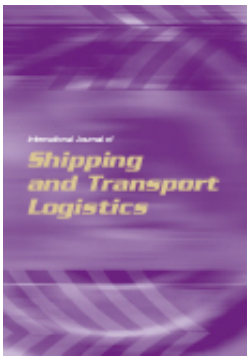

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Port choice in Rio de Janeiro, Brazil: an analysis of the perspectives of exporters and importers in the container market

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Abstract: This paper analysed the port choice process from the perspective of two types of agents: 1) exporters/forwarders; 2) importers/forwarders. We used stated preference data collected in the state of Rio de Janeiro, Brazil. Discrete choice models were tested. The best-performing models were mixed logit regression for both groups. The export model showed that road transport tariff, risk of cargo theft, number of ship calls, port tariff and cargo release time are important factors. The import models showed that taxation, road transport tariff, ship calls, port tariff and cargo release time are important variables. The models indicate that the ports in the region analysed are highly dependent on exogenous variables that port authorities cannot control. Some findings are achieved by comparing the outcomes for both groups. The value of time (VOT) referring to the willingness of companies to pay for the reduction of one unit

(day) to release cargo at ports was calculated for each group. VOT for importers has a greater value. Different policy scenarios have been simulated to examine the impact of each policy on the market.

Keywords: port choice; stated preference; mixed logit model; port competition; port policy; Brazilian market; Brazil.

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1 Introduction and background

Port choice is related to port competition analysis (Lagoudis et al., 2017). Thus, it is important to identify factors influencing port selection. Once the different factors regarding the port choice process have been identified, the Port Authority (PA) can improve the competitiveness and assess the impact of port policies and strategies.

Previous researchers have revealed the most prominent factors influencing shippers and freight forwarders in container port selection (Tiwari et al., 2003; De Langen, 2007; Nugroho et al., 2016). However, there are few studies on this topic in Brazil or in fast-developing countries where ports attract increasing attention (Ugboma et al., 2006; Cantillo et al., 2018, 2022; Vega et al., 2019).

Freight demand models have evolved more slowly than passenger models. The difficulty of obtaining disaggregated data has been pointed out as a major challenge for freight transport studies (Rashidi and Roorda 2018) especially in developing countries (Tapia et al., 2019). Besides data, the decision-making process for freight transport is more complex than for passengers because it diverges from the latter in terms of players and product diversity (Marcucci, 2013; Holguín-Veras et al., 2021).

This study aims to conduct a parallel analysis of the behaviour of two groups:

1 exporters/freight forwarders

2 importers/freight forwarders in their port choice.

The study used stated preference (SP) data collected from firms located in the State of Rio de Janeiro (RJ). The analysis of the behaviour of exporters and importers in the port choice is important for the formulation of policies (Vega et al., 2019). Therefore, this paper has three objectives:

1 to develop models using SP data to identify the most relevant attributes and predict port choice for each group

2 to calculate value of time (VOT) representing the willingness of companies to pay for the reduction of one unit (day) to release cargo at ports for each group

3 to analyse different simulation scenarios and to discuss which strategies could enhance port competition in the region.

This article makes three contributions. Firstly, this article presents specific port selection factors for the Brazilian market, not usually explored in the literature: cargo theft risk during transport to the port (exporters) and taxation on the value of the imported cargo (importers). In 2020, Brazil was the country that had more cargo theft cases than any other country (TT, 2021). Besides, the southeast region is the area with the highest rate of cargo theft in Brazil, and Rio de Janeiro and São Paulo account for 80% of cargo theft cases in Brazil (ISP/RJ, 2019). Regarding taxation, port states grant tax benefits to attract taxpayers and encourage investment in their territories. Some states have created measures to stimulate the economy. One of the measures was to grant tax benefits to import companies established in the state. These measures have the main characteristic of reducing taxation and attracting importers. These factors were highlighted by companies in Brazil during qualitative research (Souza et al., 2021b). However, they have received limited attention in previous port choice studies. Secondly, this paper investigates a context different from those generally reported in the literature. Few studies on this subject have been undertaken in developing countries, particularly in South America. For instance, Vega et al. (2019) analysed port selection in Colombia using revealed preference (RP) data, considering containerised cargo. Few studies have been found with a disaggregated approach in Brazil (Larranaga et al., 2017; Galvão Novaes et al., 2006; Souza et al., 2021a) in freight transport. These studies analysed travel mode choice for

freight transport. Modelling freight transport demand in Brazil is limited due to the difficulty in obtaining data from companies. Thirdly, although there have been many empirical studies on VOT for passenger transport, relatively few contributions have been made to freight transport (Konishi et al., 2014). In the Brazilian context, there are few reference values for freight transport (Larranaga et al., 2017, 2021), and to the best of the authors' knowledge, no values for port studies. Additionally, the literature explores few values about the marginal rate of substitution between the time of cargo release and port cost. Thus, the results obtained in this article can be used for developing regions with similar characteristics to the study area analysed.

The remainder of this article is structured as follows. Section 2 describes the local context. Section 3 presents the materials and method. The fourth section presents estimations of port choice models, and results regarding VOT and market share simulation. Finally, the last section presents the main conclusions and suggestions for future studies.

2 Local context

The state of RJ is located in the Southeast region of Brazil. It has the second largest GDP in Brazil, and it is in second place in terms of participation in the country's foreign trade (13%) (Firjan, 2019). The preferences of companies from the State of RJ were analysed because in this area there is market competition in which ports in the southeast region compete in partially overlapping inland areas (UNB, 2012).

The southeast region of Brazil has the largest port handling volume in the country. This study focuses on the deep-sea part, with the main ports of the Southeast region of Brazil with operations in the container market. The State of RJ is part of the hinterland of four ports in the Southeast region (UNB, 2012):

