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PORT CHOICE DETERMINANTS: A REVEALED PREFERENCE ANALYSIS OF COLOMBIAN PUBLIC PORTS

Tesis para optar por el título profesional de Magister en Ingeniería Civil

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RESUMEN

Identifying the most influential attributes considered by exporters and importers when choosing a port is crucial for logistics policy formulation. In this paper, the port choice process is modelled using revealed preference data obtained from the official records of imports and exports in Colombia. Results show that the cost of port access, frequency of maritime lines, maritime freight rates, maritime travel time, origin or destination of the cargo and the type of cargo, play an important role in the port selection process. The calculated elasticities indicate that exporters and importers are highly sensitive to the access cost of the port. Policies and strategies aimed to improve the efficiency of a port's operation and their level of service, such as increasing the frequencies of lines or decreasing maritime freights and transit times, could have an important impact on demand.

INTRODUCTION

Maritime transport has become the predominant mode of transport in the Colombian foreign trade. In fact, 96% of exports and imports are mobilized around this transport modality (Ministry of Transport, 2014). Colombia has experienced an annual growth rate close to 7.5% in their exports and imports over the last decade. This increased demand for maritime transport has derived in the evolution in size and capacity of ships, and in the adequacy and modernization of ports seeking to diversify the services provided and maximize their efficiency by decreasing their costs.

Until 1993, port terminals in Colombia were administrated by the state company Ports of Colombia –COLPUERTOS–, who monopolized the handling of import and export freight in the country. During this period, high indexes of low productivity and inefficiency appeared causing high operational costs for the government. Those high operational costs lead to the necessity for modernization of maritime terminals by linking the private sector to the port's activities.

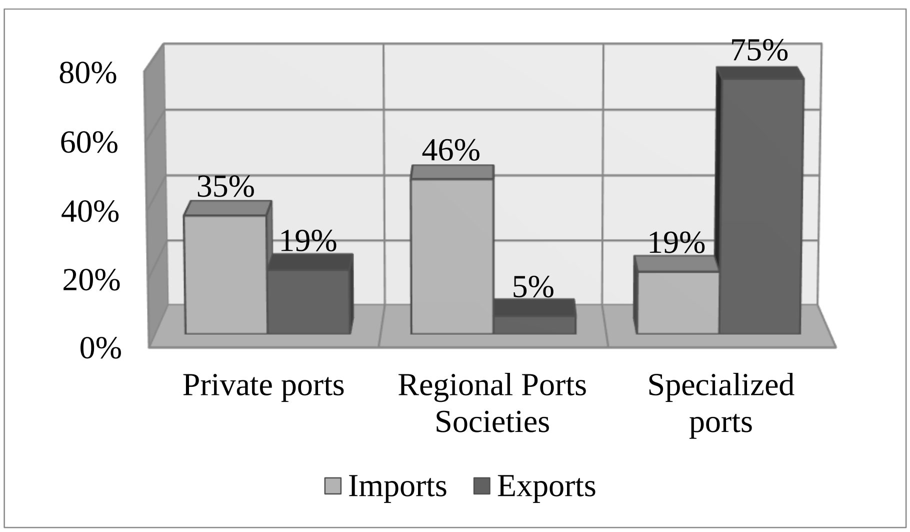
In 1991, changes in port policy were proposed and then implemented. The national government motivated and encouraged private companies to manage and operate the port facilities of the country. Inside this frame of privatization of port activity, the principal state ports (Buenaventura, Santa Marta, Cartagena, Barranquilla and Tumaco) were given in concession to private entities, the Regional Port Societies, in 1993. The targets of those concessions were lowering the rates, improving the levels of efficiency of port operations and modernizing the port services. The results for the mentioned principal ports were positive as they became more efficient and competitive.

Currently, the maritime transport system is formed by three types of piers: private, specialized, and the Regional Port Societies. The privates are managed by private companies for their exclusive use. The specialized ports handle exclusively one product and they are used to export traditional commodities such as oil, coal and bananas. Finally, the regional ports render their service to the productive sector in general and are of public use. The entire system is under private capitals.

In 2013, across the Colombian ports, a total of 183 million tons were mobilized, growing 5.5% compared to the previous year (Superintendency of Ports and Transportation, 2014). From the total of mobilized tons, 90.5% (165.6 million tons), imports represent around 17.2% while exports are

73.3%, mainly coal and oil and its derivatives, which constitute 78.4% of the Colombian foreign trade mobilized by the maritime ports.

From the foreign trade cargo, the market share of Regional Port Societies (RPS) of public service is 46% of the total of tons mobilized of imports, over the private piers and the specialized ports, as is shown in figure 1 (Ministry of Transport, 2014). In the case of exports, the specialized ports are those with the largest cargo movement. This fact is explained because those ports move high volumes of coal and petroleum, which represent about 88% of exported tons.



Source: Ministry of Transport (2014), Note: The participations were calculated based on the total of tons mobilized in the Colombian foreign trade for the year 2013.

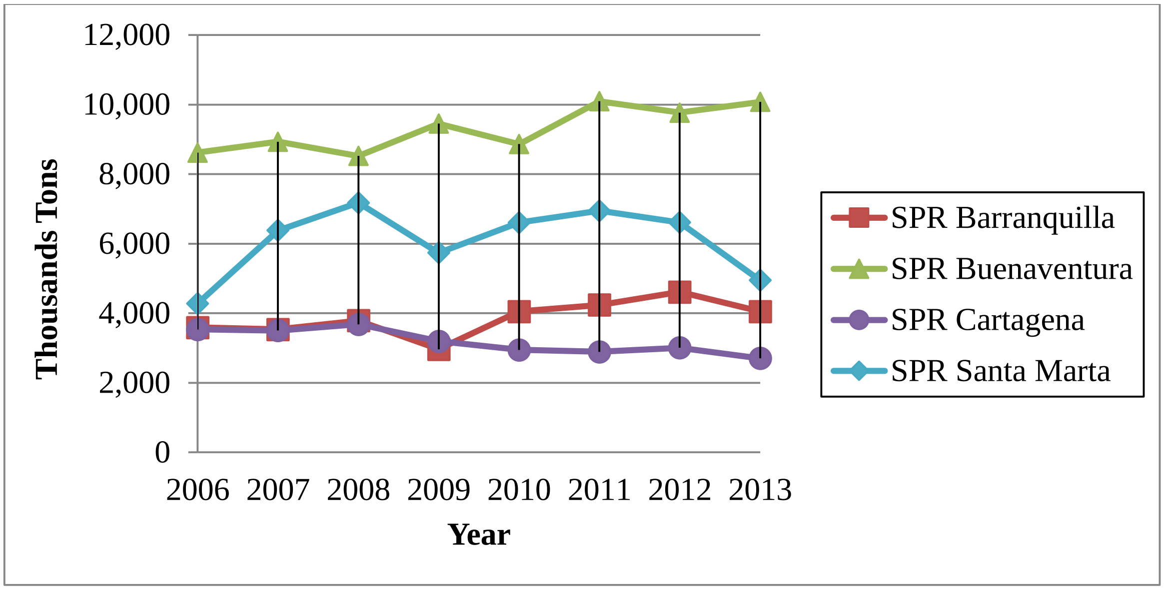
Figure 1. Participation of the maritime transport in the foreign trade.

The most important ports for the public service of the country are Barranquilla, Cartagena and Santa Marta which are located on the Colombian Caribbean coast. The separation between the extreme ports, Cartagena and Santa Marta is close to 220 km. At the same time, the most important port on the Pacific Ocean is Buenaventura. The location of these ports is shown in figure 2.

