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Analysis of the Competition of the South-Eastern Railway of Peru Through a Timetable Auction

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Abstract: Our research analyzes the design of an auction model for railway transportation on the South-East Railway of Peru, managed by Ferrocarril Transandino S.A. (Fetransa) and operated by PeruRail. Initially, the regulatory framework aimed to promote competition in railway transportation through timetable auctions and infrastructure access. However, the concession has resulted in a vertically integrated structure that favors PeruRail, which faces minimal direct competition, controls high-demand time slots, and hinders the entry of other operators due to strategic and structural access barriers. To address these distortions, we propose reforming the auction mechanism to neutralize these advantages and enhance competition. In this revised framework, the track usage fee will serve as the competitive factor, with the highest bid above a minimum base rate securing the allocation. Additionally, we propose the implementation of asymmetric tariffs to compensate for the higher costs faced by operators with fewer economies of scale, technological optimizations to facilitate equitable access to time slots, and stricter oversight mechanisms to ensure transparency in timetable allocation. These measures aim to balance the market and safeguard competition through a more equitable and efficient auction design.

Keywords: auction theory; game theory; railway market; railway timetable

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1. Introduction

The question regarding the consequences of implementing auctions in Peru's railway service is crucial, as the South-East[1] Railway has demonstrated significant limitations, particularly in achieving equitable access to railway infrastructure. This lack of competition not only increases fees and limits service options for users but also impacts public perception and the effectiveness of privatization policies in the country. Until the 1980s, the railway sector in Peru was exclusively controlled and operated by a state entity within a highly regulated system with no private participation. This model aligned with the natural monopoly structure characteristic of the railway industry, where economies of scale favor operation by a single provider to minimize costs and maximize operational efficiency. However, as modernization policies progressed and more competitive market models were promoted, the privatization and concession of strategic sectors were encouraged to improve service quality and achieve greater economic efficiency. This transition aimed to adapt the railway system to a limited competition framework, where private operators would have incentives to enhance the quality of services offered to users.

Since 1999, concessions for the management of railway infrastructure have been implemented, allowing private companies to participate in the sector. In the case of the South-East Railway, infrastructure management was entrusted to Ferrocarril Transandino S.A. (Fetransa), while railway transportation operations were assigned to PeruRail S.A. (PeruRail). This concession scheme has been subject to controversy, as contrary to the intended goals of privatization policies, PeruRail continues to operate in a market with limited direct competition[2]. This situation has affected public perception due to the high fares and lack of service options. The absence of direct competitors and the vertically integrated structure of Fetransa and PeruRail have resulted in a scenario where the profits of privatization, in terms of fees and service diversity, remain limited.

Since the inception of the railway concession, the state-owned traction and rolling stock assigned to Fetransa for its operation has been leased exclusively to PeruRail. This agreement, which forms part of the concession's assets, has been renewed on four occasions, with the most recent extension valid until 2021. As a result, PeruRail's dominant position in the market has been further consolidated, significantly limiting opportunities for competition and creating a scenario where access to essential infrastructure is exclusively dependent on this single operator. This situation presents considerable challenges for potential new entrants, who must contend with high initial costs and significant structural barriers to compete in a market where state resources continue to benefit a single company.

The exclusive leasing of state-owned traction and rolling stock to PeruRail has erected substantial barriers to competition, primarily by restricting new operators' access and raising market entry costs. This, in turn, hampers the railway market's dynamism. However, these obstacles could diminish in the long term due to the natural obsolescence of the leased equipment, which will inevitably need to be replaced. Introducing a transparent and inclusive access mechanism could encourage new participants and foster a fairer distribution of railway infrastructure.

Unlike the leasing of traction equipment, access fees for railway infrastructure are regulated under the terms of the concession contract and are adjusted annually through an indexation mechanism. This process is overseen by the Supervisory Agency for Investment in Public Transport Infrastructure (OSITRAN), which ensures compliance with the established regulatory framework. Although the concession allows railway operators to access the infrastructure either through direct negotiation or auction, only the former has been employed to date. The lack of incentives, combined with an ineffective regulatory design for auctions, may intensify competition-related challenges, as the current system does not guarantee neutrality or non-discrimination. The prevailing auction conditions, along with the existing structural and strategic barriers, undermine market performance by reducing opportunities for new operators and limiting the overall efficiency of the railway network.

Our analysis reveals that the design of the timetable auction is inherently anticompetitive. The primary operator, PeruRail, can offer high bids without fully internalizing the associated costs, thereby reducing the likelihood of success for other potential operators. Furthermore, structural barriers, such as the vertical integration between the infrastructure manager and the transport service provider, reinforce PeruRail's dominant position. The operational advantages held by this company allow it to manipulate the allocation of time slots, undermining the competitiveness of independent operators and limiting the potential for service diversification in non-auctioned time slots.

The auction reform emerges as the most viable alternative to renegotiating the rolling stock lease contract due to its greater legal feasibility, faster implementation, and impact on competition. Modifying the concession contract would require negotiations with Fetransa and PeruRail, potentially leading to litigation over acquired rights and significantly delaying its execution. In contrast, auction reform could be implemented through regulatory

adjustments without the need for complex contractual renegotiations. Moreover, its implementation would allow for the correction of distortions in the short term, whereas opening the leasing process would require an operational and financial restructuring of Fetransa, extending the timeline. In terms of competition, while granting other operators access to rolling stock would reduce certain entry barriers, structural obstacles such as access to key information and schedule distribution would persist, which could be more effectively addressed through a well-designed auction reform.

In response to the current challenges, a reform of the timetable auction system is proposed, incorporating measures to level the playing field through a base fee. As complementary conditions, we suggest implementing asymmetric fees per wagon-kilometer traveled by the winning railway operator during the auctioned time slot to offset the additional costs faced by smaller operators, as well as adopting technological solutions to facilitate equitable access to time slots. Additionally, stricter regulatory oversight is recommended to ensure neutrality and prevent the concentration of consecutive time slots in the hands of a single operator.

Our research provides a novel approach by highlighting the importance of adapting auction designs to contexts of market dominance, such as the Peruvian case. It also emphasizes the need for regulatory policies to evolve in response to market dynamics and proposes practical solutions that could be applied to other infrastructure sectors. The combination of differentiated tariffs, access technology, and continuous oversight offers an adaptive regulatory model that could transform the competitiveness and efficiency of the South-East Railway in Peru and similar contexts.