1 Port of Itaguaí

2 Port of Rio de Janeiro

3 Port of Santos

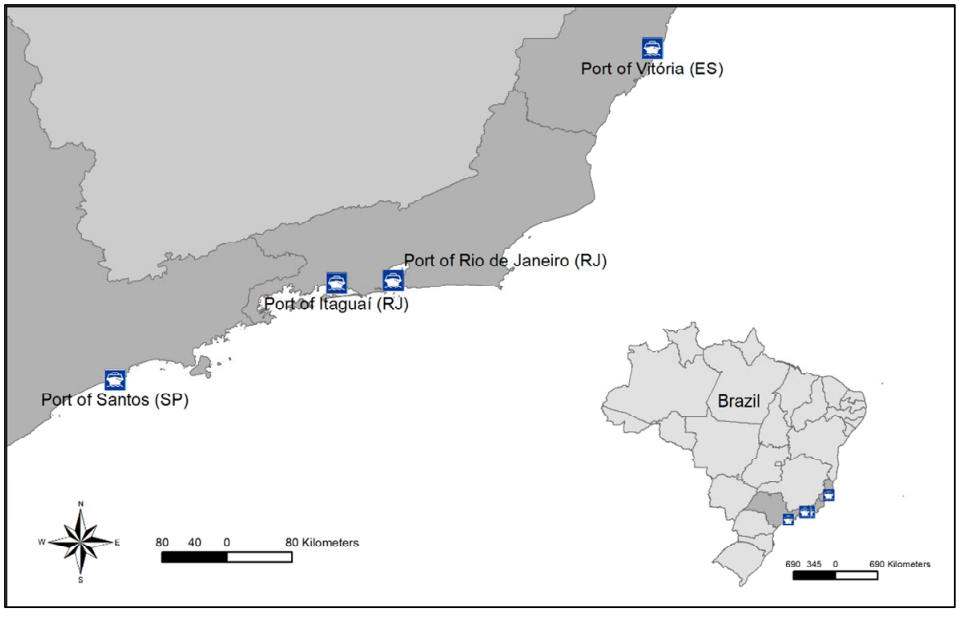
4 Port of Vitória.

Thus, these four ports were included in the paper (Figure 1).

The Port of Rio de Janeiro and the Port of Itaguaí are located in the Rio de Janeiro Metropolitan Area. The Port of Rio de Janeiro is in Guanabara Bay, in the city of Rio de Janeiro (capital of RJ). The Port of Itaguaí is in Sepetiba Bay, in the city of Itaguaí, adjacent to the state capital. The Port of Itaguaí is located approximately 90 km west of the municipality of Rio de Janeiro and approximately 60 nautical miles southwest of the Port of Rio de Janeiro. *Companhia Docas do Rio de Janeiro* (CDRJ) is the PA responsible for managing these ports in the state of Rio de Janeiro.

The Port of Santos, the largest in Brazil, is located in State of São Paulo. *Santos PA* is responsible for the infrastructure of the Port of Santos. The port of Vitória is located in the State of Espírito Santos (ES) and *Companhia Docas do Espírito Santo* is responsible for managing the ports in this state.

Figure 1 Ports in the Southeast Region of Brazil (see online version for colours)



Source: Souza et al. (2021b)

3 Materials and method

This section presents the research development regarding the literature review and interviews, data collection, questionnaire design and modelling approach, detailed in the following subsections.

3.1 Literature review and interviews

Firstly, we identified the port choice factors in Brazil using the literature review and interviews. Due to the lack of studies on port choice in Brazil, interviews were carried out with companies and specialists to understand the port sector and define the most prominent factors. Previous researchers have revealed factors influencing companies in port selection. The factors found in the literature can be varied (port location; port tariff; transport costs; frequency of ships; quality; efficiency; port equipment; information services; size of the shipper) according to previous container port choice studies carried out in different regions: Africa (Ugboma et al., 2006; Onwuegbuchunam, 2013); Asia (Tiwari et al., 2003; Tongzon, 2009; Nugroho et al., 2016); Europe (De Langen, 2007; Garcia-Alonso and Sanchez-Soriano 2009; Martínez-Pardo et al., 2020); North America (Malchow and Kanafani, 2004; Steven and Corsi, 2012); South America (Cantillo et al., 2018, 2022; Vega et al., 2019) and Oceania (Ng et al., 2013). More information about interviews with companies in the region and the literature review on the topic can be found in Souza et al. (2021b).

We selected the following six attributes for each group, according to interviews (Table 1). *Ship calls*, *port tariff*, *road transport tariff*, *cargo release time*[1] and *port tariff* are commonly used in studies as factors on this topic. However, the interviews detected companies highlighting specific factors in the Brazilian market taking into account the port choice process: *cargo theft risk in transport to the port* (for exporters) and *taxation* (for importers). Congestion was also highlighted by companies in the region and included in the experiment. Congestion in ports was analysed by Tiwari et al. (2003), with RP data, in China.

Table 1 Selected attributes

Survey	*Attributes*
Exporters and forwarders	Ship calls
	Port tariff
	Road transport tariff
	Cargo release time
	Cargo theft risk in transport to the port
	Incidence of congestion in Port access
Importers and forwarders	Ship calls
	Taxation
	Cargo release time
	Road transport tariff
	Port tariff
	Sea freight tariff

It should be noted that among the factors highlighted in the interviews, only two are considered to be in control of the Port: *Port tariff* and *cargo release time*. The other criteria can be considered not within the control of the port. Martínez Moya and Feo Valero (2017) argue that the choice of port depends on factors under control such as efficiency or port fees. However, the port choice is also influenced by factors not within the control of the port.

3.2 Experimental design

The dimension of the attributes in the alternatives can be seen in Table 2 (export model) and Table 3 (import model). In the export survey, the attributes were defined as follows:

1 *Ship calls*: number of weekly calls at the port

2 *Port tariff*: is represented by the handling cost of 1 TEU full container load (FCL)

3 *Road freight tariff*: inland mode cost to transport 1 TEU container from the origin to the port by road transport

4 *Cargo release time*: number of days to release the cargo to be exported

5 *Cargo theft risk*: risk of theft (%) of cargo in transport to the port

6 *Congestion in access to the port*: occurrence of traffic formation in access.

In the import survey, the attributes were defined as follows:

1 *Ship calls*: number of weekly calls at the port

2 *Taxation* (ICMS[2]): aliquot on the value of imported cargo

3 *Port tariff*: represented by the handling and storage cost of 1 TEU FCL

4 *Cargo release time*: number of days to release the cargo after the container arrives at the port

5 *Sea freight tariff* (Incoterm FOB): ocean freight for transporting 1 TEU FCL from a foreign port to a port in Brazil[3]

6 *Road freight tariff*: inland mode cost to transport 1 TEU container from the port to the company by road.

The models have 4 variables in common (*ship calls*, *port tariff*, *cargo release time* and *road transport tariff*). It should be noted that all values were defined and tested with port managers and freight forwarders with experience in the port market to increase the realism of the SP scenarios. For the *ship calls* attribute in both models, we used three levels (1, 2 and 3), except for the Port of Santos, which had a fixed level (3) since this port has the highest frequency of ships in Brazil (Souza et al., 2021b, 2022). For the *port tariff*, we use the values of handling fees (export) and container storage fees (import) charged at the container terminals with the highest movement in each port analysed. The *cargo release time* had different values: for export, we adopted three levels (1, 2 and 3) for all alternatives. For import, we adopted three levels (3, 5 and 7) for all alternatives, as the time to release cargo on import is longer due to bureaucratic aspects. The *road transport tariff* was adopted with three levels, and the values depend on the company's location, considering a truck transporting containerised cargo.

