



Contents lists available at ScienceDirect

## Transportation Research Part E

journal homepage: [www.elsevier.com/locate/tre](http://www.elsevier.com/locate/tre)

# Joint mode and port choice for soy production in Buenos Aires province, Argentina

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## ARTICLE INFO

## Keywords:

Freight modelling  
Behavioural models  
Joint modelling  
Grain transport

## ABSTRACT

This study analyses the decision of port and mode choice of soy consolidators and producers from southern Buenos Aires province, Argentina. Nested logit models were estimated combining stated and revealed preference data. Estimations for Willingness to pay for one-day reduction in inventory, travel time, elasticities, iso-utility curves and hinterland were made. FAS (Free Alongside Ship) price, typically not considered, proved to be a relevant parameter in the mode-port choice. Other variables included were Service headway, freight price and travel time. Simulation results showed that reducing the train's service headway and freight price are effective measures to encourage train demand.

## 1. Introduction

Freight transport has attracted a growing interest due to its importance in the economy and its effect on climate change (Brooks and Trifts, 2008; Meyer, 2006; Stelling, 2014). A worldwide increasing trend on freight volumes has been followed by an expansion of truck transport's market share (Capka, 2006; Wang et al., 2013). This growth in transport demand increases congestion, limits logistical flows and affects the competitiveness of the economy (Capka, 2006).

One of the problems derived from the increase of freight transport is the rise in transport emissions. According to Piecyk and Mckinnon (2010), freight transport accounts for a major share of transportation greenhouse gas emissions and it is the fastest growing sector for oil consumption (Tian et al., 2014). These circumstances motivated the development of research in advanced logistics and modelling studies, devised to understand the underlying elements of freight choice decision-making (National Academy of Science, 2010; Windisch et al., 2010).

Besides the effect on climate change, transportation costs are an important factor when analysing the competitiveness of certain supply chain within a country, especially for commodities. In the case of soybean, transportation efficiency plays a major role in the US competing in the global soy market (Hyland et al., 2016; Schnepf et al., 2001). In the case of Argentinian soybean, transportation costs are one of the most important production costs (Cohan and Costa, 2011). This is mainly caused by the large participation of truck transportation in freight modal split, accounting for approximately 84%.

Several researchers analysed how shippers evaluate and select freight transport modes. Advances in data acquisition and in econometric estimation techniques enabled the use of disaggregate demand models to replace the aggregate models used in earliest applications (Tavasszy and de Jong, 2013). These models can be derived from Revealed Preference (RP) data (Jiang et al., 1999; Ravibabu, 2013), Stated Preference (SP) data (Beuthe and Bouffieux, 2008; Chiara et al., 2008; Danielis and Marcucci, 2007; de Jong

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et al., 2000; de Jong et al., 2014; Feo-Valero et al., 2011; Feo et al., 2011; Larranaga et al., 2016; Kurri et al., 2000; Nugroho et al., 2016) or a mixed RP/SP data (Rich et al., 2009; Vellay and de Jong, 2003). Mixed data sources enriches models forecasting power. This approach has been preferred over RP or SP only models (Cherchi and Ortuzar, 2002).

Freight-related decision models tend to include logistic and service-related variables, as pointed out in a European models review (de Jong et al., 2013) and in the models used in the United States (Chow et al., 2010). Previous researches revealed that the most prominent factors influencing freight-related decisions are: travel time, cost, frequency of service, port efficiency, mode reliability (Tongzon, 1995, 2009; Cullinane and Toy, 2000; Hoffman, 2000; Malchow and Kanafani, 2001, 2004; Shingal and Fowkes, 2002; Nir et al., 2003; Tiwari et al., 2003; Lirn et al., 2004; Guy and Urli, 2006; Danielis and Marcucci, 2007; Tongzon and Sawant, 2007; Feo et al., 2011; Steven and Corsi, 2012; Larranaga et al., 2016).

Regarding port choice models, the literature reports that the main motivating variables include port efficiency, services and cost (Lirn et al., 2004; Nugroho et al., 2016; Tiwari et al., 2003; Tongzon and Sawant, 2007; Tongzon, 2009). These works focus on the exporters' perspective and do not address the mechanism used to attract cargo. In the cases where exporters do not own the product and have to compete for it, an important variable that reflects this interaction is the selling price, such as FAS (Free Alongside Ship) price, which is particularly important in commodity markets. However, no study including such a variable has been found in the literature.

Moreover, few works have been found with a disaggregated approach in South America (i.e. those conducted by Larranaga et al. (2016), Novaes et al. (2006) in Brazil and Zambrano (2016) in Colombia). These studies used SP data to model the logistics managers' choice. No studies were found mixing SP and RP data. There could be great differences in the modal competition for freight between developed and developing countries, due to natural or inherited causes, such as geography, distances, infrastructure, technology, efficiency, production and commodities. Additionally, an important limiting factor, especially in developing countries, is the scarcity of suitable data, which difficult the estimation of models with adequate predictive power.

