	0	1	1	0	0	0	0	259	11.882	110.461
Max	9,876	3,001,234	1	3	5	2	0.92	1	3,285	20,953	85.39	10273.799
Skew	2.282	6.79	−0.351	0.724	2.501	0.147	0.917	1.571	4.539	3.957	−0.707	2.219
Kurt	10.421	49.272	1.123	1.92	12.258	1.022	1.973	3.469	21.713	18.223	3.336	7.654
DTFP	1.000											
DTFF	0.284	1.000										
RSSV	0.104	0.135	1.000									
RSSH1	0.379	0.267	0.034	1.000								
RSSH2	0.405	0.695	0.067	0.735	1.000							
RRPO1	−0.099	−0.150	0.493	−0.068	−0.085	1.000						
RRP02	0.178	0.300	0.473	0.127	0.166	0.421	1.000					
RRAR	0.322	0.323	0.314	0.420	0.535	−0.011	0.098	1.000				
LOCOM	0.403	0.764	0.181	0.360	0.594	−0.196	0.382	0.390	1.000			
RND	0.191	0.146	0.049	0.152	0.140	−0.122	0.151	0.179	0.486	1.000		
RPR	−0.170	−0.231	0.031	−0.232	−0.247	0.149	−0.361	−0.154	−0.265	−0.092	1.000	
GDPC	0.076	0.444	−0.029	0.288	0.427	−0.128	0.347	0.233	0.448	0.162	−0.733	1.000
Data source	WDI data base BAD data (AINP) O.N data base Country and Continental Reports		SSA National and Continental Rail Sector Reports BAD data Africa Infrastructure Knowledge Program (AINP) Africa Infrastructure Railways data (world bank data base)							W.D.I data base		

Source(s): Authors