In the experiment for the export model, the *Cargo Theft Risk* attribute was defined in percentage values. Conveying risk levels is a difficult task due to multiple perception biases among respondents (Baron, 2004). We chose to use numerical levels with values determined from consultation with professionals in the freight transport sector. We determined three levels: low (0%), medium (15%) and high (30%). However, the high level was assigned only to the Port of Rio de Janeiro, while the other alternatives had two levels (low and medium). During the interview phase, it was found that this variable leads companies to change vehicle routing to minimise the risk of cargo theft in the region, and this perception of risk is mainly associated with the Port of Rio. The main access routes to the city of RJ present greater insecurity for cargo transportation (ISP/RJ, 2019) in the region than other routes. This insecurity can lead companies to divert cargo to other Ports, as the high number of cases in the region raises costs (vehicle tracking, insurance and armed escort) (Portos and Navios, 2017). The variable *congestion in port access* was determined as a binary attribute, indicating the possibility of having traffic in port access.

In the experiment for the import model, *Taxation* was defined in percentage values: 4%, 8%, 12% and 18%. These values represent the ICMS rate adopted in the Brazilian market. For instance, ICMS in the States of SP and RJ is 18% (average), while ICMS in ES averages 12%. In other Brazilian states, the rate reaches 4%. *Sea freight* was determined in consultation with freight forwarders. For each alternative, we used three levels, with a current value as reference.

Table 2 Attributes and levels for the export model

Attribute	*Unit*	*Itaguaí*	*Rio de Janeiro*	*Santos*	*Vitória*
Ship calls	Calls/week	1, 2, 3	1, 2, 3	3	1, 2, 3
Port tariff	R$	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%
Road transport tariff	R$	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%
Cargo release time	Days	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
Cargo theft risk	%	0%, 15%	0%,15%,30%	0%, 15%	0%, 15%
Congestion on access to the port	Binary	Yes/No	Yes/No	Yes/No	Yes/No

Table 3 Attributes and levels for the import model

Attribute	*Unit*	*Itaguaí*	*Rio de Janeiro*	*Santos*	*Vitória*
Ship calls	Calls/week	1, 2, 3	1, 2, 3	3	1, 2, 3
ICMS*	%	4, 8, 12, 18	4, 8, 12, 18	4, 8, 12, 18	4, 8, 12, 18
Cargo release time	Days	5, 6, 7	5, 6, 7	5, 6, 7	5, 6, 7
Port tariff	R$	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%
Sea freight	US$	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%
Road transport tariff	R$	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%	–20%, present level, + 20%

Note: *In all choice tasks, the ICMS of the Port of Rio de Janeiro alternative presents the same value of the Port of Itaguaí alternative, as these ports are located in the same state (RJ).

Following conclusions pointed out by Walker et al. (2018), which suggest that the use of efficient design is indicated under conditions of reliable prior parameters, this study developed an efficient design (Rose and Bliemer, 2009) without priors using Ngene software (ChoiceMetrics 2018). An orthogonal design was not possible due to model specifications (levels and constraints). The efficiency of an experimental design is sensitive to the precision of the estimation of the parameters used in the experiment (Walker et al., 2018). Brazil does not have studies on the port choice, which limits the availability of appropriate parameter values.

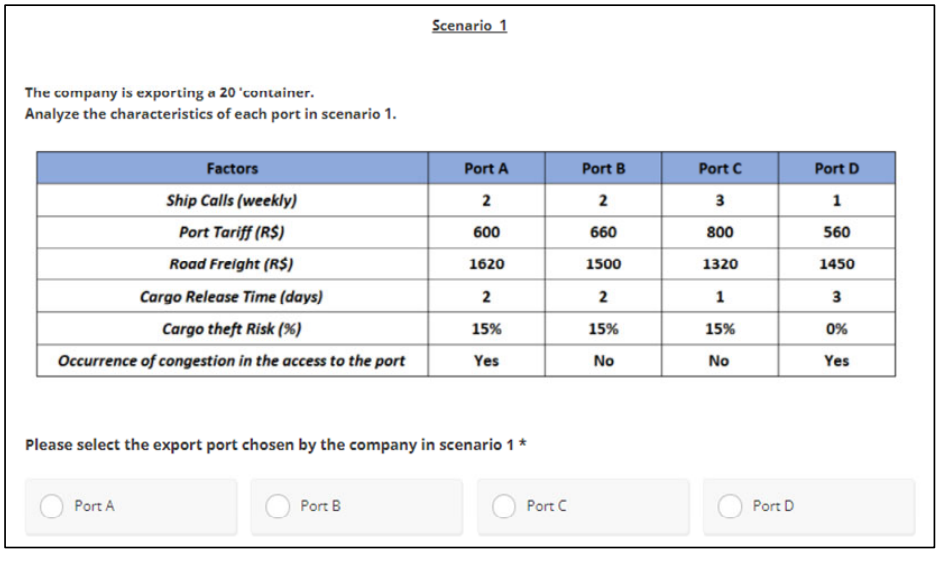
Unlabelled alternatives for the port were adopted[4], rather than the actual port names to reduce bias in company responses. Ten choice tasks were generated for each respondent. The study avoided a high number of choice tasks due to the possibility of fatigue, which can lead respondents to simplify their choices. To increase realism of the survey, we categorised companies according to the transport distance (considering the region of the firm). The state of RJ was divided into six mesoregions, according to the Brazilian Institute of Geography and Statistics – IBGE (1990). Each mesoregion has two specific efficient designs (export and import), considering different levels. Each SP choice situation shown to the respondent is described using six factors. Figures 2 and 3

show examples of choice tasks presented. In the questionnaire for importers, a value of the imported cargo was presented so that the respondent could consider the value of the cargo and the applicable taxation. The questionnaires had two sections:

1 SP experiment

2 general information about the company.