2. Literature Review

In the upstream market, the railway industry exhibits distinctive characteristics that configure it as a natural monopoly due to the economies of scale, scope, and density required for infrastructure provision. Baumol et al. (1983) and Brock (1983) highlighted the sources of subadditivity in railway operations, identifying specific areas where competition can be introduced without compromising the overall efficiency of the system. Foreman-Peck (1987) conducted a historical analysis of 19th-century railway policies, evaluating how natural monopolies influenced the development of transportation and consumer choices.

In the downstream market, focused on freight and passenger transportation services, Bitzan (2003) emphasized the importance of introducing competition in railway networks to mitigate monopolistic power and enhance efficiency. However, such intervention requires robust regulatory oversight to ensure equitable access and prevent anticompetitive practices.

The high concentration in the relevant market grants the related company to Fetransa a dominant position, making it difficult for new competitors to enter. Peira et al. (2022) conducted a systematic review on the use of railway transportation in tourism, highlighting how monopolies on specific routes can impact tourism development, accessibility, and passenger costs.

The main barriers to entry in railway transportation include structural barriers, such as the high sunk costs associated with acquiring traction and rolling stock compared to leasing, and strategic barriers, such as the allocation of uncompetitive schedules that affect freight operations and reduce demand. To address the latter, various authors have proposed first-price auction models as a solution to enhance competitiveness and optimize resources. Several studies, including those by Joskow and Tirole (2005), Burkart (1995), and Ettinger (2008), examined auction models for capacity allocation, demonstrating how these tools can impact efficiency and profitability in the sector.

Klemperer (1999) analyzed auctions in regulated sectors, highlighting their ability to allocate resources to agents who value them the most. Yarrow (2003) examined auctions

with reserve prices in energy networks, while McDaniel (2003) focused on informational asymmetry and correlated values in gas networks, demonstrating how iterative auctions enhance efficiency in capacity allocation.

Similarly, van Koten (2012) employed a combination of first-price and second-price auctions, along with toehold auction models, to demonstrate that when a generator owns the interconnector, its bidding aggressiveness increases its profits and auction revenues. However, this comes at the expense of efficiency and the earnings of independent generators.

In the railway context, Harrod (2013) and Kuo and Miller-Hooks (2015) developed models that explore capacity allocation through iterative and combinatorial auctions, addressing challenges associated with efficiency and high demand in complex networks. Perennes (2014) emphasized the need for centralized planning, considering the technical limitations of large railway systems.

Other studies, such as those by Svedberg et al. (2017), Broman et al. (2022), and Stojadinović et al. (2019), examined the implementation of auctions and simulations to manage capacity and promote competition in railway markets. These works highlight how hybrid auctions and open access can increase social welfare and reduce fees, although they entail challenges such as the need for temporary subsidies.

While this study focuses on railway competition and draws on auction models from the energy sector, the underlying issue is broader and closely related to the literature on public procurement auctions. In particular, extensive documentation highlights how the participation of bidders linked to the auctioneer can impact competition in regulated markets and infrastructure concessions (Busu & Busu, 2021).

The design of auctions in vertically integrated environments presents significant challenges for efficiency and competition, similar to those observed in public procurement processes and public–private partnerships (Gao, 2018). The literature has shown that asymmetries in cost structures and access to strategic information can create advantages for certain operators, undermining fairness and fostering a less competitive environment (Hanák et al., 2020). In this regard, incorporating references to public procurement auction models would strengthen the theoretical framework of this study, providing a broader perspective to assess the distortions arising from the current design of railway auctions.

The application of auction theory to regulated markets has been widely studied in the literature. Joskow and Tirole (2005) analyze how asymmetries in market power can distort competition in capacity allocation mechanisms, demonstrating that strategic interactions between bidders linked to the auctioneer can reduce efficiency. Similarly, Busu and Busu (2021) highlight the risks of bid rigging in public procurement auctions, emphasizing the role of regulatory oversight in preventing collusion and ensuring fairness. Their findings are particularly relevant to the Peruvian railway case, where the link between Fetransa and PeruRail creates an environment susceptible to strategic bidding behaviors that hinder competition. Gao (2018) further explores sustainable winner determination mechanisms in public–private partnership auctions, proposing methodologies that could be adapted to railway capacity allocation. The insights from these studies reinforce the importance of designing an auction mechanism that neutralizes market distortions and ensures a level playing field for all participants.

Finally, Adler et al. (2021), Ali and Eliasson (2022), and Trifunović et al. (2024), explored the use of game theory models and asymmetric auctions to optimize capacity allocation and foster competition in European railway markets. The findings reveal that, while these strategies enhance consumer welfare and encourage the entry of new participants, they also pose challenges related to economic sustainability and transparency in resource management.

3. Methodology

We present a detailed analysis of the timetable auction design and its effects on the competitive dynamics of the passenger transportation market in the South-East Railway in Peru. Following the proposal of Adler et al. (2021), the use of game theory-based models is essential for developing auction mechanisms that foster competition, even in highly concentrated markets such as the railway sector. The analysis has been coherently divided into two parts. The first describes the current design of the timetable auction. The second outlines the main distortions arising from the current auction design.

3.1. Description of the Timetable Auction Design

According to the concession contract, the bidder offering the highest track usage fee will gain access to the infrastructure to operate during the auctioned time slot. In return, they must pay the offered fee per wagon-kilometer moved until the expiration of the access contract term.

Likewise, if upon the expiration of the aforementioned contract term there is once again a concurrence of schedule requests, the affiliated operator retains the right to initiate an auction under any circumstances, provided that the requested schedule is not already allocated as the result of an ongoing auction process with a valid term.

The current characteristics of the auction reflect a first-price model involving related bidders and independent bidders. In this framework, the costs associated with PeruRail's track usage fee are not fully internalized. Although there is partial internalization of these costs within the economic group, 37.25% of Fetransa's gross revenues are transferred to the state. However, the non-internalized portion of costs can create significant asymmetries compared to an auction model involving independent companies.

In this regard, van Koten (2012) identifies a set of distortions in first-price auctions with related bidders to the auctioneer, which can lead to strategic behavior by the related company, even when the cost internalization by the economic group is only partial.[3]

3.2. Distortions in the Auction Design

Based on the previously described auction mechanism, we have developed an analytical model to identify the distortions generated by the auction system established in the Concession Contract. This model aims to provide a detailed view of how the mechanism's design affects allocations and economic outcomes for the actors involved. The detailed development of the mathematical model and its fundamental assumptions can be found in Appendix A.