The freight movement in these ports has become more specialized in the last few years. Barranquilla's RPS is a multipurpose terminal that handles solid bulk, liquid bulk, general and containerized cargo, similar to the RPS of Buenaventura. On the other hand, the RPS of Cartagena specializes as a container transhipment terminal. Finally, the RPS of Santa Marta moves mainly solid bulks, but also general and containerized cargo (Marenco & Cantillo, 2015).

Figure 2. Location of the most important public service ports in Colombia.

During 2013, through the four most important RPS's of the country, 21.7 million tons of foreign trade were mobilized (Superintendency of Ports and Transport, 2014). The RPS of Buenaventura represented 46.3% of this volume, followed by the RPS of Santa Marta, and Barranquilla's RPS, with 22.7% and 18.6%, respectively. Finally, the RPS of Cartagena has a market share of 12.4%. Figure 3 shows the evolution of the port traffic of these RPS's of public service between 2006 and 2013.



Source: Superintendency of ports and transport (2014).

Figure 3. Evolution of the foreign trade cargo movement in Colombian RPS (2006-2013).

Colombia is a unique South American country with ports in the Atlantic and the Pacific Ocean, having a maritime geographical privileged position regarding shipping routes. Nevertheless, the country has some factors that impose difficulties for an efficient mobilization of products. Among them, the most highlighted difficulties are the road infrastructure and the distance between the ports and the major producer and consumer centers. In the Global

Competitiveness Index 2014-2015, prepared by the World Economic Forum (WEF, 2014), Colombia obtained position 66 out of 144 economies, climbing three positions compared to the previous year. Although progress was mainly due to improvements in the pillars of technological readiness and infrastructure, the infrastructure is still considered the second most problematic factor for doing business in the country. The quality of roads in Colombia (126th), the quality of overall infrastructure (108th) and the quality of port infrastructure (90th) are highly deficient. The major producer and consumer centers are located in the central part of the country, over 900 km from the Caribbean ports and about 450 km from Buenaventura. They are connected by roads located on a mountainous relief that in most of their extension have only two lanes. In such conditions, the operation speeds of truck are around 40 km/h. As a consequence, a truck trip from Bogotá or Medellin to any port, which represents an approximate average distance of 800 kilometers, may take more than 20 hours with high operation costs involved (Márquez and Cantillo, 2013). Table 1 shows the inland distances and the average inland freight rates per ton from major producer and consumer centers to the main ports of Colombia (Ministry of transport, 2013).

Table 1. Representative inland distances and inland freight rates to ports

Major producers and consumers centers	**Inland distances (km)/ Inland freight (US$/ton)**							
	Barranquilla		**Buenaventura**		**Cartagena**		**Santa Marta**	
Bogotá	978	67.5	511	43.8	1060	66.2	941	63.8
Cali	1127	81.8	126	12.6	1065	79.4	1207	83.4
Medellin	701	49.8	475	40.7	644	47.4	792	58.2

Source: Ministry of transport

The analysis of exporter and importer behaviour regarding port choice is essential for the creation of policies for the development of adequate port infrastructure and other logistic improvements that allow the efficiency and the attractiveness of port zones to be increased. In Colombia, there is a need to promote projects and policies that allow port development, making them more competitive in terms of the logistic costs involved. To develop port zones and take advantage of the maritime geographical privileged position of Colombia, one essential step is related to the identification of the most important factors that attract exporters and importers to use the ports, which is a task not really accomplished in the country.

The aim of this research is to estimate models that allow studying which factors influence the decision of exporters and importers when selecting which ports they should ship their cargo to. Through the specified models, the relevant variables considered by the economic agents in the logistic process that includes port choice will be sought. This research is focused on the four most important ports of public service of the country: the RPS's of Barranquilla, Buenaventura, Cartagena and Santa Marta. The data corresponds to information of revealed preferences, extracted from the official record of imports and exports reported by the Directorate of National Taxes and Customs (DIAN) of Colombia during 2012, and complemented with official information of the ports, the Ministry of Transport and the shipping lines.

FACTORS INFLUENCING PORT SELECTION

The port choice is a decision affected by a great amount of external factors related to exporters and importers. The costs of transport to the port, the port costs, the characteristics of the port, the port's rates, the location of the port, the supply of maritime lines, the country of origin or destination of the cargo and the type of goods that are commercialized are examples of those external factors. Table 2 synthetizes a literature review for factors affecting port choice, and also includes the methodology which was applied to obtain those factors.

Several studies have analyzed the reasons why shippers, forwarders and shipping lines choose a particular port to ship their goods. Slack (1985) established that the number of sailings is the most important factor considered by exporters and freight forwarders in the port selection process. Murphy and Daley (1994) considered shipment information and loss and damage performance as the most important factors for international shipments. Malchow and Kanafani (2004) demonstrated through a multinomial logit model, that the variables beyond the control of port authorities, oceanic and inland distances, have the highest impact on a carrier's distribution of shipments. Tiwari et al. (2003) used a multinomial logit model to model the port choice behaviour of shippers in China, concluding that the distance of the shipper from port; the distance to destination (in exports); the distance from origin (in imports), the port congestion in terms of the number of TEUs manipulated in a port; the number of berths and the shipping line's fleet size play an important role in port choice. Also, in the Chinese context, Song and Yeo (2004) identify the competitiveness of container ports from the outsider's perspective, using an Analytic Hierarchy Process. They found that location plays the most significant role in the process of evaluating the port's competitiveness.

Table 2. Literature review of the variables in port choice.

Author (year)	**Methodology**	**Perspective**	**Factors**
Slack (1985)	Survey	Shippers and freight forwarders	Number of sailings, inland freight rates, port congestion and intermodal links.
Murphy et al. (1992)	Survey, univariate and multivariate analysis	Shippers, international water carriers, international water ports and international freight forwarders	Loading and unloading facilities for large and/ or odd sized freight, large volume shipments, low loss and damage frequency, equipment available, convenient pickup and delivery times, information concerning shipments, assistance in claims handling and flexibility in meeting special handling requirements.

Murphy and Daley (1994)	Survey	Shippers	Shipment information, loss and damage performance, low freight charges, equipment availability, convenient pickup and delivery, claims handling ability, special handling ability, large volume shipments and large and odd-sized freight.
Tongzon (1995) ; (2009), Tongzon and Sawant (2007)	Survey, regression analysis	Freight forwarders and shipping lines	Port efficiency, shipment frequency, adequate infrastructure, port location, port charges, wide range of port services and connectivity to other ports.
Malchow and Kanafani (2001);(2004)	Discrete choice model	Shippers	Port location, oceanic and inland distances, frequency of sailings and vessel capacity.
Tiwari et al. (2003)	Discrete choice model	Shippers	Distance of the shipper from port, distance to destination, distance from origin, number of berths, shipping line's fleet size and port congestion.
Nir et al.(2003)	Discrete choice model	Shippers	Travel time, maritime cost, number of available routes and frequency.
Lirn et al. (2004)	Analytic Hierarchy Process	Global container carriers and terminal operators	Physical and technical infrastructure, geographical location, port management and administration and carrier's port cost.
Song and Yeo (2004)	Analytic Hierarchy Process	Ship owners, shipping companies, Shippers, terminal operators, academics and researches	Port location, port facility, cargo volume and service level.
Guy and Urli (2006)	Multicriteria analysis	Shipping lines	Port location, port infrastructure, service and port charges.