Figure 2 Questionnaire (export) (see online version for colours)



Scenario 1

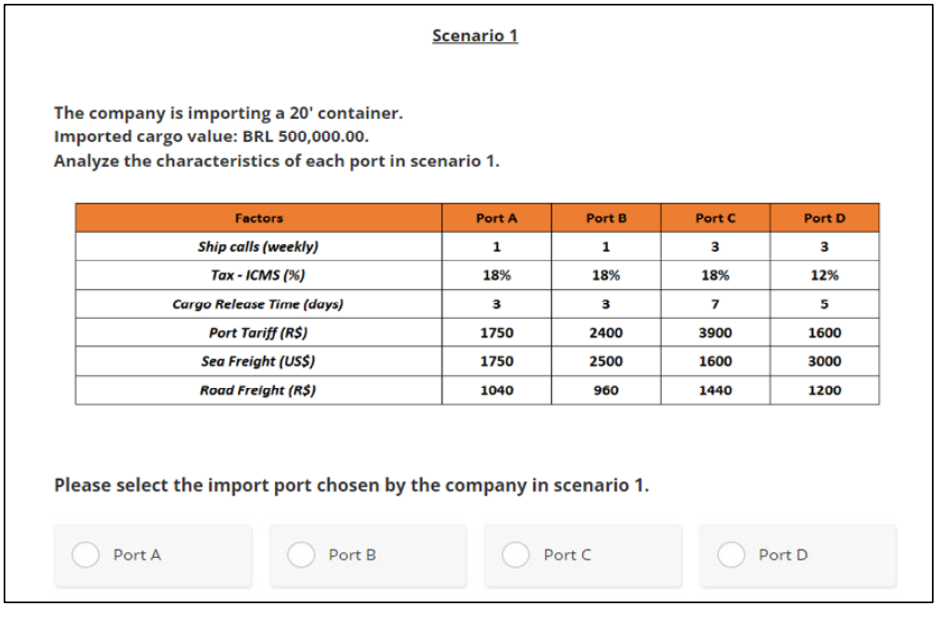
The company is exporting a 20 'container.
Analyze the characteristics of each port in scenario 1.

Factors	Port A	Port B	Port C	Port D
Ship Calls (weekly)	2	2	3	1
Port Tariff (R$)	600	660	800	560
Road Freight (R$)	1620	1500	1320	1450
Cargo Release Time (days)	2	2	1	3
Cargo theft Risk (%)	15%	15%	15%	0%
Occurrence of congestion in the access to the port	Yes	No	No	Yes

Please select the export port chosen by the company in scenario 1 *

Port A Port B Port C Port D

Figure 3 Questionnaire (import) (see online version for colours)



Scenario 1

The company is importing a 20' container.
Imported cargo value: BRL 500,000.00.
Analyze the characteristics of each port in scenario 1.

Factors	Port A	Port B	Port C	Port D
Ship calls (weekly)	1	1	3	3
Tax - ICMS (%)	18%	18%	18%	12%
Cargo Release Time (days)	3	3	7	5
Port Tariff (R$)	1750	2400	3900	1600
Sea Freight (US$)	1750	2500	1600	3000
Road Freight (R$)	1040	960	1440	1200

Please select the import port chosen by the company in scenario 1.

Port A Port B Port C Port D

3.3 Data collection

The SP experiment was carried out in two phases: a pilot survey was conducted in November/December 2020, and the main survey was conducted between January and March 2021. For data collection, online questionnaires were used from the *surveyhero* platform. The pilot survey with 10 companies was important to adjust the questionnaire after comments and suggestions from respondents. A difficult issue in SP surveys on freight transport is choosing the person to be interviewed in the company (Tavasszy and de Jong, 2013). During the pilot study, we concluded that the questionnaire would be better answered preferably by managers in the areas of foreign trade and/or logistics.

During the main survey, companies were contacted by email or telephone. To encourage the candidates to fill out the questionnaire, they received reminders. In total, 65 companies (36 exporters and 29 importers) fully completed the survey with a response rate of 22 % of the total number of companies that received the questionnaire.

Nine respondents were excluded because some answers were contradictory (e.g., providing the same answers for all choice scenarios and/or their completion times were very short). In these cases, it was considered that the data may not be valid to use in the estimation process. In general, the lexicographical response may result from the lexicographical preference for (at least) one of the factors in the choice scenario (Killi et al., 2007). The lexicographical response can mainly indicate preferences, steep indifference curves or a simplification strategy (Carlsson and Martinsson, 2001).

Table 4 Sample information

Survey	*Category*	*Number of companies*
Export	Type	Exporters (22); forwarders (8)
	Size	Large (18); small and medium companies (12)
	Product	Steel and metallurgical (3); chemical (3); food and beverage (13); automotive (4); cotton (1); oil and gas (5); Others (1)
	Cargo destination	Asia (16); Europe (12); North America (7); South America (3);
	Shipment frequency (per month)	>=4 (12); <4 (18)
Import	Type	Importers (18); Forwarders (8)
	Size	Large (17); Small and medium companies (9)
	Product	Chemical (5); Plastic (3); Food and beverage (7); Pharmaceutical (4); Oil and gas (4); Automotive (3)
	Cargo origin	Asia (14); Europe (17)
	Shipment frequency (per month)	>=4 (11); <4 (15)

Hence, data from 30 respondents were used in the export survey and 26 respondents in the import survey. Even though the sample size is smaller than conventionally used, the sample size used in freight transport demand modelling is lower than that usually used for passenger transport because the population of interest is smaller (Larranaga et al., 2017). The sample size obtained is in line with studies in the area of freight transport (Shinghal and Fowkes, 2002; Larranaga et al., 2017; Souza et al., 2021a; Galvão Novaes et al., 2006). Furthermore, restriction on obtaining data from freight

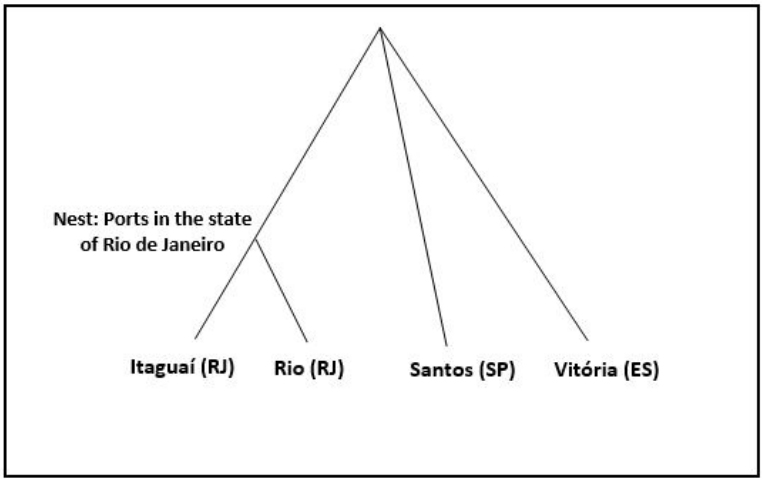
companies and the lack of public available disaggregated data related to freight transport make it less common to estimate disaggregated models (Tavasszy and de Jong, 2013). Table 4 summarises the sample information.