This work pursues three goals. First, analyse and quantify the decision of port and mode choice of grain shippers -consolidators and producers - in the south of Buenos Aires province (Argentina). Second, develop a model combining SP and RP data to forecast the access mode choices to the ports. Third, test if elasticities values reported in the literature hold in a developing country and as such, discuss which transport policies could encourage more sustainable uses of available transport infrastructure.

The contributions of this paper are twofold. Firstly, the inclusion of the FAS (Free Alongside Ship) price as an explanatory variable. This variable is related to the port cost, and it is computed as the FOB (Free On Board) price minus port and export costs, delays and inefficiencies – so it can be used as a proxy for port efficiency and other exported-oriented capabilities. The inclusion of these characteristics is especially important in developing countries and allows studying how the shippers react to different selling prices, which can be affected by tolls or port infrastructure. The literature review performed did not identify studies including this variable. Secondly, this work investigates the decision-making process in a different context from those generally reported in the literature. Few researches on this subject have been undertaken on developing countries. A question arises about whether these observed relationships remain in developing countries and if they are relevant to inform policymaking. The analytical results suggest some possible strategies for the policy makers to encourage rail transport that could increase the competitiveness of the region.

The rest of the paper is organised as follows: Section 2 describes the methodology adopted for models' formulation; Section 3 discusses the data collected; and Section 4 presents the estimation and simulation results. The paper ends with conclusions and suggestions for future research. Appendix A contains the abbreviations used.

## 2. Local context

Argentine agriculture has undergone great transformations over the last 30 years. The sector experienced a shift to a more export-oriented economy, an increase in the usage of new technologies, genetically modified seeds, agricultural machinery, fertilisers and new farming techniques (Regunaga, 2010). In the late 1990s, Argentina became a major global player in the soybean market (Schnepp et al., 2001). By 2015, Argentina was the main soybean meal and oil net exporter and the third most important soybean exporter after the United States and Brazil (United States Department of Agriculture, 2017). In the same year, the products represented a third of all Argentinian exports (Instituto Nacional de Estadística y Censos, 2014) and 55% of its agricultural production (Ministerio de Agroindustria, 2017).

Argentina's agricultural production is carried out by a great number of scattered producers. Approximately 94% of the producers in 2008 were accountable for 46% of the production (Regunaga, 2010). Once harvested, the soybean supply chain takes two forms (Giancola et al., 2009). One configuration involves a consolidator as an intermediary in the commercialisation. Consolidators offer storage, conditioning, technical support and commercial services. They can achieve larger volumes and they are more likely to use the railroad than individual producers are, since some of them have their own rail loading facility. The other alternative is for the producer to sell directly to exporters or crushers, who are mostly located in the port area, and it is an option available mainly to big producers. Even in the latter case, they could only use the railroad if they use a consolidator's loading facility. This makes the consolidators the main agent when it refers to modal choice.

Consolidators have 54% of the fixed storage capacity (Regunaga, 2010). Most of the crops must go through the consolidator for conditioning. The development of in situ grain storage has given producers the ability to store grains temporarily giving them greater bargaining power, so they can choose the best time to sell, as well as allowing them to export directly through brokers. They are key agents in the decision making process of the supply chain because they concentrate cargo from producers, operate with industries and exporters, and have the possibility to gain economy of scale.

Most of the grains produced in Argentina are transported by truck. Approximately 84% of the tons produced are carried by road,

14% transported by rail, and 2% by waterway (Barbero, 2010; Cohan and Costa, 2011; Garcia and Canitrot, 2013; Regunaga, 2010; World Bank, 2009). Due to the large market share of road mode, transportation costs of soybeans, wheat and sunflower vary from 30% to 70% of direct production costs (seeds, land, fertilisers, etc.). Corn transportation costs might represent from 70% to 115%, depending on the production location (Cohan and Costa, 2011). The freight cost is a major factor in the sector's economic competitiveness and in the choice of grains produced. Some authors attribute this mode allocation to the fact that most of the production areas are within a radius of 300 km from an exporter port (Barbero, 2010; Regunaga, 2010; Schnepf et al., 2001). Road transport becomes more competitive than the railroad for shorter distances. This can be interpreted as a productive disadvantage if compared to the US and Canada (Hyland et al., 2016). Although transport distances might be longer in these countries, the average cost of transport is lower, due to the larger rail market share (Regunaga, 2010; Schnepf et al., 2001).

During the 1990s, as the volume of railroad freight transportation declined, the rail network was privatised. Although rail freight volumes have risen after privatisation, this increase happened at a lower rate than total amount of transported goods, thus reducing rail's market share (Garcia and Canitrot, 2013). During the privatisation, a process of vertical integration occurred, where operating companies tend to prioritise its own products. For instance, part of the south of Buenos Aires Province's network is operated by a quarry company that transports almost no agricultural products (CNRT, 2015). There have been efforts from public authorities to promote investments and improve the level of service of the railroad, such as the purchase of new rolling stock, change of railway ties and the implementation of an "Open Access" policy. This last measure, although not yet implemented, would consist of allowing new operators to function in the existing network, independently of its ownership.