Ugboma et al. (2006)	Analytic Hierarchy Process	Shippers	Efficiency, frequency of ship visits, adequate infrastructure, location, port charges, ports reputation for cargo damage and quick response to port user's needs.
Chang et al. (2008)	Survey	Shipping lines	Local cargo volume, terminal handling charge, berth availability, port location, transhipment volume and feeder connection.
Chou (2010)	Analytic Hierarchy Process	Carriers	Port charge, tax, rent and cost, port operation efficiency, port loading/discharging efficiency, size and efficiency of container yard, hinterland economy and depth of containership berth.
Tang et al. (2011)	Network-based Integrated Choice Evaluation	Shipping lines	Number of port calls, port traffic, trade volume, port charges, draught, ship turnaround time, annual operating hours and availability of inter-modal transport.
Veldman et. al (2011)	Discrete choice model, regression analysis	Imports and exports	Inland transport cost, maritime transport cost and hub-port effects.
Steven and Corsi (2012)	Discrete choice model	Shippers	Crane productivity, port congestion, carrier frequency, freight charges, oceanic transit time, inland transit time and number of container berths at port.
Lam and Dai (2012)	Analytic Hierarchy Process	Carriers	Port location, port charges, port infrastructure, ship calls, container traffic and water depth.

Onwuegbuchunam (2013)	Discrete choice model	Shippers	Crane efficiency, cargo handling speed at the port, level and functionality of port facilities, shipment size, ship-calls' frequency and shipper warehouse distance from port.

Tongzon and Sawant (2007) examined surveys of revealed and stated preferences to determine the port choice from the perspective of shipping lines, finding that the results of both surveys differed. The analysis of the stated preferences showed that the efficiency of the port is the most relevant factor, followed by the port charges; the connectivity of the port; the location of the port and the infrastructure. In contrast, the revealed preference survey exposed that the most important factors are the port charges and the wide range of port services; the other factors being insignificant. Magala and Sammons (2008) suggest that a new approach must be taken to modelling port choice, taking into perspective that it is an important element of a supply chain to provide a better comprehension of the determinants of the process. Tongzon (2009) found that the most important factor in port choice from the freight forwarder's perspective is the efficiency of the port; followed by the shipment frequency; the adequate infrastructure of the port and its geographical location. The research conducted by Tang et al. (2011) shows that port efficiency and scale economies have influence on the line shipping companies when selecting among mayor Asian ports. Steven and Corsi (2012) stated that the importance of the factors vary according to the shipper: large shippers are more sensitive to the factors that enable speedier transport and delivery of their cargo; smaller shippers, on the other hand, place more emphasis on the ocean transport costs of the shipment.

Even though a lot of different studies have found various factors affecting port selection as mentioned, there is no consensus about which factors are the most influential on this decision. Moreover, there are no conclusive guidelines stating which factors should be promoted first to make port zones more attractive; neither applied to the context of Latin American nor Colombian ports.

DATA

The data used to estimate the models was extracted from the record of imports and exports reported by the Colombian Bureau of National Taxes and Customs during 2012 (DIAN, 2013). The database contained 935,888 export registries and 2’472,468 registries of imports. Each registry had additional information concerning the mode of transport, importer/exporter data, product type, user type, quantity, price paid, origin and destination of the cargo and the national port used for the shipment.

Every registry represents a transaction and not the number of tons shipped, that is, a port can have many shipments or transactions which only mobilizes small cargo, or it may have only a few transactions with large cargo. Of the total number of registers, 13% corresponds to the port of Barranquilla, 31% to the port of Buenaventura, 49% to the port of Cartagena and 7% to the port of Santa Marta.

Inland freight rates, inland distance and inland transit time were obtained from established rates for the national transport of cargo by trucks in Colombia (Ministry of Transport, 2013). It is important to highlight that the access to ports mainly occurs by truck. Although ports located in Barranquilla and Cartagena may be accessed through the Magdalena River, the use of this inland waterway is low. The Port of Buenaventura has railway access but less than 2% of the cargo actually travels by train. In contrast, most of the cargo shipped in the port of Santa Marta arrives by train. The port of Santa Marta is highly specialized due to coal companies shipping their cargo there because of the railway connection to the port, which allows for moving large amounts of their product from the mines.

The maritime freights were taken from the registers about maritime transport by Proexport[1] (2013). The maritime transit times were obtained from the information referenced in SeaRates (SeaRates LP, 2013). Port charges and the frequency of the shipping lines for each port were taken from the official pages of each one of the ports included in this study (RPS Barranquilla, 2013; RPS Buenaventura, 2013; RPS Cartagena, 2013; RPS Santa Marta, 2013). Information concerning the Colombian transport network was taken from the strategic freight model proposed by Cantillo et al. (2014).

To build the database for modelling purposes, a random sample of 20,000 registers were taken, 10,000 registries concerning exports and 10,000

[1] Proexport was rename to Procolombia (www.procolombia.co)

imports. Table 3 shows the descriptive statistics of the variables for each port used for the estimation of the models.

Table 3. Descriptive statistics of variables

Variable (Unit)	Description	Barranquilla	Buenaventura	Cartagena	Santa Marta
Maritime transit time (days)	Max.	42	41	42	42
	Min.	2	2	2	2
	Mean	14	17	13	14
	SD.	11	13	8	8
Frequency of the shipping line (trips for month)	Max.	40	60	44	12
	Min.	4	4	4	4
	Mean	33	48	29	11
	SD.	10	17	11	2
Maritime freight rate (US$/ton)	Max.	128	105	120	120
	Min.	28	20	22	48
	Mean	43	30	38	55
	SD.	12	16	12	9
Port charges (US$/ton)	Max.	5.0	5.0	5.8	5.0
	Min.	4.5	4.5	4.5	4.0
	Mean	5.0	4.6	5.7	4.9
	SD.	0.1	0.1	0.3	0.2
Inland freight rates (US$/ton)	Max.	110	88	113	79
	Min.	5	13	5	5
	Mean	17	30	52	46
	SD.	24	15	23	23
Inland distance (kms)	Max.	1,402	1,175	1,443	1,135
	Min.	12	126	11	8
	Mean	202	343	769	661
	SD.	368	181	380	359
Inland transit time (days)	Max.	0.9	0.8	1.0	0.7
	Min.	0.02	0.10	0.02	0.02
	Mean	0.1	0.3	0.5	0.4
	SD.	0.2	0.1	0.3	0.2
Shipment size (tons)	Max.	3,251	39,373	10,419	55,000
	Min.	0.0001	0.0001	0.0001	0.0001
	Mean	15	27	10	207
	SD.	129	685	122	2,749

SPECIFICATION AND ESTIMATION OF MODELS

Discrete choice models allow for estimating the choice of individuals (or companies) among a finite set of alternatives. The random utility theory provides the theoretical framework establishing that once a general set of alternatives is given, the individual chooses the alternative that represents the maximum utility. It is assumed that a trader (company) makes the decision to choose a particular port by taking into account its impact on their operations, particularly on their expected profit. Based on the former assumption, the hypothesis is that the port choice can be modelled under a disaggregate approach using discrete choice models.

It is thought that using discrete choice modelling is appropriate in this case because decision makers (exporter/importer) can be viewed as economical rational agents who maximize their utility (profit) when choosing a port for the transaction. The utility function of each port depends on the attributes of the port (e.g. port charges, frequency of the shipping lines, equipment, and draught); the characteristics of the intermodal connections (e.g. travel time, travel cost, and travel distance); the characteristics of the cargo (e.g. type of cargo, value); site of origin or destination of the cargo and the characteristics of the exporter/importer (e.g. geographical location and size of the operations).