3.4 Modelling approach

Having collected the data, discrete choice analysis was used to model firms' preferences. Most of the discrete choice models used for shipping behaviour applications is based on the random utility theory (McFadden, 1974). The models tested in this paper are: multinomial logit (MNL), nested logit and mixed logit with random coefficients. Simpler structures were tested first such as the MNL model (McFadden 1974), which is the most used discrete choice model for transport studies. It assumes stochastic errors have an IID Gumbel distribution. This assumption for the distribution of residuals is rather simplistic, as they depend on the hypothesis of independence and homoscedasticity of the residuals (Ben-Akiva et al., 2003). Other models were tested to overcome this limitation.

Nested logit (NL) models (Daly and Zachary, 1979; Williams, 1977) were estimated to include possible correlations between unobserved attributes of ports. Among the NL structures tested, the specification with alternatives Rio and Itaguaí nested (Figure 4) resulted in the best NL model. This specification implies that there is more substitution between Rio and Itaguai than between these ports and other posts. The ports of Itaguaí and Rio are located in the metropolitan area of the state of RJ, sharing the same hinterland area in the region.

Figure 4 NL structure



Another model tested was Mixed Logit (ML) that has a highly flexible model that can approximate any random utility model (McFadden and Train, 2000). Thus, ML models with random coefficients (ML-RC), considering normal distribution, were estimated to investigate taste variation (e.g., in a cost coefficient) by assuming that preferences were randomly distributed in the population.

Parameters estimated from discrete choice models with the best choice model were also used to compute subjective VOT savings or, equivalently, the willingness to pay to reduce cargo release time by one unit in ports. The VOT in cargo transportation usually refers to a monetary value that decision-makers are willing to pay to decrease transportation time when moving cargo from source to destination. This value's knowledge allows policymakers to conduct cost-benefit analyses of infrastructure projects and service improvements (de Jong, 2007). The calculation was performed considering the marginal rate according to equation (1), an adaptation from (de Dios Ortuzar and Willumsen, 2011), representing the willingness of companies to pay for the reduction of one unit (day) to release cargo at ports to exporters and importers:

$$VOT = \frac{\partial V_i / \partial Cargo\_release\_time_i}{\partial V_i / \partial Port\_Cost_i} \tag{1}$$

Market share simulations were carried out to assess the impact of port strategies using the best model. The study does not have a real market share due to transhipment. The Port of Vitória, for example, does not receive large ships from Asia. The ship arrives at the Port of Santos and Itaguaí, and the cargo is transferred to a feeder ship with a stopover in Vitória. We do not have correct data on data movement, and we prefer not to recalibrate ASC's based on the market share. The estimations of models were carried out and cross-validated using NLOGIT software (Econometric Software, 2016). Different iterations were tested. The model included the statistically significant iterations that had logic with the evaluated attributes in order to capture the influence of specific company characteristics (e.g., product, company size, type, origin/destination of cargo and others) for the analysed attributes. There are two models in this study. In the export model, the utility can be expressed by the equation (2):

$$\begin{aligned} V_{port\ ij} = {} & ASC_i + B_1 * SC_i\left[by\ cargo\ destination\right] + B_2 * PT_i \\ & + B_3 * RT_i\left[by\ shipping\ \ frequency\right] + B_4 * CT_i\left[by\ company\ size\right] \\ & + B_5 * RC_i\left[by\ type\ of\ \ product\right] + B_6 * CP_i \end{aligned} \tag{2}$$

In (2), the attributes are: SC; PT; *RT tariff*; CT; RC *theft*; *congestion in port access* (CP). $V_{port\ ij}$ is utility function of port *i* for the company *j*. *ASC* is the Alternative specific constant. B_1, B_2, B_3, B_4, B_5 and B_6 are coefficients to be estimated for each attribute.

For the import model, the utility can be expressed by the equation (3):

$$\begin{aligned} V_{port\ ij} = {} & ASC_i + B_7 * SC_i\left[by\ cargo\ origin\right] + B_8 * IC_i\left[by\ company\ type\right] \\ & + B_9 * PT_i + B_{10} * CT_i\left[by\ company\ size\right] + B_{11} * SF_i \\ & + B_{12} * RT_i\left[by\ shipping\ \ frequency\right] \end{aligned} \tag{3}$$

In (3), the attributes are: SC; IC (*taxation*); PT; CT (*cargo release time*); *sea freight* (SF); RT *tariff*. $V_{port\ ij}$ is utility function of port *I* for the company *j*. *ASC* is the alternative specific constant. B_7, B_8, B_9, B_{10}, B_{11} and B_{12} are coefficients for each attribute to be estimated.

4 Results and discussion

This section presents the results of two groups:

1 export

2 import.

The results are based on the SP data collected in the region.

4.1 Export model

The parameters were estimated using MNL, NL and ML-RC models. According to the value of final log-likelihood, AIC and ρ^2, the ML-RC model was selected as the best model. The ML-RC had the highest value of final likelihood and ρ2. The comparison of the Likelihood Ratio Test of ML-RC and MNL shows that ML-RC performs significantly better than MNL as the difference in Loglikelihood (times 2) equals 21.68 and this falls outside of the critical range for three degrees of freedom (7.82). The comparison of the models' parameters is presented in Table 5. The best model for the exporters (ML-RC) model is presented in Table 6. The constant for the Port of Vitória alternative was set to zero.

Table 5 Comparison of the models (export model)

Model	*Number of parameters*	*AIC*	ρ^2	*Final likelihood value*
MNL	16	648.3	0.26	–308.15
NL	17	637.6	0.28	–301.81
ML-RC	19	632.6	0.29	–297.31

Among the factors investigated, the *occurrence of congestion* factor was not significant, and was excluded from the final model. The authors recognise that using the binary level was not the correct choice to display this variable. The ports did not provide enough statistics to quantify this variable, which did not allow us to use numerical levels in the SP experiment. All of the utility parameter coefficients have the expected signs. Coefficients of parameters for *road transport tariff*, port tariff, cargo release time and risk of cargo theft show negative signs, meaning that increases in any of these factors will reduce the port utility. Conversely, positive coefficients for ship calls indicate that improvements in these factors will increase the utility of the alternative. The *road transport tariff* for shipment frequency ≥ 4 per month, the *risk of cargo theft for food and beverage*, the *risk of cargo theft for other products* are the attributes that show significant observed and unobserved heterogeneity (Train, 2012). For each random coefficient, we estimated a mean and a standard deviation (s.d), presented in Table 6.

We tried to test the type of cargo of the companies to verify if any sector of the companies has adherence to any analysed port and the automotive sector was significant for the Port of Santos. One reason for this result is the greater number of ship calls in the Port of Santos (Souza et al., 2022). The state of São Paulo has the largest automotive production in Brazil. The automotive companies are located in the southern region of the State of RJ, closer to the Port of Santos located in the State of São Paulo. The southern region of the State of RJ has an influence of the Port of Santos in terms of hinterland.