The port export system is responsible for approximately 90% of the volume exported from Argentina (Sánchez et al., 2008). The ports are divided into two main areas according to their hinterland and physical characteristics: ports located on the Paraná River and those in the South Atlantic, in the province of Buenos Aires (Gardel, 2000). In the year of 2010, 68% of the volume of grain was exported through the ports of Rosario region on the Parana River, 16% through Bahía Blanca (BHB) and 12% through Quequén (QQN), both in the South Atlantic. All Argentine ports present road capacity bottlenecks in the access to ports (Barbero, 2010).<sup>1</sup> Fig. 1 shows these ports and the production density of Argentina and the main ports.

The port of BHB is located in a bay that provides protection from tides and waves. It is the deepest grain port in the country. Since the port of QQN is located off the river mouth, the maximum draught depends on the tides and needs extra protection from waves. This location particularity requires the closure of the port on some days. In 2004, the port closed 87 days, 16 of them were consecutive days (Galván et al., 2006). This problem might cause penalisation in the price paid to producers in QQN since exporters are likely to pass along extra costs to producers. This is reflected by the FAS price, since QQN tends to have a lower price than BHB.

Although the ports of QQN and BHB are not the most important ones in Argentina, they have some features that constitute an interesting case study. First, they are the only two ports serving the region with more than 240 km of separation between them, in contrast with the Rosario complex, which includes more than 20 independent terminals in its 46 km of length. The area where both ports compete is large and each port's characteristics are well defined and known to all the relevant players. Second, the FAS price penalisation of the port of QQN gives the opportunity to study how the consolidators react to different selling prices.

Both ports have a relatively densely paved two-lane roads network, but the area is not well served by rail. Many of the rail tracks are not currently functional, especially the ones serving QQN. Fig. 2a shows the main road infrastructure offered while Fig. 2b illustrates the operating rail network. Moreover, access to train stations is not currently available for every consolidator, therefore many producers and consolidators are not accustomed to rail transport. This lack of access is because the current rail operator specialises in quarry transport and only transports grain when dealing with a big shipper. Currently, the Ministry of Transport is interested in improving railway infrastructure, access and service to increment its market share.

### 3. Method

Discrete choice models were estimated to analyse consolidators and producers behaviour, combining SP and RP data. The proposed approach is based on a behavioural framework (Winston, 1983), using disaggregate demand models (Ben-Akiva and Lerman, 1985; Domencich and McFadden, 1975; McFadden, 1974). Most of the discrete choice models used for travel/shipping behaviour applications are based on random utility theory (McFadden, 1974), which assumes that the decision-maker's preference for an alternative can be reduced to a scalar utility value. The decision-maker selects the alternative in the choice set with the highest utility value. Depending on the assumptions considered on the various random terms different model forms were developed (Ben-Akiva and Bolduc, 1996; Bhat, 1998; Brownstone and Train, 1999; McFadden, 1974; McFadden, 1978; Vovsha, 1997; Williams, 1977).

In this study, a simultaneous estimation method was adopted, which is the common practice in estimation of choice models with multiple data sources (Hensher et al., 2007; Ortuzar and Willumsen, 2011). The simultaneous estimation method (known as nested logit trick) consists of constructing an artificial tree with twice as many alternatives as reality: RP alternatives and SP alternatives. The use of a nested logit (NL) structure is adopted to reveal differences in scale between data sources (Bradley and Daly, 1994; Bradley and Daly, 1997; Hensher and Bradley, 1993; Hensher et al., 2007; Ortuzar and Willumsen, 2011).

Two discrete choice model structures were tested to estimate joint mode and port choice: (i) multinomial logit (MNL), and (ii) nested logit (NL). Initially simpler structures were tested such as MNL models (McFadden, 1974), assuming that stochastic errors have IID Gumbel distribution. This assumption is rather simplistic, as they depend on the hypothesis of independence and

<sup>1</sup> Production density was estimated by dividing the total production of a department by its area. This causes that the results are different from the yields of the region due to the presence of other crops.