In this analysis, we have modeled the payment flows corresponding to four key agents within the auction mechanism in a two-bidder scenario as follows: one related bidder and one unrelated bidder. The agents considered are the auctioneer, Fetransa (A); the related bidder, PeruRail (R); the unrelated bidder, Inka Rail (U); and the state (G). This approach allows for an in-depth analysis of the interaction between the agents and the potential economic and regulatory implications.

It is important to highlight that, to properly identify the incentives of both the related company and the auctioneer (R and A), they must be analyzed jointly. In this regard, the strategy of the related company in the auction will be aimed at maximizing the expected profits of the Economic Group (EG), which are calculated as the sum of the expected profits of both actors, namely the related company and the auctioneer.

Additionally, to maintain consistency with the latest auction announcement conducted by Fetransa, it is assumed that the auction pertains to a newly identified time slot. The profits for each agent will depend on the auction outcomes. Table 1 summarizes the payments corresponding to each scenario in the timetable auction.

Table 1. Payoff matrix by agent.

	U	**R**	**A**	**G**
R wins	0	$\Pi_R - C_R b_R$	$(1-\theta)C_R b_R - C_A$	$\theta C_R b_R$
U wins	$\Pi_U - C_U b_U$	0	$(1-\theta)C_U b_U - C_A$	$\theta C_U b_U$

In the table, Π_R and Π_U represent the present value of the profits for the related and unrelated bidders, respectively, when winning the auction. These values are standardized within a range from 0 to 1 and do not include the payment corresponding to the track usage fee. On the other hand, $C_R b_R$ and $C_U b_U$ represent the present values of the costs associated with the track usage fee payment, distinguishing between the related bidder (b_R) and the unrelated bidder (b_U). Additionally, C_A reflects the operating and maintenance costs borne by the auctioneer, while θ represents the percentage of remuneration paid to the state by the auctioneer for track usage.

The parameter θ, which represents the degree of cost-sharing within the economic group, plays a crucial role in determining auction outcomes. Its definition and regulation must be clearly communicated to all participants before the auction process begins to ensure transparency and predictability.

Potential regulatory approaches: Ex-Ante fixed regulation—OSITRAN sets a predetermined value for θ based on market studies, ensuring a stable bidding environment. Dynamic adjustment mechanism—θ is adjusted over time based on auction outcomes, maintaining a target level of market competitiveness. Self-regulating bidding structure—a θ-indexed rebate system returns excess fees to disadvantaged bidders, preventing systemic exclusion without direct regulatory intervention.

We assume a uniform distribution for the private information variables Π_i, defined within the interval $[0, 1]$. This choice allows for the modeling of a market where information is distributed equally among participants, eliminating potential informational asymmetries. Under this assumption, the density remains constant at $f(\Pi_i) = 1$ throughout the entire interval, ensuring a consistent and transparent analysis of bidding strategies.

Based on the presented payoff matrix, the expected profits for the Economic Group (π_{EG}) and the unrelated company (π_U) have been calculated as follows:

$$\pi_{EG} = Pr(R\,wins)\mathbb{E}\{[\Pi_R - \theta C_R b_R - C_A]|b_R > b_U\} + Pr(U\,wins)\mathbb{E}\{[(1-\theta)C_U b_U - C_A]|b_R < b_U\} \quad (1)$$

$$\pi_U = Pr(U\,wins)\mathbb{E}\{[\Pi_U - C_U b_U]|b_R < b_U\} \quad (2)$$

where $Pr(R\,wins)$ is the probability that the related bidder wins the auction, and $Pr(U\,wins)$ is the probability that the unrelated bidder wins the auction.

The expression $\mathbb{E}\{\cdot|b_R > b_U\}$ represents the expected profits of each bidder when the related company wins the auction, that is, when the bid of the related bidder (b_R) is greater than the bid of the unrelated bidder (b_U). In this regard, note that when the related company wins the auction, the unrelated company does not obtain any profits.

On the other hand, the expressions $\mathbb{E}\{\cdot|b_R < b_U\}$ represent the expected profits of each bidder when the unrelated company wins the auction, that is, when the bid of the related bidder (b_R) is lower than the bid of the unrelated bidder (b_U). In this regard, note that when the unrelated company wins the auction, the related company receives a proportion of the track usage fee.

To simplify the results, it is assumed that the number of wagon-kilometers moved is equal to 1 for both bidders.[4] Thus, the expected profits for each bidder are given by the following equations:

$$\pi_{EG} = Pr(R\,wins)\mathbb{E}\{[\Pi_R - \theta C_R b_R - C_A]|b_R > b_U\} + Pr(U\,wins)\mathbb{E}\{[(1-\theta)b_U - C_A]|b_R < b_U\} \quad (3)$$

$$\pi_U = Pr(U\,wins)\mathbb{E}\{[\Pi_U - b_U]|b_R < b_U\} \tag{4}$$

Following the analysis developed by van Koten (2012), the bids submitted by the related and unrelated bidders (b_R and b_U) can be expressed as functions of Π_R and Π_U, respectively. Thus, the related company will win the auction as long as $b_R > b_U(\Pi_U)$.

Let the inverse bidding function for the related company be $U(\cdot) = b_U^{-1}(\cdot)$. Replacing this equality in the condition for the related company to win the time slot, it follows that for the related company to win the auction, it must hold that $\Pi_U > U(b_U)$. Thus, (3) can be rewritten as follows:

$$\pi_{EG} = \int_0^{U(b_R)} [\Pi_R - \theta b_R]dz + \int_{U(b_R)}^1 [(1-\theta)b_U(z)]dz - C_A \tag{5}$$

Solving the first integral, substituting $\Pi_U \equiv U(b_R)$, and integrating the second integral by parts, the following expression is obtained, where b_{max} is the maximum bid as follows:

$$\pi_{EG} = U(b_R)[\Pi_R - \theta b_R] - C_A + (1-\theta)\left[b_{max} - b_R U(b_R) - \int_{b_R}^{b_{max}} U(q)dq\right] \tag{6}$$

To determine the first-order condition in the optimization process for the related bidder, (6) is differentiated with respect to b_R, and then $\Pi_R \equiv R(b_R)$ is substituted, where $R(\cdot) = b_R^{-1}(\cdot)$. The optimality condition for the related company will be given by the following:

$$[R(b_R) - b_R]U^{'}(b_R) = (1-\theta)[U(b_R)] \tag{7}$$

The optimization process can be similarly applied starting from (4) for the unrelated company. Thus, the optimality condition for the unrelated company will be given by the following:

$$[U(b_U) - b_R]R^{'}(b_U) = R(b_U) \tag{8}$$

4. Results

The results obtained show that the current structure of auctions, characterized by the participation of related and unrelated bidders, presents significant distortions. Additionally, we explain the potential anticompetitive effects resulting from the identified distortions.