Each decision maker (trader) in the choice process faces a set of eligible alternatives (port) which are described by a number of measurable and comparable attributes. Each port *i* has an associated utility (U_i) for trader $q \in Q$, whose structure is assumed as shown in equation (1).

$$U_{iq} = V_{iq} + \varepsilon_{iq} \quad (1)$$

The term V_{iq} is a systematic component of the utility that can be measured. This component is based on a number of measurable attributes specific to each port as was previously mentioned. The observed choice of the trader *q* is the one that maximizes its utility function. On the other hand, ε_{jq} is a random component which reflects the uncertainty about attributes considered by traders that cannot be observed by the modeler. This uncertainty can explain two situations which can be considered as irrational which are when: (i) two traders with identical attributes and equal port alternatives make a different port selection; (ii) one specific trader does not select the best apparent port alternative. Depending on the assumption about the random term in equation (1), different choice models will result. In particular, when an independent and identical Gumbel distribution is assumed for that random term, that is the classical multinomial logit model (MNL). The MNL model does not consider correlation among alternatives; in consequence, other most advanced models such as the nested logit (NL) and the error component (EC) logit models may be used when correlation among alternatives exist (Ortúzar and Willumsen, 2011). For the error component logit model, the utility associated to each port (U_i) for trader q is shown in equation (2).

$$U_{iq} = V_{iq} + \eta_{iq} + \varepsilon_{iq} \tag{2}$$

Where the term η_{iq} corresponds to the error component term that allows the presence of correlation and heteroscedasticity over alternatives in the unobserved terms of the utility (Brownstone & Train, 1999).

Initially, multinomial logit models, logit nested models and error component logit models were calibrated in separate form for exports and imports. However, due to the fact that in all the considered models the same significant variables were obtained, it was decided that a joint model merging the 20,000 registries for exports and imports should be estimated. However, when merging different databases (i.e. exports and imports) there is a possible existence of heteroscedasticity, which can be captured by using a scale factor to equalize the variances of both data in the estimation of the joint model (Hensher et al., 1999). In consequence, using the multinomial logit model, the probability of choosing one of the ports *i* (*i*=1, 2, 3, 4 for Barranquilla, Buenaventura, Cartagena and Santa Marta, respectively) for the trader *q* is given by:

$$P_{iq} = \frac{e^{\lambda V_{iq}}}{\sum_{j} e^{\lambda V_{jq}}} \qquad (3)$$

Where the systematic utility V_{iq} is the utility function associated to the port *i* for the trader *q* which is commonly expressed as a linear combination of the variables that affect the port choice. The scale factor λ allows equalizing the variances of both sets of data (i.e. imports and exports). The scale factor was fixed to one for exports while it had to be estimated for imports.

The variables used in the specification of the chosen models are described in table 4. It is expected that the parameters associated to variables of access cost, maritime freight rate and maritime transit time have a negative sign, considering that their marginal utility is negative. Meanwhile the parameter associated to the frequency of the shipping line has a marginal positive utility. The dummy variable Pacific was only considered in the utility equation for the port of Buenaventura. The port of Buenaventura is the only one located on the Pacific coast of Colombia that was included in the analysis. It is expected that the parameter for this variable has a positive sign. The sign of the dummy variable containerized cargo, when positive, reflects the preference of using the port for the movement of cargo in containers.

Table 4. Variables included in models.

Variable	**Definition**
Access cost	Access cost from/to the port *i* for trader *q*. Includes the inland freight rates to the port and port charges (US$/ton).
Maritime freight rate	Maritime freight rate of port *i* for trader *q* (US$/ton).
Frequency of shipping line	Frequency of maritime line of port *i* for trader *q* (trips per month).
Pacific	Pacific ocean: Dummy variable that takes the value of 1 if the place of origin (for imports) or destination (for exports) is located on the Pacific Ocean and 0 otherwise.
Maritime transit time	Maritime transit time of port *i* for trader *q* (days)
Containerized	Containerized cargo: Dummy variable that takes the value of 1 if the cargo is containerized and 0 otherwise.

Alternative specific constants dealing with export data were notated as ASC^E_i, while the ones for imports were ASC^I_i. Ports are noted as follow: *i*=1 for Barranquilla, 2 for Buenaventura, 3 for Cartagena and 4 for Santa Marta. Alternative specific constants for the port of Barranquilla were fixed to zero. For the estimation of the nested logit model, it was hypothesized that the ports located on the Atlantic Ocean (Barranquilla, Cartagena and Santa Marta) are correlated. Figure 4 shows a tree diagram of this model, where the first level corresponds to the categories of ports on the Atlantic and the ports on the Pacific.

An alternative approach was used to considerer correlation among Caribbean ports. In this case, an error component model was estimated correlating Barranquilla, Cartagena and Santa Marta. To achieve that, an error term with mean zero and standard deviation (SD) to be estimated was added to the utility functions. The estimation of the EC model was made by using simulated maximum likelihood (Ortúzar and Willumsen, 2011)

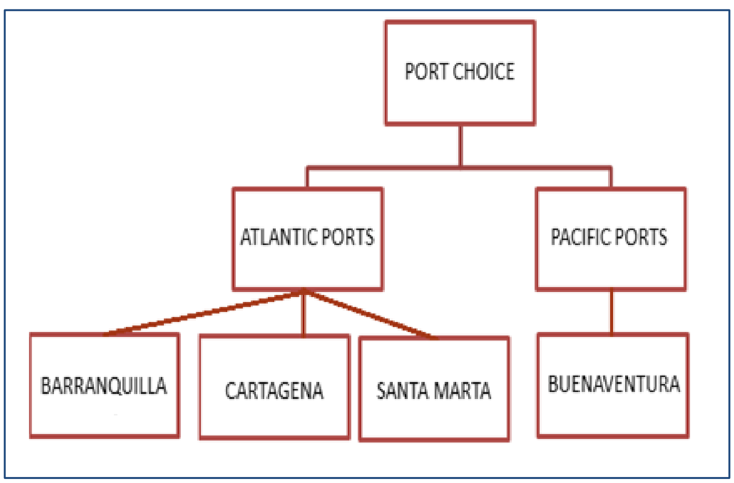


Figure 4. Tree diagram nested logit model.

RESULTS

After evaluating diverse specifications of the utility functions, the models presented in Table 5 were chosen. For each case, the parameters and their respective t-statistics (in parentheses) for the multinomial logit model, the nested logit model and the error component logit model are shown. The variable containerized cargo is specific for every alternative and the variable Pacific is specified only for alternative 2 (Buenaventura). Remaining variables (i.e. access cost, maritime transit time, maritime freight rate and frequency of shipping lines) are generic.

Other variables such as shipment size, type of cargo (solid bulk, liquid bulk and general cargo), inland distance, inland transit time and draught, were also tested in the models. However, they were removed from the models for not being significant. On the other hand, it was found that the variables inland distance and inland transit time were strongly correlated with the inland freight rates. In consequence, it was finally decided that only inland freight rates should be included.

In the models presented in Table 5, all the included variables turned out to be relevant, highly significant and with the expected sign. The access cost from/to the port is a determinant factor in the port choice in Colombia, where land freights usually exceed the maritime freights due to the conditions of the road infrastructure (e.g., land transport from Barranquilla to Bogotá has a cost of 67.5 dollars per ton, while maritime transport from Barranquilla to Rotterdam has a cost of 50 dollars per ton) making it evident that reductions in the access cost of a port will increase the probability of choosing that specific port.

The frequency of the maritime line was equally significant, which indicates that an increase in the frequency of the lines in the ports would increase the probability of choosing a port. As expected, the maritime freight rate and the maritime transit time are negatively related to the port choice and depend on the position of the port with respect to the origin location (in the case of imports) or destination (in the case of exports).

Table 5. Discrete choice models estimated.