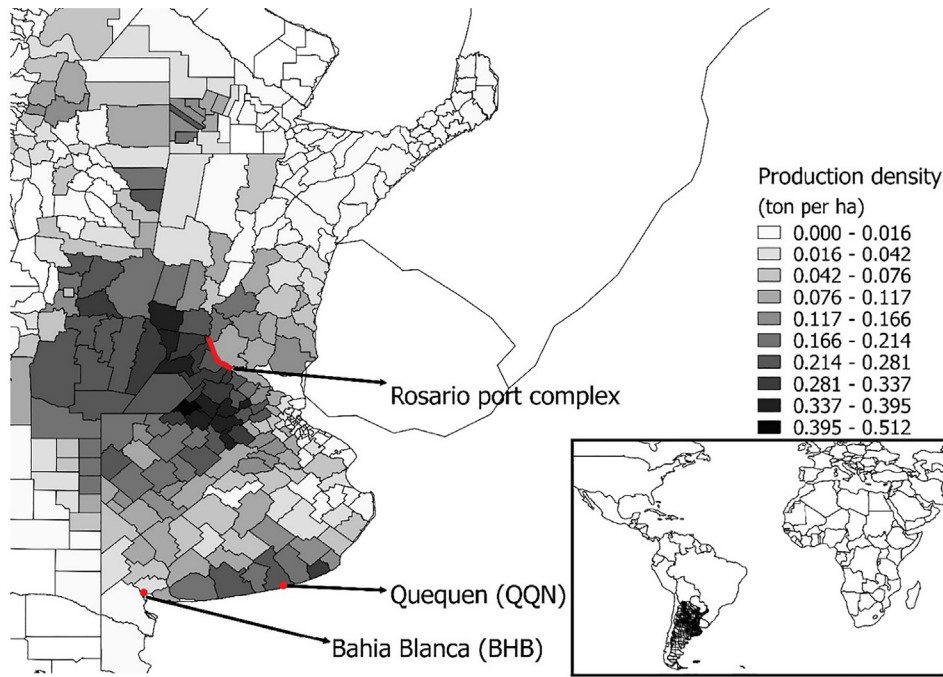


Fig. 1. Main Argentinian ports and soy production densities.

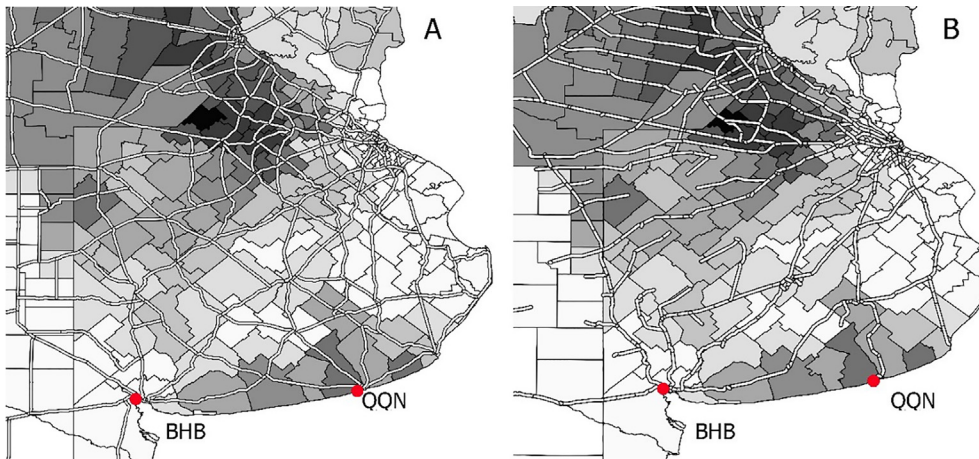


Fig. 2. (a). Main roads serving Buenos Aires province; (b) Operating rail network serving Buenos Aires province.

homoscedasticity of the residues (Ben-Akiva et al., 2003). Therefore, NL models (Daly and Zachary, 1978; Williams, 1977) were estimated in order to include possible correlations between unobserved attributes of port (QQN, BHB) and mode (truck, train) alternatives. Models' estimation was performed using the software Biogeme (Bierlaire, 2003). Fig. 3 shows the NL structure used for modelling.

The models were formulated with linear and non linear in-parameters utility functions, common practice in modelling transport demand (Ben-Akiva and Lerman, 1985). The systematic utility function can include variables related to the cost and time of each alternative, variables related to logistics aspects (such as flexibility) or other supply chain related decisions such as shipment size, inventories (Chow et al., 2010; de Jong and Ben-Akiva, 2007; de Jong et al., 2013; Pourabdollahi et al., 2013; Wang et al., 2013). Section 4 describes in detail the variables considered in this study and equations.

Parameters estimated from discrete choice models were used to compute direct- and cross-elasticities of the probability of choosing a transport mode-port with respect to the independent variables. The elasticities were computed to analyse the change in the demand when a given percentage change in the independent variables occurs. The direct-elasticities relate to attributes of the alternative under consideration and the cross-elasticities to attributes of competing alternatives. The direct elasticity was computed with the expression given by Eq. (1) and the cross-elasticity according to the expression given by Eq. (2) (Ortuzar and Willumsen, 2011). Elasticities were computed for individuals' choices and aggregated by sample enumeration techniques for the overall value

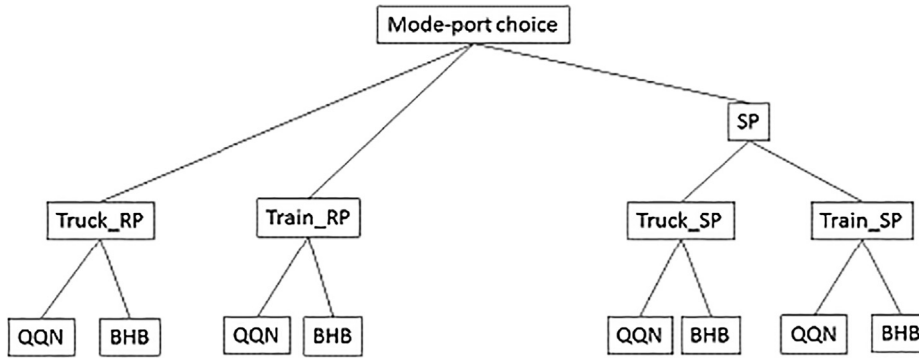


Fig. 3. Nested Logit (NL) structure.