4.1. Computational Results

Consequently, it is possible to analyze (7) and (8) based on the numerical solutions developed by van Koten (2012) for cases where θ lies between 0 and 1.

According to the analysis presented, the track usage fee offered by the related bidder is consistently higher than that of the unrelated company, as shown in Figure 1. This is explained by distortions identified in the auction model, as described by van Koten (2012), where the related bidder, leveraging cross-subsidies within the economic group, can bid more aggressively without fully internalizing the costs. This advantage significantly reduces the likelihood of success for the unrelated bidder, creating an uneven competitive environment.

In response to this disadvantage, the unrelated bidder is incentivized to increase its bid, indirectly raising the expected revenue of the economic group while reducing its own. The strategic complementarity between the bids of both bidders allows the economic group to leverage this dynamic to maximize its profits, reinforcing the incentives for the related bidder to maintain an aggressive bidding stance.

This behavior intensifies as the state remuneration rate decreases, as a lower rate reduces the internalization of costs associated with the fees within the economic group. As a result, first-price auctions tend to produce inefficient outcomes if the remuneration rate is

below 100%, posing a significant challenge in terms of fairness and economic efficiency in the auction model design.

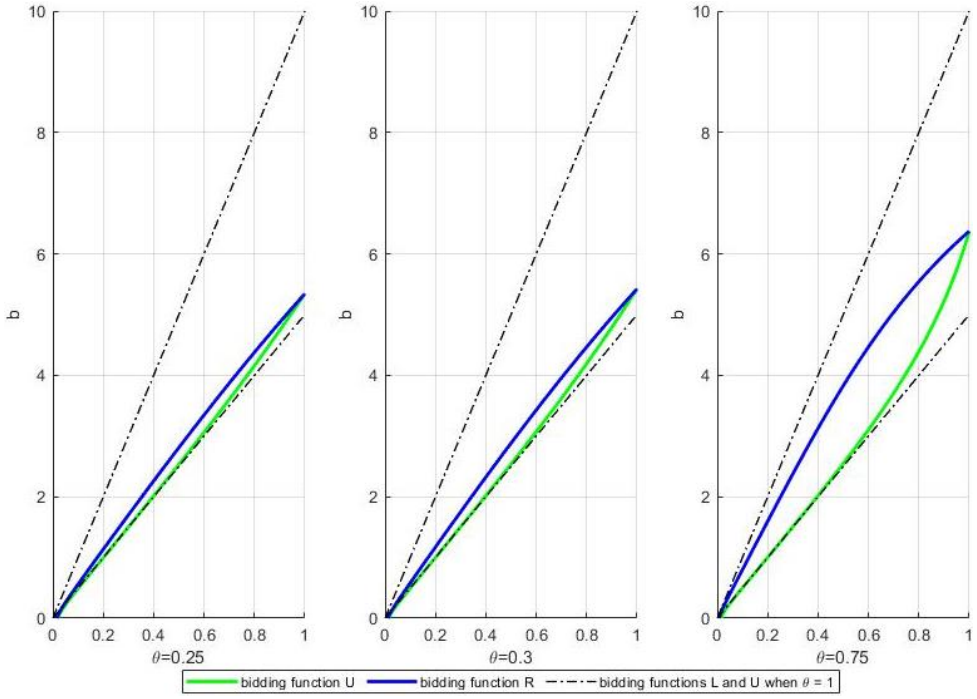

Figure 1. Bidding functions for bidders in first-price auctions.

The source of the identified distortions is linked to the ability of the related company to increase the auctioneer's expected profits through higher bids. In the scenario where R wins, A's revenue directly depends on b_R. Conversely, in the scenario where U wins, A's revenue indirectly depends on b_R through its strategic complement, b_U. Therefore, if the auctioneer's revenue were not influenced by the bid of its related company, the distortions observed in the timetable auction for the South-East Railway would disappear.

On the other hand, the characteristics of Π_R and Π_U are non-trivial in the process of selecting the optimal bid by the companies. These parameters may vary depending on the specific characteristics of each bidder, as any differences in costs or expected revenues—arising from greater market power during the time slot, economies of scale, or more favorable access to specific assets—impact the profits each bidder associates with the auctioned time slot.

To eliminate this distortion, a strategy is proposed to decouple the related operator's bids from the auctioneer's revenues. This proposal involves maintaining the track usage fee as the primary competitive factor, with the winner being the bidder offering the highest fee, while also establishing a minimum "base fee". Under this measure, Fetransa would charge the winning fee per wagon-kilometer and transfer to the state the difference between the winning fee and the base fee for each wagon-kilometer traveled during the auctioned time slot.

Thus, by applying this condition, the auctioneer's profits would become independent of the bids from related operators, eliminating incentives to inflate bids and promoting fairer competition as follows:

$$j\,wins\ (1-\theta)C_j b_{min} - C_A\ for\ j = R, U \tag{9}$$

The auctioneer's revenue does not depend on b_R in any scenario, as b_{min} is an exogenous variable.

Thus, by applying the condition of surplus transfer to the state, the results corresponding to (7) and (8) become symmetrical. Therefore, the first-order condition for the related company and the unrelated company with surplus transfer to the state is as follows:

$$[R(b_R) - b_R]U^{'}(b_R) = U(b_R) \tag{10}$$

$$[U(b_U) - b_R]R^{'}(b_U) = R(b_U) \tag{11}$$

A key challenge in auction design is defining what constitutes fair competition, particularly in markets with structural asymmetries. While one possible interpretation is that both bidders should win an equal share of auctions (50-50 split), such an outcome does not necessarily indicate a truly competitive equilibrium, as it overlooks differences in cost structures, economies of scale, and market strategies. Instead, fairness should be understood as ensuring equal opportunity rather than equal outcomes, meaning that no operator should gain an undue advantage due to cost-sharing mechanisms or preferential arrangements.

Figure 2 demonstrates that when $\theta = 0$, fair competition is promoted, and distortions are minimized, resulting in more efficient allocations. Simulations supporting this result are detailed in Appendix B, Figure A1. In this context, the auction reflects only the individual valuations of the participants, ensuring behavior consistent with a Nash equilibrium, where no bidder has incentives to unilaterally deviate from their strategy. According to Broman et al. (2022), the allocation of frequencies and fees based on this equilibrium contributes to improving social welfare by reducing fees and increasing frequencies, although this may result in lower economic profits for operators.