Table 6 ML-RC[#] – export model

Variables	*Alternative*	*Estimate*	*T-test*
Constant	Vitória	0	-
Constant (ASC_1)	Itaguaí	–.11744	–0.33
Constant (ASC_2)	Rio de Janeiro	–.17888	–0.46
Constant (ASC_3)	Santos	0.44465	1.46
SP variables			
Ship calls (per week)			
Product destination: Asia	All	0.3726**	2.90
Product destination: Europe	All	0.078	0.65
Product destination: North America	All	0.0662	0.27
Product destination: South America	All	0.4563	1.41
Port Tariff (R$) – per container			
For all Shipping Frequency	All	–.00146**	–2.08
Road transport tariff (R$) – per container			
Shipping frequency (per month) >=4			
Mean	All	–.00313***	–4.03
s.d	All	.00166***	3.16
Shipping frequency (per month) <4	All	–.00233***	–4.7
Cargo release time (days)			
Big company	All	–.25398**	–2.22
Small/Medium company	All	–.22056*	–1.70
Risk of cargo theft (%)			
Type of product: food and beverage products			
Mean	All	–9.2698***	–4.54
s.d	All	4.42208**	2.62
Type of product: steel and metal products	All	–11.274***	–3.49
Type of product: others[†]			
Mean	All	–4.68787**	–2.58
s.d	All	4.324**	2.42
Dummy variables			
Automotive companies	Santos	1.291**	2.72

Notes: Significance at ***1%, **5%, *10% level
[#]Considering normal distribution for the road transport tariff coefficient (> = 4) and risk of cargo theft coefficient (food and beverages and others)
[†]Other products: cotton, oil and gas equipment, chemical, vehicle parts and others

The coefficient associated with *port tariff* is significant for exporters and freight forwarders. This study tried to estimate separately the impact of port tariff for different shipment frequency per month but no significant difference between these two groups was found. According to Martínez Moya and Feo Valero (2017), the importance attached to the variable substantially varies depending on the decision-maker considered.

Table 6 ML-RC[#] – export model (continued)

Model statistics	
Number of individuals (sample)	30
Number of observations	300
Draws (Halton)	1000
Number of parameters	19
Final log-likelihood	–297.31
AIC	632.6
Pseudo-R^2 w.r.t. a model with only ASCs	0.285

Notes: Significance at ***1%, **5%, *10% level
[#]Considering normal distribution for the road transport tariff coefficient (> = 4) and risk of cargo theft coefficient (food and beverages and others)
[†]Other products: cotton, oil and gas equipment, chemical, vehicle parts and others

The parameter associated with *road transport tariff* is highly significant for companies with shipments more than four times a month and less than four times a month. Companies try to minimise the cost of transportation (Tongzon, 2009; Steven and Corsi, 2012).

The coefficient associated with *risk of cargo theft* is highly significant for exporters and forwarders. The fact indicates that firms seek to minimise the risk of cargo theft during transport, changing the port selection. For companies in food and beverages category, this factor was more important. Food and beverages correspond to the product categories that are most stolen in Brazil (ISP/RJ, 2019). For the category of steel and metal products, *risk of cargo theft* was also important. These types of products have a lower frequency of cargo theft; however, the southeast region has the performance of groups specialising in cargo theft for this type of category. The third category covers more products (cotton, oil and gas equipment, plastic, vehicle parts and others), which represent categories less targeted by groups specialising in cargo theft.

The coefficient associated with *cargo release time* is significant for exporters and freight forwarders. However, it should be noted that this variable is more important for large companies. The literature shows that large companies prefer efficient ports. This result is also in line with that obtained by the importers' model. Larger shippers seem more focused on the speed of delivery (efficiency). This has been analysed in the USA (Steven and Corsi, 2012) and Europe (Kashiha et al., 2016).

Regarding *ship calls*, the parameter associated with frequency of ships is highly significant to Asia (99% confidence). Asia (in particular China) is Brazil's main trading partner and the main destination of Brazilian exports. The coefficients referring to other destinations (Europe, North America and South America) were not significant due to the low number of companies with these destinations.

4.2 Import model

As adopted in the export model, different choice models were tested to analyse the import group. The comparison of the models is presented in Table 7. The best model (ML-RC model) is shown in Table 8. Among the factors investigated, the *sea freight tariff* factor was not significant and was excluded from the final model.

Table 7 Comparison of the models (import model)

Model	*Number of parameters*	*AIC*	*ρ2*	*Final likelihood value*
MNL	13	607.4	0.19	–290.70
NL	14	608.6	0.22	–290.28
ML-RC	15	600.9	0.208	–285.45

Table 8 ML-RC[#] – Import model

Variables	Alternative	Estimate	T-test
Constant	Vitória	0	-
Constant (ASC_1)	Itaguaí	–2.29296***	–5.50
Constant (ASC_2)	Rio de Janeiro	–2.45516***	–5.69
Constant (ASC_3)	Santos	–0.048	–0.16
SP variables			
Ship calls (per week)			
Product origin: Asia	All	0.23706*	1.94
Product origin: Europe	All	0.23365*	1.73
Taxation (ICMS) (%)			
Importers		–14.0405***	–6.18
Forwarders		–13.6987***	–4.40
Cargo release time (days)			
Big company	All	–0.20817***	–3.65
Small/Medium company	All	–0.19247**	–2.84
Road Transport Tariff (R$)- per container			
Shipping frequency (per month) >=4			
Mean	All	–0.00320***	-5.03
s.d	All	0.00102**	1.98
Shipping frequency (per month) <4			
Mean	All	–0.00283***	-4.7
s.d	All	0.00110***	2.97
Dummy variables			
Automotive companies	Santos	1.08123*	1.94
Model statistics			
Number of individuals		26	
Number of observations		260	
Draws (Halton)		1000	
Number of parameters		15	
Final log-likelihood		–285.45	
AIC		600.9	
Pseudo-R^2 w.r.t. a model with only ASCs		0.208	

Notes: Significance at: *** 1%, **5%, *10% level
[#]Considering normal distribution for the freight coefficient.

All of the utility parameter coefficients have the expected signs. Coefficients of parameters for road transport tariff, port tariff, cargo release time and ICMS (tax) show negative signs, meaning that increases in any of these factors will reduce utility. Conversely, positive coefficients for ship calls indicate that improvements in these factors will increase the utility of the alternative. The *road transport tariff* (for shipment frequency ≥ 4 per month) and *road transport tariff* (for shipment frequency < 4 per month) are the attributes that show significant observed and unobserved heterogeneity. We estimated a mean and a standard deviation (s.d) for each random coefficient (Table 8).