Variables	MNL Coeff. (t)	NL Coeff. (t)	EC Coeff. (t)
ASC^{E}_{1}	-	-	-
ASC^{I}_{1}	-	-	-
ASC^{E}_{2}	-4.14 (-24.8)	-4.69 (-32.79)	-9.15 (-16.84)
ASC^{I}_{2}	-3.75 (-23.69)	-4.42 (-30.58)	-8.16 (-16.23)

ASC^E_3	1.11 (14.58)	0.59 (12.93)	1.15 (12.84)
ASC^I_3	0.45 (5.32)	0.29 (6.46)	0.65 (6.3)
ASC^E_4	1.01 (8.80)	0.76 (11.58)	1.74 (12.58)
ASC^I_4	2.85 (22.14)	1.76 (19.88)	3.95 (21.94)
$Containerized_1$ (1)	1.49 (12.2)	0.77 (11.24)	1.82 (11.92)
$Containerized_2$ (2)	1.61 (11.76)	0.79 (7.26)	1.82 (8.38)
$Containerized_3$ (3)	2.29 (19.47)	1.19 (16.39)	2.81 (18)
Access cost (1,2,3,4)	-0.11 (-43.68)	-0.11 (-46.26)	-0.21 (-21.77)
Maritime freight rate (1,2,3,4)	-0.06 (-31.2)	-0.04 (-23.21)	-0.09 (-26.44)
Frequency of shipping lines (1,2,3,4)	0.07 (36.45)	0.05 (26.34)	0.10 (29.14)
Pacific (2)	2.33 (23.08)	2.74 (28.21)	5.05 (15.44)
Maritime transit time (1,2,3,4)	-0.16 (-8.2)	-0.12 (-9.71)	-0.27 (-9.8)
Scale factor	0.84 (37.17)	0.80 (38.96)	0.69 (25.99)
Nest parameter	-	0.47 (25.32)	-
SD of error term (1,3,4)	-	-	-3.34 (-14.92)
Sample size	20,000	20,000	20,000
Log-likelihood	-12,130	-11,950	-12,028
Adjusted rho – squared	0.562	0.568	0.566

Results suggest that a strong correlation exists among the three Caribbean ports, given that the structural parameter of the nested logit model and the term of error of the error component logit model are both significant. Additionally, there is an improvement in the goodness of fit measure in comparison to the multinomial logit model. The models also reflect a preference for using the port of Buenaventura when the cargo has, as its origin (for imports) or destination (for exports), a place found towards the basin of the Pacific Ocean.

The parameters for the containerized cargo variables indicate that the port of Cartagena is the most attractive option to mobilize this type of cargo, which is in line with the port facilities available for handling containers. The port that is least attractive to mobilize cargo in containers is the one located in Santa Marta, which is specialized in handling bulk cargo.

Table 6 shows the subjective value of maritime transit time, calculated as the marginal rate of substitution between maritime transit time and maritime freight rate for each of the estimated models. This value indicates that an exporter or importer is willing to pay around $2.67-$3.00 per ton to save an additional day in maritime transit time. The table also presents the willingness to pay for a marginal increment in the frequency of shipping, estimated as the marginal rate of substitution between the frequency of shipping lines and the maritime freight rate. This value indicates than an exporter or importer values an additional trip in a month at about $1.20 in terms of maritime freight rates per ton.

Table 6. The value of maritime transit time and frequency of shipping lines in terms of the maritime freight rate.

Model	Subjective value of maritime transit time US$/Ton-Day	Willingness to pay for marginal increment in frequency of shipping lines US$/trips per month
MNL	2.67	1.17
NL	3.00	1.25
EC	3.00	1.11

The direct and cross elasticities were estimated using the selected models, as shown in table 7. When using the MNL model, an increase or decrease in the attributes of an alternative reduces or increases the probability of choice of all other alternatives in the same percentage; that is, cross elasticities are equal. This pattern of proportional substitution of alternatives is a manifestation of the property of independence of irrelevant alternatives (IIA) of the multinomial logit models. The nested logit model allows relaxing the IIA hypothesis, but this is kept within each group and between groups selection. Because of this, the cross elasticities of the remaining model structures suggest that substitution patterns among different port alternatives vary with the correlation.

The high value of direct elasticities is not surprising. As ports are competitive substitute services, it is expected that the more and closer the substitutes available are, the higher the elasticity is likely to be. When competitive, exporters and importers can easily switch from one port to another if a better level of service is offered. In consequence, there is a stronger substitution effect when the distance among the ports decreases.

The analysis of values in table 7 indicates that the port choice is much more sensitive to the access costs, than to other variables. Table 7 shows that the probability of choosing a port is highly elastic compared to the access cost of the port. Also, high cross elasticity values for access cost were found between the ports of Buenaventura and Cartagena despite being located on the Pacific and the Atlantic coasts respectively. In the MNL model, an increase in the cost of port access of Buenaventura's port by 1%, decreases the probability of choosing this port by 4.04% while the probability of choosing all other ports increases by 1.11%. Similarly, an increase in the cost of port access of Cartagena's port by 1%, decreases the probability of choosing this port by 3.32% while the probability of choosing all other ports increases by 2.87%.

Table 7. Direct and cross elasticities of the MNL, NL and EC models.

Variable	Model	Port	Barranquilla	Buenaventura	Cartagena	Santa Marta
Maritime transit time	**MNL**	Barranquilla	-1.81	0.20	0.20	0.20
		Buenaventura	0.72	-1.40	0.72	0.72
		Cartagena	0.95	0.95	-1.11	0.95
		Santa Marta	0.14	0.14	0.14	-1.89
	NL	Barranquilla	-2.86	0.15	0.37	0.37
		Buenaventura	0.54	-1.09	0.54	0.54
		Cartagena	2.08	0.74	-1.27	2.08
		Santa Marta	0.31	0.11	0.31	-2.95
	EC	Barranquilla	-2.73	0.24	0.33	0.33
		Buenaventura	0.69	-1.67	0.69	0.69
		Cartagena	1.81	1.13	-1.36	1.81
		Santa Marta	0.26	0.16	0.26	-2.83
Frequency of the shipping line	**MNL**	Barranquilla	1.35	-0.24	-0.24	-0.24
		Buenaventura	-0.90	1.15	-0.90	-0.90
		Cartagena	-0.94	-0.94	0.82	-0.94
		Santa Marta	-0.03	-0.03	-0.03	0.51
	NL	Barranquilla	1.86	-0.16	-0.37	-0.37
		Buenaventura	-0.59	0.78	-0.59	-0.59
		Cartagena	-1.62	-0.62	0.85	-1.62
		Santa Marta	-0.05	-0.02	-0.05	0.71
	EC	Barranquilla	1.81	-0.26	-0.35	-0.35
		Buenaventura	-0.84	1.21	-0.84	-0.84
		Cartagena	-1.47	-0.98	0.91	-1.47
		Santa Marta	-0.05	-0.03	-0.05	0.69
Maritime freight rate	**MNL**	Barranquilla	-2.36	0.28	0.28	0.28
		Buenaventura	0.55	-1.82	0.55	0.55
		Cartagena	1.16	1.16	-1.11	1.16
		Santa Marta	0.17	0.17	0.17	-3.45
	NL	Barranquilla	-3.03	0.17	0.4	0.4
		Buenaventura	0.36	-1.11	0.36	0.36
		Cartagena	1.93	0.71	-1.05	1.93
		Santa Marta	0.27	0.1	0.27	-4.44
	EC	Barranquilla	-3.05	0.29	0.38	0.38
		Buenaventura	0.47	-1.81	0.47	0.47
		Cartagena	1.8	1.15	-1.17	1.8
		Santa Marta	0.24	0.16	0.24	-4.49
Cost of port access	**MNL**	Barranquilla	-5.54	0.53	0.53	0.53
		Buenaventura	1.11	-4.04	1.11	1.11

Variable	Model	Port	Barranquilla	Buenaventura	Cartagena	Santa Marta
		Cartagena	2.87	2.87	-3.32	2.87
		Santa Marta	0.28	0.28	0.28	-5.97
	NL	Barranquilla	-10.27	0.41	1.07	1.07
		Buenaventura	1	-3.69	1	1
		Cartagena	8.03	2.64	-4.2	8.03
		Santa Marta	0.67	0.24	0.67	-11
	EC	Barranquilla	-9.28	0.55	0.92	0.92
		Buenaventura	1.16	-5.52	1.16	1.16
		Cartagena	6.37	3.45	-4.45	6.37
		Santa Marta	0.53	0.3	0.53	-9.98

An increase in the maritime transit time by 1%, decreases the probability of choice of those alternatives by around 1.1% to 2.9%, depending on the port used. Similarly, an increase in the maritime freight rate by 1%, decreases the probability of choice of those alternatives by around 1.0% to 4.5%. However, an increase in the frequency of the shipping lines by 1%, only increases the probability of choosing a port by around 0.5% to 1.86%.