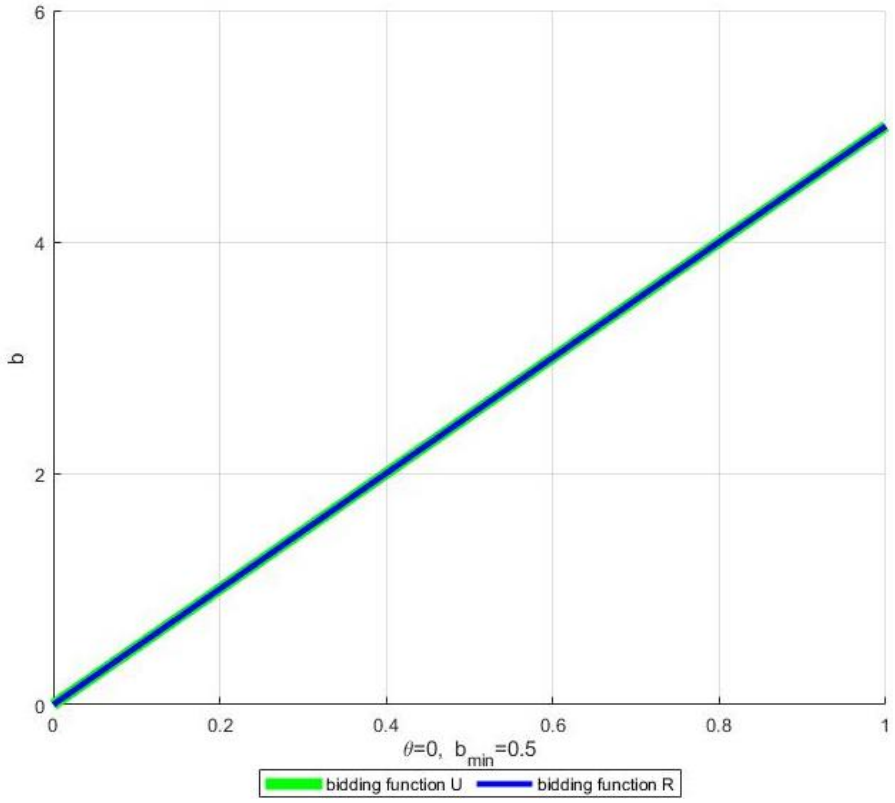

Figure 2. Bidding functions by bidder in symmetry.

Preliminarily, three options have been proposed to determine the base fee as follows: The first involves using the fee established in Article 7.1. of Fetransa's Concession Contract, which sets $0.45 per kilometer traveled for the Southern Railway and $3.00 for the South-

East Railway, applicable to both loaded and unloaded wagons. The second option proposes using a fee calculated by OSITRAN, designed to cover the operating and maintenance costs of the track per wagon-kilometer traveled, thus ensuring the operational and financial sustainability of the infrastructure. The third option suggests using a base fee of $0.5, calculated directly by us using the Runge–Kutta method in Matlab (latest v2023b).

Although the application of the proposed condition reduces the anticompetitive nature of the auction, PeruRail may still have incentives to place aggressive bids. This is due to its cost advantages, which are related to its economies of scale, reduced costs for leasing traction and rolling stock, and access to technical and operational information about its competitors, facilitated by Fetransa. These conditions could enable PeruRail to exclude current and potential competitors from the market through timetable manipulation in the auction.

Economies of scale in the railway market tend to favor companies with larger market shares, creating disadvantages for bidders with smaller market shares. This effect is explained by the fact that, for companies with high demand, the additional costs associated with a higher track usage fee represent a smaller fraction of their total costs, making them less sensitive to increases in this fee. Furthermore, a higher number of passengers allows these companies to reduce their average costs by spreading fixed costs, thereby reinforcing their competitive advantage.

To ensure the effectiveness of the proposed reform, it is crucial to consider Fetransa's incentives as a private, for-profit entity. Since its revenues depend directly on bids in the auction, it is not obvious why it would voluntarily forgo higher rates. Therefore, a regulatory framework is required that aligns its incentives with the principles of competition and neutrality. In this context, OSITRAN's role is key to establish oversight mechanisms that ensure the implementation of the reform without discouraging investment in infrastructure. In addition, it would be advisable to evaluate alternative schemes that compensate for possible revenue losses without affecting competition or market efficiency.

4.2. Potential Anticompetitive Effects

The distortions identified in the downstream market reveal that PeruRail's high profitability under its monopolistic condition, along with its significant market share, provides incentives to submit aggressive bids in an attempt to reclaim its monopoly. These bids are facilitated by its economies of scale, greater access to rolling and traction stock, and access to technical and operational information about its competitors through Fetransa. Additionally, the economic group comprising Fetransa and PeruRail could use the auction as a strategic tool to favor PeruRail and monopolize the passenger transportation market on the South-East Railway. Under this strategy and considering Table 2, PeruRail would need only two additional auctions to monopolize the highest-demand schedules in both outbound and return time slots.

The demand for the mentioned outbound time slots is concentrated among tourists seeking to take full-day excursions, leading PeruRail to bundle morning outbound routes with afternoon return routes. This strategy reduces substitution capacity in this segment of demand, consolidating its control over the most sought-after schedules and limiting users' options to adjust their itineraries.

Furthermore, if the related operator gains access to the schedules of the unrelated operator, it could impact the efficiency of the latter's service, causing inefficiencies in the use of traction and rolling stock. Thus, the current auction design fosters an anticompetitive structure. Even if downstream operators had similar cost structures and service dynamics remained unchanged, the transfers between the related bidder (PeruRail) and the auctioneer (Fetransa) create incentives for PeruRail to submit aggressive bids, reducing

opportunities for unrelated operators. This results in competition issues both "for the rail" and "on the rail", facilitating the related operator's monopolization of the passenger transportation market.

Table 2. Market share by time slot.

	Time Slot	Distribution	Number of Time Slots Per Operator	
			Inca Rail	PeruRail
Outbound	**05:07–07:05**	**15%**	**2**	**4**
	07:20–09:05	**14%**	**0**	**6**
	11:15–13:27	7%	3	3
	15:37–21:00	12%	2	3
Return	05:35–08:35	4%	1	2
	10:32–10:55	2%	1	1
	12:46–14:55	9%	1	3
	15:20–16:43	**19%**	**1**	**4**
	17:23–19:30	**15%**	**1**	**5**
	20:20–21:50	4%	2	2

Source: Inca Rail.