and a naïve approach has been used for the district elasticities.

$$E_{P_{iq}, x_{ikq}} = \frac{\partial P_{iq}}{\partial x_{ikq}} \cdot \frac{x_{ikq}}{P_{iq}} \quad (1)$$

$$E_{P_{iq}, x_{jkq}} = \frac{\partial P_{iq}}{\partial x_{jkq}} \cdot \frac{x_{jkq}}{P_{iq}} \quad (2)$$

where  $E_{P_{iq}, x_{ikq}}$  is the elasticity of the probability of choosing  $A_i$  with respect to a marginal change in a given attribute  $x_{ikq}$ ;  $E_{P_{iq}, x_{jkq}}$  is the elasticity of the probability of choosing  $A_i$  with respect to a marginal change in the value of the  $k$ th attribute of alternative  $A_j$ , for individual  $q$ .

Aggregate choice probabilities were computed for each zone within the study area using a naïve approach. Each district produces different volumes of soy, so the probability of each mode was estimated as a weighted mean of probabilities by zone's production. Aggregate probabilities were used to forecast market shares for different policy scenarios. In order to analyse the implications of different scenarios, iso-utility curves were estimated for modal competitiveness, hinterland analysis for port competitiveness, and expected mode income.

#### 4. Data

The data set contains SP and RP data. The SP data were drawn from a stated choice experiment conducted in the south of Buenos Aires province in May 2014. The RP data are based on a consignment bill database provided by the Ministry of Transport of Argentina for the year 2014.

##### 4.1. Stated preference

A SP survey was conducted in order to analyse consolidators' decision-making for freight transport service in the south of Buenos Aires province in May 2014. Although the inclusion of big producers could have been beneficial, due to their relevance and to take into account heterogeneity between stakeholders (Gatta and Marcucci, 2016b), they were difficult to contact and several interviews were made prior to the survey and it was concluded that there were no structural differences between consolidators and big producers.

Personal interviews with 32 consolidators were conducted. Even though the sample size is smaller than conventionally used for passenger transport demand modelling, the population of interest is smaller than in passenger studies. The sample selected represents half of the installed storage capacity and around 27% of the total number of companies in the study area. Fig. 4 shows the study region with the percentage of total installed storage capacity as a pie chart and the percentage of total consolidators interviewed through the degree of shading. The sample size is slightly higher than the minimum sample size required for stated choice studies (Bliemer and Rose, 2005, 2009, 2010; and Rose and Bliemer, 2005, 2012), recommend that a minimum of 30 respondents be sampled for any discrete choice study. In order to obtain a representative sample of consolidating companies in the region the selection of consolidators considered their geographical location and transport volumes.

Each respondent faced a set of 9 shipping choice scenarios. Four alternatives were presented in each choice scenario: (i) train to QQN, (ii) truck to QQN, (iii) train to BHB and (iv) truck to BHB. As many respondents had never used the railway in their shipments and had never answered this type of survey, a more flexible approach was adopted to ensure more confidence in the response. They could freely allocate the percentage of cargo between the alternatives, as long as they all added up to 100%, a similar approach to that performed by Brooks et al. (2012) and by Nugroho et al. (2016). The continuous variable had good acceptance since 94% of the respondents split at least once their responses.

The continuous response variable was discretised for the purpose of modelling. The choices were allocated to the alternative correspondent to the highest percentage of cargo. The respondents were asked to assume that the rail network was renovated and