As it was tested in the export model, we verified the cargo type preference and the port in the import model. Again, automotive companies have preference for the Port of Santos.

The parameter associated with *port tariff* is significant for companies. The port cost on imports is more important than the port cost for exporters[5]. In fact, cargo storage at the port has a higher cost on importers. This is the reason why the *port tariff* has greater influence for import process compared to export process.

The coefficient associated with *Road Transport Tariff* is highly significant for both groups. For importers and freight forwarders with more frequent shipments (more than four times per month), the *Road Transport Tariff* is found to be more important.

The parameter associated with *ICMS* (*tax*) is highly significant for both groups: importers and forwarders. Importers are more sensitive to this variable, and one reason for this result may be due to the fact that importers are the real owners of the cargo and are responsible for paying the tax.

The parameter associated with *cargo release time* is significant for importers and freight forwarders. However, it should be noted that this variable is more important for large companies. This result is also in line with that obtained by the exporters' model. It should be noted that the time to release cargo on import is longer in relation to the time to release for export. This is the result of bureaucracy in Brazil. Thus, we can observe that the import model indicates that importers are more sensitive to cargo release time in relation to exporters.

The parameters associated with frequency of ships are significant to Asia and Europe (90% confidence). In the import sample, there were companies that imported from Asia and Europe only. There were no companies importing from other regions.

4.3 Value of time

Table 9 shows the cargo release time value for large and small companies representing the willingness of companies to pay for the reduction of one unit (day) to release cargo at ports to exporters and importers.

In the export model, the estimated time value for large companies was R$[6]/t.day 173.95 (31.31 U$S/t.day) and for small companies was R$/t.day 151.05 (27.20 U$S/t.day). Large shippers are willing to pay 15% more for a one-day reduction in cargo release time in ports compared to small companies. In the import model, the estimated time value for large companies was R$/t.day R$ 416.65 (74.99 U$S/t.day) and for small companies was R$/t.day 385.23 (69.34 U$S/t.day). Large shippers are willing

to pay 8 % more for a one-day reduction in cargo release time in ports compared to small companies.

Table 9 Value of cargo release time (US$/ t.day)

Size of company	*Export*	*Import*
Large companies	31.31	74.99
Small companies	27.20	69.34

Comparing with the export model, we found that the average VOT for importers is R$/t.day 400.9 (72.16 U$S/t.day), while for exporters the VOT is R$/t.day R$ 162.5 (29.25 U$S/t.day). Importers are more willing to pay to reduce the time for releasing the cargo, which is an effect of the excessive bureaucracy for the import process in Brazil. In exports, the time to release the cargo is faster, while in the import categories, products take several days or weeks for the cargo to be released at the port.

4.4 Market share simulations

Different policy scenarios have been simulated to examine the impact of each policy on the port shares in the region. These policies and strategies were defined with experts in the port sector. The scenarios tested in the simulations are:

1 *First scenario*: 10% reduction in the level of cargo theft in the city of RJ to analyse the impact on the share change of the Port of Rio de Janeiro (export model)

2 *Second scenario*: Tax reduction (ICMS) in the State of RJ from 18% (current rate) to 4% (import model)

3 *Third scenario*: 30% reduction of cargo release time at the Port of Rio de Janeiro (both models)

4 *Fourth scenario*: Increase ship calls (Asia route) at Port of Rio de Janeiro from 1 ship call/week (current situation) to 3 ship calls/week (both models)

5 *Fifth scenario*: Provision of subsidy to port tariff in Port of Itaguaí to reduce the tariff by 20% (both models)

6 *Sixth scenario*: Provision of subsidy to road freight transport to reduce the road transport tariff by 20% (both models).

We used the best models to simulate the market shares of the alternatives and predict the possible effects of implementing different strategies to enhance port competition in the region. We obtained the market share predictions of the model changing one factor according to each scenario while keeping the remaining factors constant with average values. We also emphasize that for the utility functions of each port we take into account the current value of ship calls per sea route (Asia, Europe, North America and South America) in each port analysed in this paper. The simulations were carried out in NLOGIT software. Section 4.5 presents discussions of the scenarios.

The impact of the suggested policies in each alternative port is presented in Table 10. It shows the market share variation in each analysed alternative from the current situation (base scenario), according to the simulated scenarios.

Table 10 Variation of the market share in each scenario

	Scenarios									
	1st	*2nd*	*3rd*		*4th*		*5th*		*6th*	
	Export	*Import*	*Export*	*Import*	*Export*	*Import*	*Export*	*Import*	*Export*	*Import*
Itaguaí	–9.5%	9.1%	–10.9%	–11.2%	–16.6%	–6.6%	4.2	4.8	1.6%	2.7%
Rio de Janeiro	10.7%	13.1%	12.2%	18.4%	18.8%	10.9%	–3.6	–3.2	–0.4%	1.6%
Santos	–0.9%	–5.5%	–1%	–1.6%	–1.8%	–0.8%	–0.5	–0.4	–1%	–1%
Vitória	–0.3%	–17.7%	–0.2%	–5.6%	–0.4%	–3.5%	–0.1	–1.2	–0.2%	–3.3%

4.5 Discussion regarding the scenarios

From the simulation results, we can observe that in all the policies suggested in the export model, there is an evident trade-off between the Ports of Itaguaí and Rio de Janeiro, as shown in Table 10.

In the 1st scenario, a decrease in the level of cargo theft associated with transport to the Port of Rio de Janeiro benefitted this port, with an increase in market share (+10.7%), while the Port of Itaguaí saw a reduction in market share (-9.5%). In the 3rd scenario, a reduction in the time for releasing cargo at the Port of Rio increased this port's market share (+12.20 %), while the share of Itaguaí declined (–10.90%). In the 4th scenario, an increase in the frequency of ships to/from Asia at the Port of Rio from 1 to 3 calls/week also increased this port's market share (+18.80 %), while Itaguaí's share was reduced (–16.60%). The result of the fourth scenario shows the potential for gain with an increase in the frequency of ships, especially services from Asia, Brazil's largest trading partner. In the 5th scenario, a decrease in cargo release time at the Port of Itaguaí by 30% increased this port's market share (+4.2%), while Rio's share was reduced (–3.6%).

In the import model, a trade-off between ports also occurred except for scenario 2. In the 2nd scenario, a reduction in the ICMS rate in the State of RJ was simulated. Importing in these two ports implied the same ICMS rate for the importer/forwarder. Currently, the ICMS rate is 18% in the State of RJ, and the simulation reduced the rate to 4%. The results show that both ports benefit from increased market shares: Itaguaí (+9.10%) and Rio de Janeiro (+13.10%). This finding is important because it shows the effect that ICMS has on the port selection process in Brazil as tax benefits attract importers. We found that the alternative to the greatest loss of market share is Vitória. As this port is located in the state of Espírito Santo (ES), the ICMS rate for imports is 12%, which is lower than the current rate adopted in the States of RJ and São Paulo (18%).