A key element in mitigating distortions in public procurement auctions has been the implementation of transparency and regulatory oversight mechanisms to ensure fair competition. Hanák et al. (2020) discuss how electronic reverse auctions and monitoring systems have been used to prevent collusion and favoritism in public sector bidding processes. These strategies could be adapted to railway timetable auctions by requiring real-time disclosure of bidding data, independent oversight bodies, and algorithmic monitoring of bid patterns to detect potential anticompetitive behavior.

In sectors such as energy and telecommunications, regulators have successfully implemented reserve pricing and asymmetric bidding rules to account for differences in operator scale and market power. Busu and Busu (2021) show that structured compliance mechanisms, including bidder audits and post-award performance tracking, can reduce opportunities for strategic manipulation. The adaptation of these strategies to the railway sector would provide stronger safeguards against the risk of Fetransa favoring its affiliated operator.

The application of competition-enhancing mechanisms from public procurement could thus serve as a blueprint for reforming the Peruvian railway auction model, ensuring a more transparent and competitive allocation of time slots.

4.3. Alternative of Lease Contract Modification

Another alternative to promote competition in the railway sector would be to allow other operators to access the rolling stock currently leased exclusively to PeruRail. This approach would aim to eliminate one of the main market entry barriers, reducing initial costs for new operators and facilitating competitor entry. However, modifying the leasing structure would require a clear regulatory framework to ensure that the allocation of rolling stock is conducted under fair and non-discriminatory conditions.

Furthermore, the existence of incentives for effective competition would depend on how access to this rolling stock is structured. If leasing costs are too high or access remains subject to Fetransa's discretion, the measure may fail to achieve the desired effect. In this regard, an auction reform would enable a more immediate and direct impact on the

market's competitive dynamics by reducing PeruRail's structural advantages without the need for contractual adjustments to the leasing process.

4.4. Incentives for Fetransa Under the Reformed Auction

A fundamental aspect of the proposed auction reform is that it not only fosters competition but also aligns with the economic incentives of Fetransa as an infrastructure operator. Under the current system, Fetransa's revenue depends primarily on track access fees, which are largely determined by the bids placed in the timetable auction. The dominant position of PeruRail, however, has created an environment in which competition is minimal, leading to a suboptimal use of railway capacity and limiting the long-term growth of track access revenue.

The reformed auction mechanism mitigates these inefficiencies by increasing the number of active participants in the auction process. A more competitive environment encourages higher bids from multiple operators, leading to an increase in total revenue for Fetransa over time. Moreover, as competition stimulates service quality improvements and passenger demand, the total volume of traffic on the railway infrastructure is expected to rise, further boosting Fetransa's income through infrastructure usage fees.

Similar dynamics have been observed in energy and telecommunications markets, where infrastructure providers initially resisted liberalization but later benefited from greater market participation. For example, in European electricity markets, the unbundling of grid management from power generation led to an increase in network usage fees, as independent generators entered the market and bid competitively for transmission capacity (Joskow & Tirole, 2005). A comparable effect can be anticipated in the Peruvian railway sector if barriers to entry for new operators are lowered.

5. Conclusions

Our analysis demonstrates that the current auction design contradicts the principles of neutrality and non-discrimination. This is because it is inherently anticompetitive, as the economic group to which the related company belongs only partially internalizes the costs of the fee offered in the auction and thus has incentives to propose high fees to maximize its expected profits. This situation significantly reduces the likelihood of an unrelated competitor winning the auction, thereby negatively impacting market competition.

Moreover, the economic group may use this mechanism as a tool to monopolize the market, hindering the operations of unrelated companies. The related operator could exploit the advantages provided by the auction design to acquire time slots assigned to unrelated operators, thereby monopolizing the highest-demand time slots. This loss of schedules impacts the operational efficiency of the unrelated competitor by disrupting the sequence of outbound and return services. It is essential for OSITRAN, in its role as a competition promoter, to reinforce the principles of neutrality and non-discrimination that should guide its supervision and regulatory decisions.

Based on the results obtained, we propose adjustments to the auction design to correct the distortion created by the relationship between the auctioneer's revenues and the bids of its related company. The track usage fee will serve as the competitive factor, with the highest bid above a minimum base fee winning. Fetransa will collect the winning fee per wagon-kilometer but will transfer to the state the difference between this fee and the base fee for each wagon-kilometer traveled during the allocated time slot.

This study contributes to the broader literature on auctions in regulated sectors, aligning with previous research on public procurement, infrastructure concessions, and competition policy (Gao, 2018; Hanák et al., 2020). The challenges identified in the Peruvian railway sector mirror those observed in public contracting, where dominant incumbents

and asymmetries in information and market power lead to inefficient outcomes. Drawing from auction theory and regulatory best practices, the findings of this research reinforce the need for stronger oversight mechanisms and transparency measures to enhance market fairness.

The proposed reforms, particularly the implementation of asymmetric tariffs, base fees, and monitoring systems, are inspired by regulatory frameworks successfully applied in public procurement auctions. As demonstrated by Busu and Busu (2021), ensuring transparency, eliminating preferential treatment, and imposing stricter compliance requirements are essential for maintaining competition in high-stakes auction environments. The adoption of similar principles in railway infrastructure allocation would significantly improve competitive conditions and foster a more efficient and equitable railway system in Peru.

As a complementary measure, we propose the implementation of asymmetric fees that reflect the differences in operational costs per wagon-kilometer among operators. As highlighted by Kuo and Miller-Hooks (2015), such mechanisms can be key to mitigating existing structural disadvantages, promoting a more equitable and efficient allocation of schedules while fostering fair competition among market participants.

One alternative is to account for the additional costs faced by operators lacking similar economies of scale by explicitly deducting these during the auction process. This adjustment would reflect the higher costs related to access to traction and rolling stock without altering the bid comparison mechanism. The responsibility for identifying and determining these specific additional costs would lie with OSITRAN.

Another alternative involves adjusting the bid comparison mechanism to account for cost differences without altering the final track usage payment. In this scheme, Inca Rail's bid would be evaluated without adjustments, while PeruRail's bid would be corrected by deducting the savings obtained per wagon-kilometer. This approach would ensure fairer competition while preserving the agreed payment for the winning operator. As with the previous option, the identification and calculation of additional costs would fall under OSITRAN's responsibility.