In general, the probability of port choice is highly elastic with respect to all the variables presented in table 7. The lower sensitivity is referred to the frequency of the shipping lines, especially in the ports of Cartagena and Santa Marta. The analysis of the results also shows that a port will increase its attractiveness substantially if they can reduce their access costs. An improvement in the operational management that allows for increasing the frequency of the services and reducing the maritime freight rates and the maritime transit times also contribute to make it more competitive.

SIMULATION OF POLICY SCENARIOS

The NL model estimate was used to examine the level of competition of these ports under different policy scenarios. The first scenario assumes that the recovery of the navigability of Magdalena River would decrease the inland freight rates from the cities of Bogotá and Medellin to Cartagena and Barranquilla, as a result of a public policy motivated by the lower externalities of inland waterway transport when compared to road transport (Márquez and Cantillo, 2013). Figure 5 shows the probability of choice for each port in this scenario for data of Bogotá shipments. The predicted port choice of the Port of Cartagena increases from 52% to 77%, the same as the port of Barranquilla increases from 9% to 16%. Otherwise, the probability of choosing Buenaventura's and Santa Marta's ports decreases as expected.

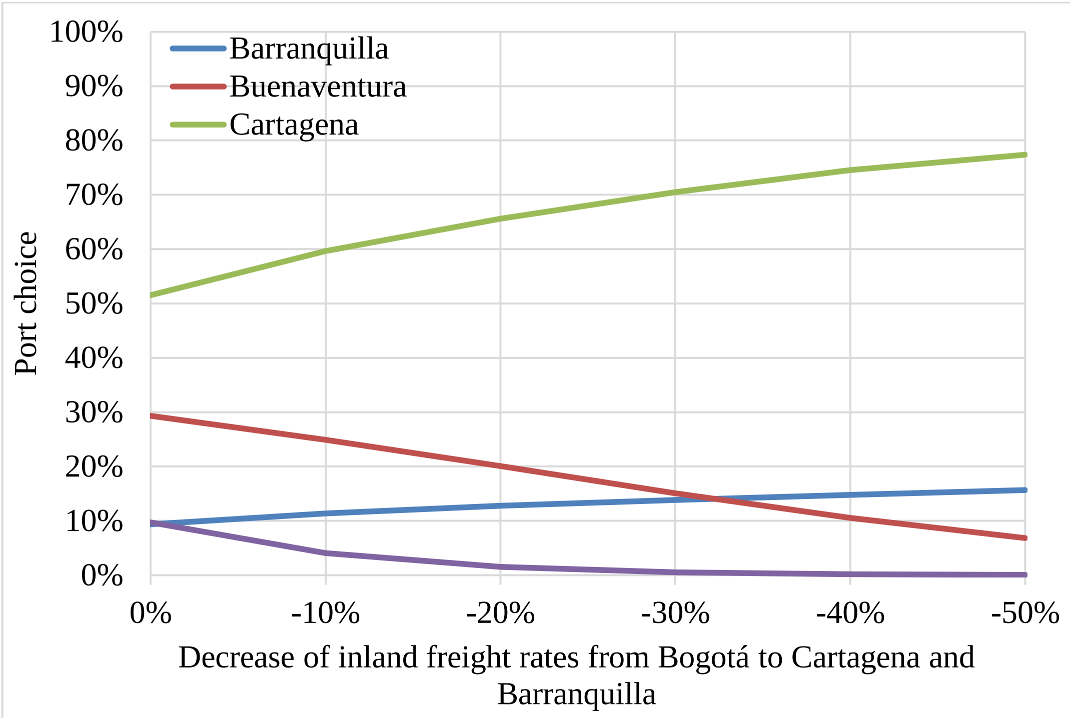


Figure 5. Impact of inland freight rates from Bogotá to Cartagena and Barranquilla on port choice.

Figure 6 shows the same scenario for the data on Medellin shipments. It can be appreciated as expected, that the port choice for Barranquilla and Cartagena increased from 9% to 13% and from 72% to 83%, respectively, while the probability of choosing Buenaventura's and Santa Marta's ports decreased. Clearly, the inland freight rates become more evident in shipments that have as origin or destination the city of Bogotá, which is the major producer and consumer of the country.

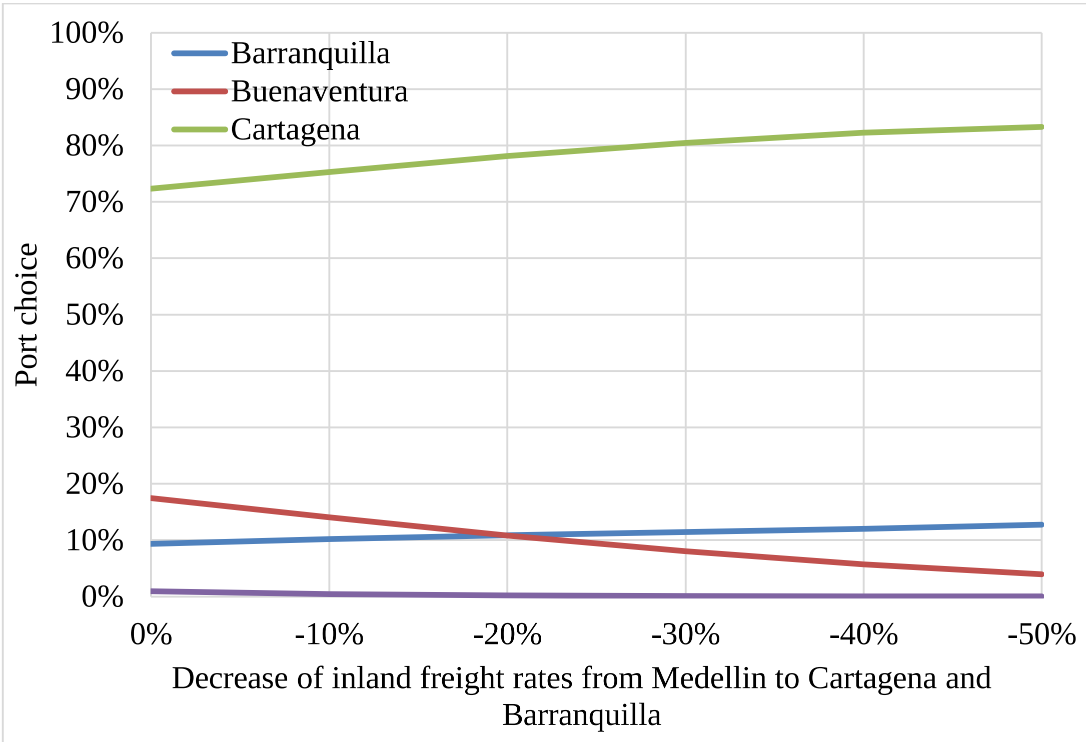


Figure 6. Impact of inland freight rates from Medellin to Cartagena and Barranquilla on port choice.