The 3rd scenario simulated in the import model shows that the Port of Rio de Janeiro had an increase in the market share (+18.8%), and Itaguaí's share was reduced (–11.20%). This increase was greater than the result obtained by the export model. Cargo release time for the import process is more critical, and importers value this attribute more compared to exporters. In the 4th scenario, an increase in the frequency of ships to/from Asia at the Port of Rio by 30% also increased this port's market share (+10.90%), while Itaguaí's share was reduced (–6.60%). The impact of the ship calls variable was reduced in the import process in relation to the export. One possible reason is the large importance of ICMS for importers. In the 5th scenario, a decrease in cargo release time at the Port of Itaguaí by 30% increased this port's market share (+4.7%), while Rio's share was reduced (–3.3%).

The 1st, 3rd, 4th and 5th scenarios in both models demonstrate that if a port in the state of RJ shows an improvement in a certain factor, the other port in the same state will show the greatest reduction in participation. Ports located outside the State of RJ (Santos and Vitória) experience limited reductions in market share.

Finally, the sixth scenario shows conflicting results. This scenario simulated a subsidy to road freight transport to reduce the freight road tariff by 20% for the ports of Rio de Janeiro and Itaguaí at the same time. In the export model, it is observed that the market share of the Port of Rio de Janeiro was reduced (–0.4%), and Itaguaí had an increase (+1.6%). In the import model, the two ports saw an increase (Itaguaí, 2.70%) and (Rio, 1.6%). This difference in results shows the difficulty of developing strategies for these two ports together. This situation highlights the competition between the ports

located in the State of RJ. *CDRJ* is the PA responsible for managing and exploring the ports of Rio de Janeiro and Itaguaí. *How can CDRJ balance the strategic conflict between these two ports? How can the ports of Rio and Itaguaí cooperate with each other and compete with other competing ports?* These issues can be further analysed in future studies.

5 Conclusions and policy implications

This paper analysed the decision-making process for container port selection in the state of RJ, Brazil. A parallel analysis was developed evaluating the perspective of export and import companies, using SP data. Results suggest that the parameters associated to the variable the *road transport tariff* is highly significant in both models. The variable *Ship calls* presents significant parameters, particularly for routes related to Asia, the main commercial partner of Brazil. The coefficient associated to *Cargo release time* is significant for both, but is more important regarding the import process, which suggests a greater concern of companies due to the bureaucratic aspect of cargo release in the import process. *Port tariff* also presents the same result. However, the high significance of specific factors should be highlighted due to the context of Brazilian market.

In the export model, an interesting result shows the concern of companies with *cargo theft* during transport to the port. The results of the export model show that the parameter related to *cargo theft* is more important for companies in the food/beverage sector, precisely product categories that are most stolen by groups in the Southeast region of Brazil (ISP/RJ, 2019). To the best of our knowledge, few studies analysed this variable as a port choice factor.

In the import model, the presence of taxation has a significant effect on the company's decision-making. Taxation is seldomly included in other port choice studies. This variable plays an important role in the respondents' decision-making in Brazil, which highlights the discussion on ICMS in Brazil and the impacts of the port sector (Souza et al., 2021b), since taxation changes the behaviour pattern of companies in the port selection process.

With respect to policy implications for port authorities, the results indicate that exogenous factors outside the control of the PA are important. For example, for export companies, cargo theft is an important attribute that influences port choice. This fact shows that the PA needs to create strategies with government security agents, aiming to create measures to reduce the occurrence of cargo theft in the region.

For import companies, taxation is highly important. These differences in import rates between states in Brazil represent a problem for the port competition in Brazil. The 1988 Constitution allowed the states to set ICMS rates on domestic operations and removed power from the Federal State to grant exemptions and rebates from the state tax (Alves, 2001). This concession of tax benefits on imported products started the so-called 'War of ports' in Brazil. Companies from other states seek to import goods through ports in states where there are tax benefits (Souza et al., 2021b). This situation shows the need for port authorities to seek a definition of rates with the federal government so that practiced values do not distort port competition.

Cargo release time is another important factor, especially for importers. The port sector in Brazil faces an excess of bureaucracy, causing delays in the release of cargo and excessive time spent with the required documentation (CNI, 2016). This result indicates

the need for port authorities to adopt strategies together with public agencies that act in the release of the container to reduce the time that the container is retained in the port. Delays in release in ports increase the storage cost for the company (CNI, 2018).

This article contributes to the port choice literature especially in a developing economy country where there is a lack of freight demand data. These results indicate that the ports in the region analysed are dependent on exogenous variables that PAs cannot control and that directly interfere in the choice pattern of companies. Thus, this article presents important contributions regarding not only representing the Brazilian context as independent variables in the decision-making process, but also interpreting the results and their implications in port competition.

This study presents methodological limitations regarding the sample due to the restrictions that companies have in providing data for freight transport studies (Tavasszy and de Jong, 2013). In addition, the lack of public data on the market share of ports in the context of the State of RJ prevents the recalibration of ASC's.

For future studies, nonlinearity in the effects of attributes by using different mathematical transformations (logarithmic and power series) may be tested with variables (Gatta and Marcucci, 2016). Furthermore, there is a potential for further studies by developing SP questionnaires with the inclusion of feeder services for different origins, such as the Ports of Santos and Itaguaí. The Port of Santos concentrates ship calls in Brazil, while smaller ports are served by feeder ships. The Port of Itaguaí has one of the largest operational drafts in the East Coast of South America and serves large ships.

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Notes

1 In the export process, the cargo release time refers to the number of days for the container terminal to release the container for export. In the import process, this attribute represents the number of days for the container terminal to release the cargo after the container arrives at the port.

2 ICMS: is the acronym for Tax on Circulation of Goods and Transportation and Communication Service. Imposto sobre Circulação de Mercadorias e Serviços (in Portuguese). ICMS is the main tax levied by the 26 Federal states and applies to: the movement of goods, the services of transportation between several States or municipalities.

3 The values of sea freight for container (1 TEU FCL) from the Port of Hong Kong to the ports analysed in Brazil were used as a reference, as Asia is Brazil's main trading partner.

4 We used Port A for Port of Itaguaí, Port B for Port of Rio de Janeiro, Port C for Port of Santos and Port D for Port of Vitória.

5 For exporters, the port tariff is related to container handling. The storage of the container does not have great costs and there is usually a period of exemption from the storage fee for exporters.

6 1 BRL = 0.18 US Dollars (date: November 17, 2022).