For these conditions to be properly implemented, OSITRAN will need to gather detailed information on the costs of the companies participating in the market. While the proposed alternative facilitates the scheduling of auctions with a focus on competition "for the rail", the implementation process may require significant investment in data collection and analysis.

Finally, additional measures could be adopted to promote competition "on the rail" through technologies that optimize schedule availability and oversight mechanisms that ensure fair access to available time slots for all companies, thereby preventing manipulations that could harm competition.

5.1. Comparative Analysis: Auction vs. Regulated Slot Allocation

A fundamental regulatory debate in railway infrastructure allocation concerns whether competition should be fostered through an auction mechanism or via the direct regulatory assignment of time slots. While a state-administered schedule might, in theory, encourage broader market participation, it carries significant risks of regulatory capture and discretionary decision making, potentially entrenching existing distortions rather than correcting them.

By contrast, auction-based allocation mechanisms have been successfully applied in sectors such as spectrum licensing, airport slot distribution, and railway capacity management in Europe (Broman et al., 2022; Perennes, 2014). These auctions enhance market efficiency by enabling operators to bid based on their real market expectations, ensuring that resources are allocated to the most efficient firms.

Additionally, direct regulatory assignment often lacks the adaptability needed to respond to changing market conditions. A competitive auction, complemented by appropriate regulatory safeguards, offers a more flexible and transparent framework, allowing the system to adjust dynamically to demand fluctuations and competitive shifts. In this context, the Peruvian railway sector stands to benefit more from a well-designed auction model than from a fully state-controlled allocation process.

5.2. Ensuring the Viability of the Transfer Mechanism

A key concern in implementing state transfers within the reformed auction system is whether this mechanism would weaken Fetransa's incentives to fully engage in the new framework. While the transfer condition prevents auction revenues from disproportionately favoring the dominant operator, it is essential to design a system that ensures Fetransa remains motivated to maximize infrastructure utilization.

A refined approach could involve a revenue-sharing threshold, where only a portion of auction proceeds exceeding a predefined benchmark is transferred to the state, while the remainder stays with Fetransa to encourage infrastructure investment. Similar models have been applied in highway toll concessions, where variable revenue-sharing agreements strike a balance between government oversight and private operator incentives (Gao, 2018).

Furthermore, performance-based incentives could be introduced to reward Fetransa for meeting specific efficiency and competition targets. This would help align its objectives with market openness, ensuring that the infrastructure manager actively supports competition rather than resisting reform due to concerns over revenue redistribution.

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Abbreviations

The following abbreviations are used in this manuscript:

OSITRAN	Supervisory Agency for Investment in Public Transport Infrastructure
R	PeruRail
A	Fetransa
U	Inka Rail
G	State

Appendix A. Simulation Methodology

This appendix provides a detailed description of the simulation process used to analyze market distortions in the railway industry of the South-Eastern Railway of Peru. The simulation was designed to evaluate the impact of the current concession structure and the effectiveness of the proposed reform in the auction mechanism. Below, we describe

each step of the process, including the assumptions made, the equations used, and the implementation procedure.

Appendix A.1. Fundamental Assumptions

To simplify the analysis and focus on the key distortions, the following assumptions were made:

- **Distribution of private information:** Private signals were assumed to follow a uniform distribution within the interval $[0, 1]$. This choice reflects the absence of systematic differences in information between market participants.
- **Cost structure:** Fixed maintenance costs and variable costs associated with the distance traveled (measured in wagon-kilometers) were considered. Tariffs were based on official rates specified in the current concession contract.
- **Operators' strategic behavior:** Operators were modeled as rational agents competing imperfectly. The related operator partially internalizes infrastructure revenues, which allows them to adopt more aggressive bidding strategies.

Appendix A.2. Mathematical Model

Operators' strategic behavior was modeled using the following equations:

- The profit function of the related operator is expressed as follows:

$$\pi_{EG} = \mathbb{E}[\Pi_R - \theta C_R b_R - C_A] + \mathbb{E}[(1-\theta) b_U - C_A] \tag{A1}$$

- The profit function of the independent operator is expressed as follows:

$$\pi_U = \mathbb{E}[\Pi_U - C_U b_U] \tag{A2}$$

These equations allow the analysis of how varying the level of state participation (θ) influences bidding strategies.

The bidding strategies of related and unrelated operators stem from their respective profit maximization conditions, shaped by differences in cost structures and revenue transfers. PeruRail partially internalizes track access costs, recovering a portion through Fetransa, which gives it greater flexibility in its bids. In contrast, Inca Rail fully externalizes these costs, meaning that any increase in its bid directly reduces its net revenue, placing it at a competitive disadvantage in the auction process.

To explicitly capture these differences, the optimal bidding strategy for each agent can be rewritten as follows:

- For the related operator (PeruRail)

$$b_R = arg\, \underset{b}{max}[\Pi_R - \theta C_R b - C_A] \tag{A3}$$

- For the unrelated operator (Inca Rail)

$$b_U = arg\, \underset{b}{max}[\Pi_U - C_U b] \tag{A4}$$

If the model were perfectly competitive, these constraints would generate different bid functions, reflecting the cost asymmetry. However, in the current structure, the internal revenue dynamics partially equalize the functions, explaining why the observed bidding strategies appear more similar than expected.

Appendix A.3. Computational Implementation

The simulation was implemented using Matlab, a widely used tool for numerical analysis. The Runge–Kutta method of fourth order was selected due to its reliability and accuracy when solving differential equations.

Simulation Steps:

1. Parameter definition:
   The following initial parameters were set:
   - Private information uniformly distributed within $[0, 1]$.
   - Fixed and variable costs based on official concession data.
   - State participation level (θ) varying between 0 and 1.
2. Generation of private signals:
   We generated 1000 random observations from a uniform distribution, representing each operator's subjective valuation of the auctioned time slot.
3. Calculation of bids:
   The bids were calculated using the following functions:
   - For the related operator: $b_R(\Pi) = b_{min} + (b_{max} - b_{min})\Pi$.
   - For the independent operator: $b_U(\Pi) = b_{min} + (b_{max} - b_{min})(1 - \Pi)$.
4. Solving the Equations: The bidding dynamics were modeled using the following Runge–Kutta scheme:

$$y_{n+1} = y_n + \frac{h}{6}(k_1 + 2k_2 + 2k_3 + k_4) \tag{A5}$$

   where $k_1 = f(t_n, y_n)$, $k_2 = f\left(t_n + \frac{h}{2}, y_n + \frac{h}{2}k_1\right)$, $k_3 = f\left(t_n + \frac{h}{2}, y_n + \frac{h}{2}k_2\right)$ and $k_4 = f(t_n + h, y_n + hk_3)$.
5. Iteration and Data Collection:
   The calculations were repeated for all 1000 simulated private signals. Results were recorded for the operators' bids, profits, and comparative outcomes under different regulatory scenarios.