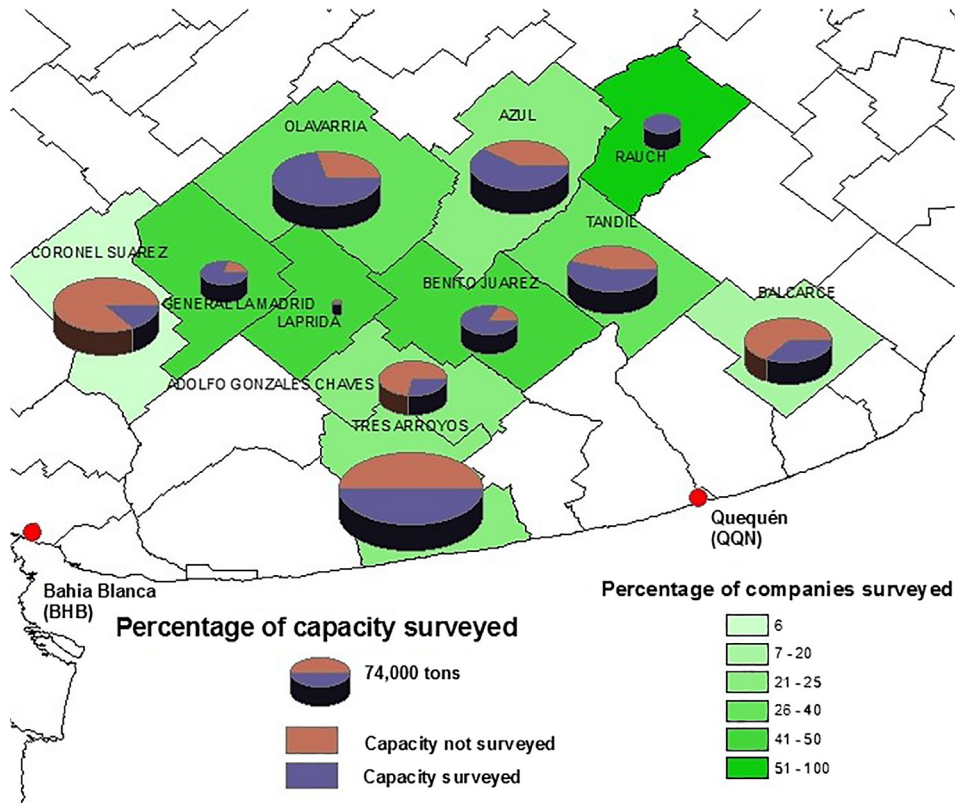


Fig. 4. Sample used.

they could access it without restrictions.

Seven attributes were used to describe each alternative: (i) *Freight price*, (ii) *Travel time*, (iii) *Tolerated losses of cargo*, (iv) *Reliability*, (v) *Service headway*, (vi) *Port delay* and (vii) *FAS price*. *Freight price* refers to the freight tariff from the cargo pick-up point to the port. The value depends, among other factors, on the mode of transport (truck, train) and distance to the port. *Travel time* accounts for the mode's time from the origin to the port. *Tolerated losses of cargo* is a proxy for insurance cost, defined as the maximum tolerated difference of weight for which the shipper was not responsible for the losses. The unit adopted to measure this attribute was kg per truck, the unit usually used. *Reliability* refers to the delivery percentage occurring within two hours of the scheduled time. This attribute considers the need for a just-in-time buyer to have his freight delivered within a delivery window that is acceptable for production process inputs or retail shelf stocking (Brooks et al., 2012). *Service headway* was measured as the maximum time interval consolidators had to wait to access the freight service and *Port delay* was the amount of days the cargo had to wait to unload at the port. *FAS price* was the price of soy paid to consolidators and was used as a proxy for port efficiency.

The attributes were selected based on a qualitative survey with consolidators' logistic managers and on the literature review of national and international relevant papers in the area. Table 1 synthesises the literature review. The selected attributes represent different characteristics of the freight service and represent core business decisions for consolidators.

Two-level attributes with a central value were used to describe all the alternatives. Table 2 summarises the attribute ranges. Given the limited number of consolidators presented in the study area, the familiarity of the agents with the truck mode and the lack of experience in answering SP surveys we choose to include more variables to place the choice exercise in a realistic context and reduce the attribute levels to increase the chances of high engagement of the interviewee.

The FAS price adopted for BHB was the soy price in BHB in 13/05/2014, 2,550 AR\$/ton (316.38 US\$ with an exchange rate of 8.06AR\$/US\$). The truck cost was the actual cost provided by transport companies (CATAC, 2014) and used as reference for train cost (as a fraction of it). Travel time for the truck alternative was constant along the levels, estimated using an average speed of 60 km/h. For the train alternative, travel time was estimated using average speeds of 30, 40 and 50 km/h, resulting in travel times 200, 150 and 125% higher than the travel time for trucks. Truck information was used as contrast because every consolidator uses truck and it would not be realistic to change the levels of the variables.

As time and freight price depend on the location, these values changed from city to city, therefore the set of scenarios was adapted to each location. Fig. 5 shows an example of the choice scenario from the final questionnaire.

The experimental design was structured using an orthogonal fractional factorial design. Prior information about the parameters was not available, leading to an orthogonal design (Montgomery, 1991) instead of an efficient one (Rose and Bliemer, 2009). Walker et al. (2015) analysed the robustness of different designs within a typical stated choice experiment context and concluded that

**Table 1**  
Variables observed in the literature review.

Variable		Paper																								Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			
Mode	Cost	x		x	x	x	x	x	x	x			x	x	x	x	x			x	x		x	16		
	Reliability	x	x	x	x	x		x	x				x		x	x	x						x	12		
	Presence of Insurance			x	x					x													x	4		
	Travel Time	x	x	x	x	x		x	x				x	x	x	x	x						x	13		
	Frequency/Headway	x	x		x	x		x		x	x	x		x				x		x	x	x	x	15		
	Other	x	x					x						x	x									5		
Port Choice	Port Efficiency	x								x								x	x	x	x	x		7		
	Port Services						x			x					x				x	x	x	x		7		
	Port Cost		x				x			x					x			x	x	x		x		8		
	Other	x	x									x	x		x				x	x		x		8		
1. Cullinane and Toy, 2000		7. Hoffman, 2000										13. Nir et al., 2003							19. Tongzon and Sawant, 2007							
2. Danielis and Marcucci, 2007		8. Larranaga et al., 2016										14. Nugroho et al., 2016							20. Tongzon, 1995							
3. Danielis et al., 2005		9. Lirn et al., 2004										15. Puckett and Hensher, 2008							21. Tongzon, 2009							
4. Feo et al., 2011		10. Malchow and Kanafani, 2001										16. Shingal and Fowkes, 2002							22. Zamparini et al., 2011							
5. Feo-Valero et al., 2011		11. Malchow and Kanafani, 2004										17. Steven and Corsi, 2012														
6. Guy and Urii, 2006		12. Mangan et al., 2002										18. Tiwari et al., 2003														