The second scenario assumes a reduction of the inland freight rates thanks to the improvement of road infrastructure between Bogotá and Buenaventura as a consequence of the construction of the tunnel 'La Linea' on the road connecting them. The scenario also considers improvement of the road between Medellin and Buenaventura, allowing reduction on access cost. Figure 7 shows the probability to choose a port from traders located in Bogotá. As expected the probability of choosing Buenaventura’s port increases from 29% to 49%, while for the other ports it decreases. From the data of Medellin shipments, as shown in figure 8, the probability of choosing Buenaventura's port increases from 17% to 32%, with an obviously minor effect on port choice.

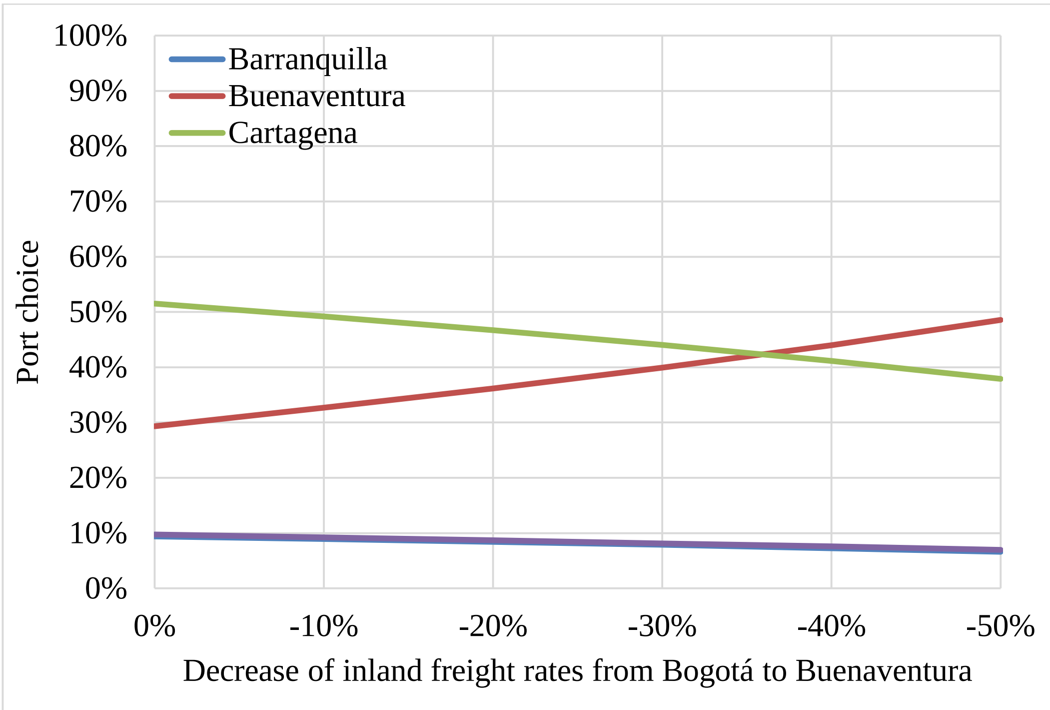


Figure 7. Impact of inland freight rates from Bogotá to Buenaventura on port choice.

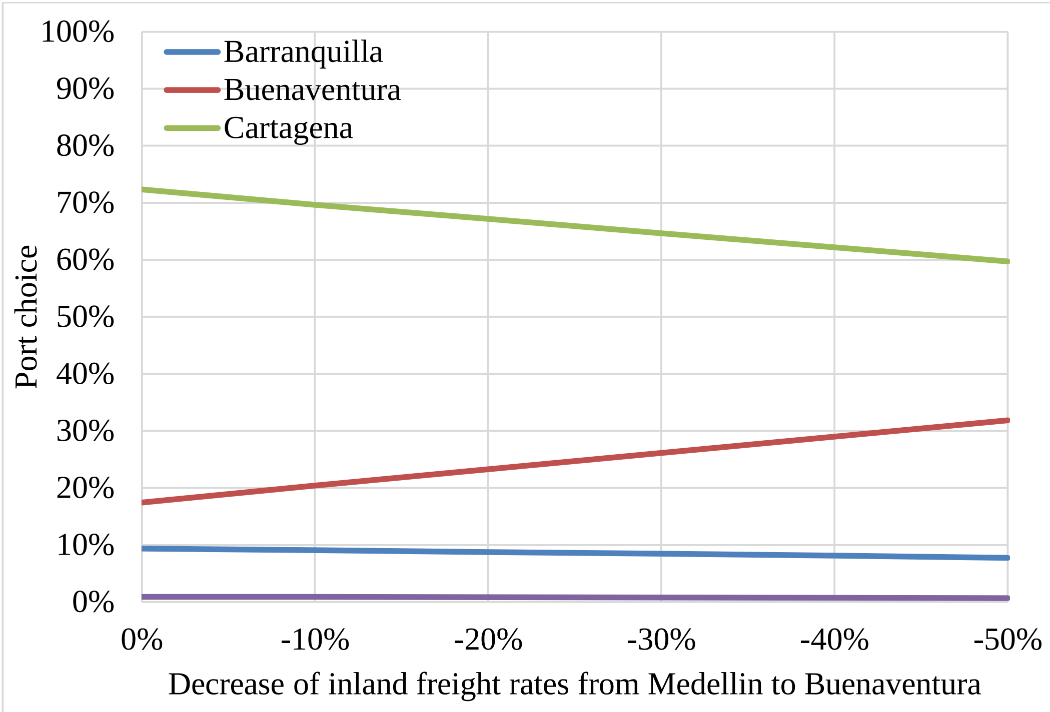


Figure 8. Impact of inland freight rates from Medellin to Buenaventura on port choice.

The third scenario assumes that the Panama Canal expansion project would increase maritime freight rates between shipments from or to places located in the Pacific Ocean and the Caribbean Ports the same as it would between shipments from or to places located in the Atlantic Ocean and the Port of Buenaventura. Figure 9 shows the probability of choice for each port for shipments from or to places located in the Pacific Ocean. As expected, the increase in maritime freight in this scenario increases the probability of choosing the port of Buenaventura from 65% to 71%, while for the Caribbean ports it decreases. Shipments from or to places located in the Atlantic Ocean are shown in Figure 10. The probability of choosing any Caribbean port increases in this case, while the probability of choosing the port of Buenaventura decreases from 11% to 8%.

Under this last scenario, the effect of the increase of the maritime freight rates does not have a major impact on port choice and that is because shipments to or from the Pacific Ocean tend to be made from Buenaventura's port (65% as shown in figure 9), and shipments to or from the Atlantic Ocean tend to be made from Caribbean ports (89% as shown in figure 10).