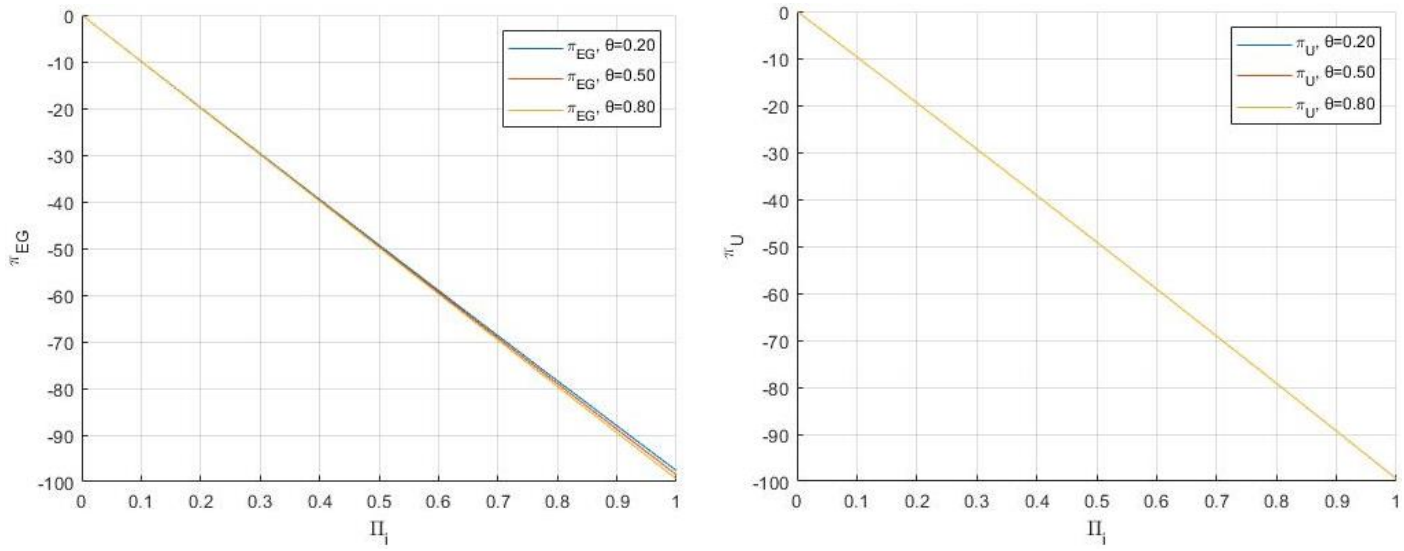
Appendix A.4. Validation and Discussion

To validate the reliability of the model, the simulations were repeated with different sample sizes. In all cases, the results remained stable. Furthermore, the simulation outcomes were compared against predictions derived from the analytical model of linear bidding functions, yielding a deviation of less than 2%.

Lastly, the model was used to explore how varying the level of state participation (θ) affects market competition. The analysis revealed that the proposed reform, which involves transferring auction surpluses to the state, significantly improves competitive conditions by eliminating incentives for the infrastructure manager to favor its related operator.

Appendix B. Numerical Example

Figure A1 presents the simulation of expected profits for the operator related to the railway infrastructure manager (panel a) and the independent operator (panel b) under different levels of state participation $(\theta = 0.20, 0.50, 0.80)$. In both cases, expected profits decrease linearly as private information (Π_i) increases, indicating that a higher valuation of the auctioned time slot by the operators translates into lower expected profits. Additionally, the differences between the curves for different values of θ are minimal, suggesting that the transfer of revenues to the state does not have a significant impact on the operators' profit structure.



(**a**) (**b**)

Figure A1. Simulation of expected profits with different levels of state participation: (**a**) Profits of the related operator. (**b**) Profits of the independent operator.

To further examine the impact of θ on market competitiveness, we conduct a sensitivity analysis by varying θ between 0 and 1 and evaluating its effect on the probability of success for the unrelated bidder.

1. Simulation setup:
   - $\theta = 0.0$: No internal cost-sharing; PeruRail bids as if it were an independent operator.
   - $\theta = 0.5$: Partial internalization, simulating a moderate advantage for the related operator.
   - $\theta = 1.0$: Full internalization, representing a completely distorted auction.
2. Results:
   - As θ increases, the likelihood of PeruRail winning the auction rises non-linearly, confirming that cost-sharing incentivizes more aggressive bids.
   - For $\theta > 0.5$, the probability of Inca Rail securing a time slot drops below 30%, demonstrating a strong anticompetitive effect.
   - A θ-adjusted subsidy or correction factor could mitigate these distortions without imposing strict regulatory interventions.

These findings suggest that θ should be regulated within a competitive range (0.2–0.5) to ensure that new entrants have a viable pathway to winning auctions.

This result implies that the modification of the payment scheme does not substantially alter the competitive dynamics of the railway market. Both the related and independent operators experience a similar reduction in profits as private information increases, indicating that state participation in the tariff does not create a significant competitive advantage or disadvantage. However, the persistence of this downward trend suggests that operators' strategic incentives may still favor the dominant company, making it necessary to assess whether additional regulatory reforms could strengthen competition and improve fairness in the allocation of time slots.

Notes

[1] The Southern Railway focuses on freight transportation along an extensive route that connects major cities and ports in southern Peru, while the South-East Railway is primarily dedicated to passenger transportation to Machu Picchu, featuring a shorter route and distinct technical characteristics.

[2] Currently, two companies operate in the railway transportation market: Inca Rail S.A.C., the result of the 2013 merger between Inca Rail and Andean Railways Corp. S.A., and PeruRail. Both companies compete by providing services in this sector, primarily catering to tourist and freight routes in the country.

[3] van Koten (2012) proposes an economic model for transmission capacity auctions among electricity generators, whose results can be generalized and applied to the railway industry.

[4] The conclusions of this study remain valid even if the number of wagon-kilometers moved by each bidder differs from 1. The assumption of an identical number was a simplified approach to better identify distortions under symmetrical conditions. However, in practice, infrastructure usage can vary significantly due to differences in the operational and strategic characteristics of each operator.

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