**Table 2**  
Attributes and attribute levels.

Attribute (unit)	Type	Reference alternative	Reference value	Mobile alternative	Code Level	Value
<i>Freight Price</i> (% of reference freight price)	<i>Mode-specific</i>	<i>Truck</i>	<i>100%</i>	<i>Train</i>	–1	40%
					0	50%
					1	60%
<i>Travel Time</i> (% of reference freight travel time)	<i>Mode-specific</i>	<i>Truck</i>	<i>100%</i>	<i>Train</i>	–1	200%
					0	150%
					1	125%
<i>Reliability</i> (% of times it arrives within 2 h of the agreed time)	<i>Mode-specific</i>	–	–	–	–1	90% (Train); 75% (Truck)
					0	80% (Train); 80% (Truck)
					1	75% (Train); 90% (Truck)
<i>Tolerated losses of cargo</i> (kg per truck)	<i>Mode-specific</i>	<i>Truck</i>	<i>150</i>	<i>Train</i>	–1	300
					0	150
					1	0
<i>Service headway</i> (days)	<i>Mode-specific</i>	<i>Truck</i>	<i>0.5</i>	<i>Train</i>	–1	20
					0	15
					1	10
<i>FAS price</i> (AR\$/ton)	<i>Port-specific</i>	<i>Port of BHB</i>	<i>2550</i>	<i>Port of QQN</i>	–1	2168
					0	2359
					1	2550
<i>Port delay</i> (days)	<i>Port-specific</i>	–	–	–	–1	3 (QQN);1 (BHB)
					0	1 (QQN);1 (BHB)
					1	1 (QQN);3 (BHB)

\*Code level 0 represents a pivot point to determine the highest and lower level.

efficient design is better if we are confident in the prior of the parameters. However, it is risky to use an efficient design with uncertain priors. Even Bayesian efficient designs and multistage-stage design could not be robust (Walker et al., 2015).

The design was fractioned in order to achieve 1/8 of the full factorial experiment and blocked into 2 blocks using the highest order interaction, which produced 9 scenarios or choice sets after the pivotal level was added. Due to the fractioning and blocking, second level interactions were confused, but main effects can be estimated (Montgomery, 1991), which permits independent estimation of all effects of interest.

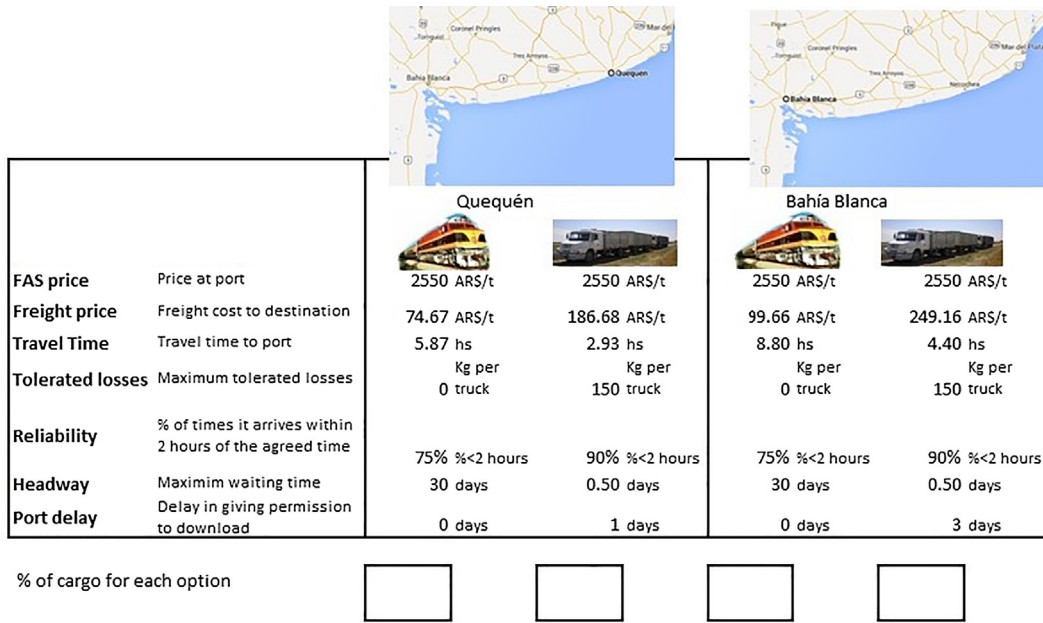


Fig. 5. Example of a card presented during the field study.