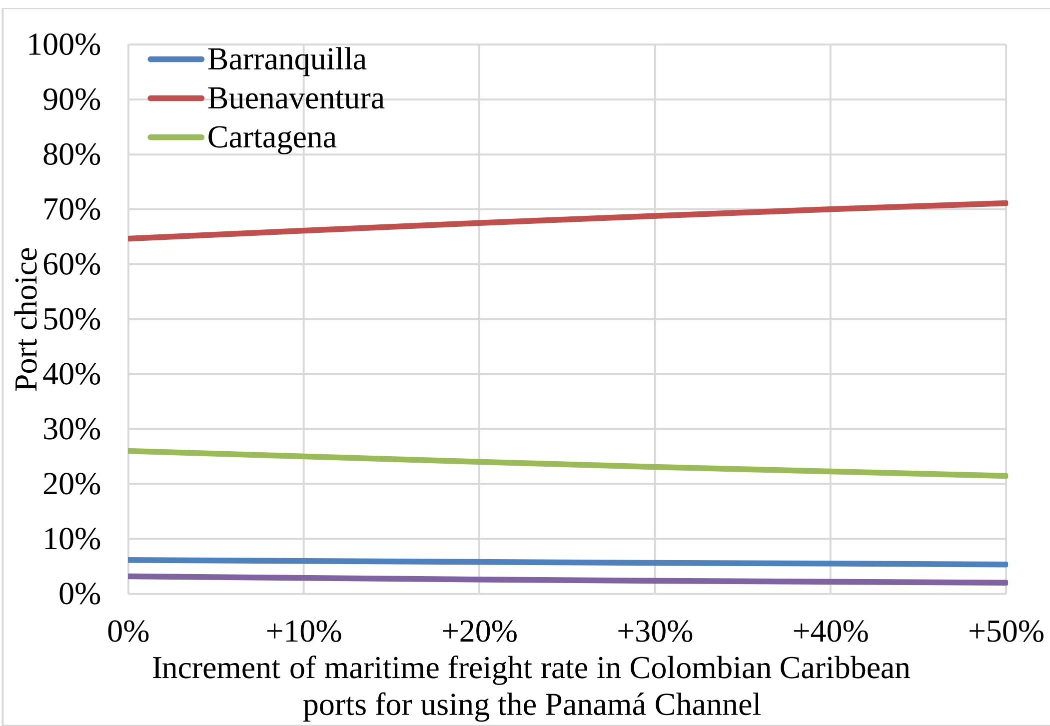


Figure 9. Impact of maritime freight rate in Colombian Caribbean ports for using the Panamá Channel on port choice.

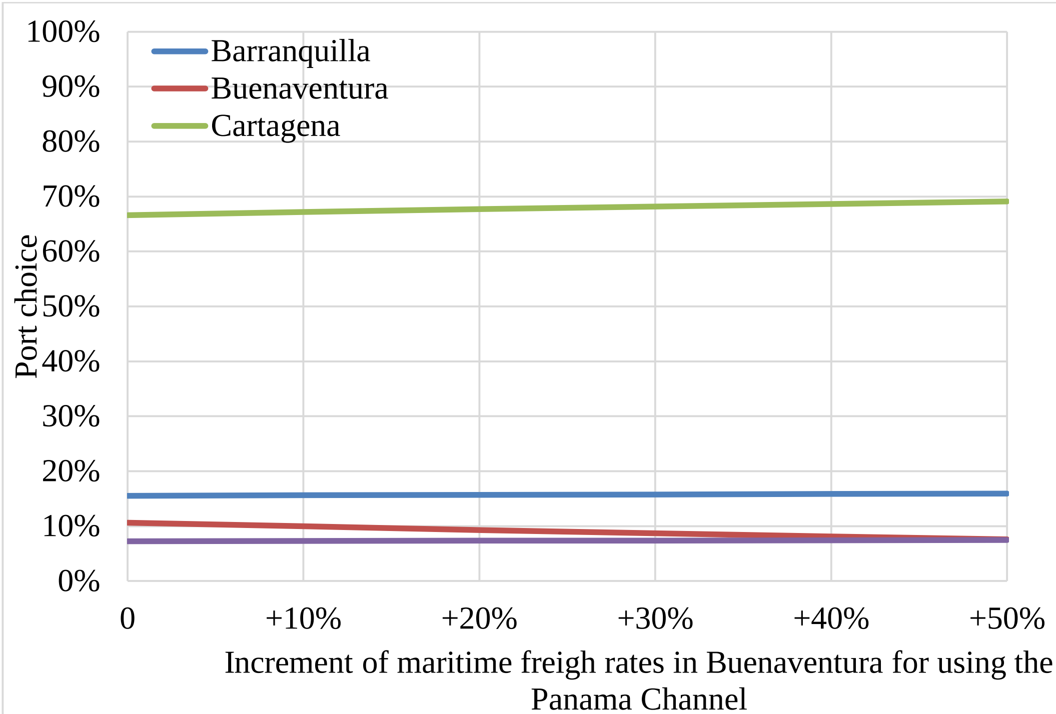


Figure 10. Impact of maritime freight rates in Buenaventura for using the Panama Channel on port choice.

CONCLUSION

The analysis of the behaviour of exporters and importers regarding the port choice is essential for the formulation of policies that allow for improving and developing a port's infrastructure. Therefore, the factors that have influence when it comes to selecting a port to ship a cargo to Colombia were evaluated, considering the main ports of the country using official data of foreign trade.

The modelling results suggest that factors such as the access cost to ports; frequency of the shipping line; maritime freight rates; maritime transit times; the origin or destination of the cargo and the cargo type, are the major determinant factors in the process of choosing a port. It is interesting to notice that the ports located on the Atlantic Ocean (Cartagena, Barranquilla and Santa Marta) are perceived as correlated, showing a higher substitution effect among them.

The willingness to pay respect to the attributes of maritime transit time and frequency of the shipping lines in terms of the maritime freight rates was calculated. The results indicate that exporters and importers are willing to pay $2.60 to $3.00 per ton to save an additional day in maritime transit time and \$1.10 to \$1.30 per ton for an additional trip in a month in terms of maritime freight rates.

The elasticity analysis indicates that exporters and importers are highly sensitive to the access cost of the port. For example, an increase in the attribute of port access cost by 1%, decreases the probability of choosing a port between 3.3% and 11%. On the other hand, the lower sensitivity is referred to the frequency of the shipping lines. An increase in the frequency of the shipping lines by 1%, increases the probability of choosing a port by around 0.5% to 1.86%. Therefore, a critical aspect for increasing the mobilization of cargo is reducing the access cost of ports by providing better road, railway and waterway infrastructure. Policies and strategies aimed to improve the efficiency in a port's operation and the level of service, like the increase in the frequencies of lines and the decrease of maritime freights and transit times also have an important impact on the demand levels. The high value of elasticities evidence the strong competitiveness among ports in Colombia, exporters and importers can easily switch from one port to another if a better level of service is offered as they are substitute alternatives.

The simulation of policy scenarios indicates that the decrease of inland freight rates with the recovery of the navigability of the Magdalena River has a major impact on the shipments from or to Bogotá, where the probability of choosing the ports of Barranquilla and Cartagena increases from 9% to 16% and from 57% to 77%, respectively. The second scenario indicates that the improvement of the road infrastructure between the cities of Bogotá and Medellin and the port of Buenaventura would have a huge impact on choosing this port, from 29% to 49% and from 17% to 32%, respectively. In the third scenario, the increase of the maritime freight rates with the Panama Canal expansion project would not have a major impact on the port choice and this could be a result of the fact that there is not much interoceanic flow in the country; the shipments to or from the Pacific Ocean tend to be made from the Port of Buenaventura and shipments to or from the Atlantic Ocean tend to be made from Caribbean ports.

Future research may involve information of revealed preferences and stated preferences, which will allow isolating the effect of variables like the port access time, and the type and magnitude of the cargo. The inclusion of other variables like the characteristics of exporters and importers, the size or capacity of vessels, the port efficiency, the cargo volume, the berth availability, the number of container berths at port and the crane productivity may also be considered. A joint investigation of port choice models and carrier selection models may also be an interesting research topic. Likewise, it is interesting to advance the development of econometric approximations that may consider the effect of variables and perceptions not easily measured as the security and the liableness in the operations.

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ANEXO 1	BASE DE DATOS	Contiene los 20,000 datos de exportación e importación con las variables utilizadas en los modelos de elección discreta.
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ANEXO 4	RESULTADOS MODELO MNL	Contiene los resultados obtenidos para el modelo MNL escogido.
ANEXO 5	MODELO NL	Contiene las especificaciones del modelo NL escogido para los datos de exportación e importación.
ANEXO 6	RESULTADOS MODELO NL	Contiene los resultados obtenidos para el modelo NL escogido.

ANEXO 7	MODELO EC	Contiene las especificaciones del modelo EC escogido para los datos de exportación e importación.
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