#### 4.2. Revealed preference

The consignment bill database provided by the Ministry of Transport of Argentina consists of all the individual grain shipments performed during 2014 in the south of Buenos Aires province, including information about origin, destination, weight transported, type of grain, transport mode and unloading date. It is a mandatory document and the database comprises information about shipments performed by consolidators and producers, without identification of shippers because of privacy issues. According to the data, 68% of the shipments were carried by truck to QQN, 27% by truck to BHB, 4% by train to BHB and the rest by train to QQN. Although the study area is geographically balanced, the area around QQN has significantly more production and therefore has caused this balance in shipments.

The data provided had to be processed to extract shipping choice information. Three different assumptions were used for this purpose: (i) consecutive shipment numbers from the same origin, product and date were considered from the same shipment, (ii) the railway was available to shippers who have used this mode on the route studied, at least once in recent years and for shipment sizes above 230 t, and (iii) missing service parameters were obtained from secondary sources.

The first assumption was necessary to process the individual truck records that could be the result of splitting a big shipment. Shippers usually request a group of permissions that have consecutive numbers so it is reasonable to suppose that consecutive shipment numbers from the same origin, product and date were from the same shipper. In the cases where additional permissions were needed, thus breaking the order, the shipment size could be underestimated. Consecutively numbered permissions from the same origin, product and date for two different shippers are unlikely because the number is electronically allocated over the entire country. After this procedure, 101,704 records were condensed into 23,140 shipments.

The second assumption is related to railway availability. Not every location has a functioning railway or access to it. The rail operator in the area specialises in quarry products and only transports agricultural goods for large shipments. Railway was identified as an available mode when it was used at least once in previous years and when the shipment size was above a minimum of 230 t (7 fully loaded trucks or around one eighth of the maximum cargo of a train). This information was obtained from interviews performed with consolidators before the SP survey.

The last assumption is related to missing service parameters necessary for the model estimation. For the US\$ and FAS price, data from the BHB board of trade (*Bolsa de Comercio de Bahía Blanca*, 2016) were used for both ports, considering all price variations of the whole year. In cases where the database presents missing FAS prices, the values adopted correspond to the prices of the previous day. Freight cost values adopted correspond to the official prices for trucks (*CATAC*, 2014) and rails (*Belgrano Cargas and Logística*, 2014). Service headway was estimated by least amount of time that elapsed between to shipments towards the same region. This means that the variable describes the capability of the train to give consecutive services to a certain area. Information about network distances and speeds was provided by the Ministry of Transport. Table 3 characterises the data available in the consignment bill database for the whole year of 2014. All variables presented were tested for modelling.

**Table 3**

Variable characterisation of RP database.

	Mean	Standard dev	Max	Min
US Dollar (AR\$/US\$)	8.16	0.21	8.56	6.55
Distance to QQN (km)	182.67	73.02	357.00	96.00
Distance to BHB (km)	300.11	85.91	433.00	185.00
Freight Price Train QQN (US\$/t)	15.29	2.96	22.96	2.96
Freight Price Truck QQN (US\$/t)	23.64	6.22	47.48	15.54
Freight Price Train BHB (US\$/t)	20.25	3.63	25.17	11.35
Freight Price Truck BHB (US\$/t)	33.58	7.34	54.14	22.71
Travel Time Train QQN (hours)	4.55	1.82	8.93	1.83
Travel Time Truck QQN (hours)	2.28	0.91	4.46	1.20
Travel Time Train BHB (hours)	8.04	2.21	10.45	4.63
Travel Time Truck BHB (hours)	3.75	1.07	5.41	2.31
Service headway Train QQN (days)	4.93	7.00	17.00	5.00
Service headway Train BHB (days)	14.90	7.78	32.00	5.00
FAS price QQN (US\$/t)	291.99	22.97	328.78	229.14
FAS price BHB (US\$/t)	298.59	23.11	335.05	229.14
Shipment size (t)	66.55	75.25	1789.74	25.02

**Table 4**

Model results for the SP data and for the combined revealed preference (RP) and stated preference (SP) choice data.

Model	SP	RP + SP
Type	MNL	NL
Service headway (days)[hd]	−0.10	−0.0617
Time (hour) [T]	−0.1800	
Logarithm of Time (log(hour)) [LnT]		−0.40
Freight Price (US\$/ton)[FP]		−0.0624
Freight Price Square [FP <sup>2</sup> ]	−0.0021	
FAS price (US\$/ton)[FAS]	0.1520	0.0275
Logarithm of FAS price [LnFAS]	−0.0014	
Truck BHB RP constant <sup>***</sup>		2.8600
Truck BHB SP constant <sup>***</sup>	−1.6600	−0.292 <sup>*</sup>
Truck QQN RP constant <sup>***</sup>		2.7200
Truck QQN SP constant <sup>***</sup>	−0.862 <sup>*</sup>	−0.6210
Train BHB RP constant <sup>***</sup>		2.4500
Train BHB SP constant <sup>***</sup>	−0.5910	0.2250
Hinterland * Freight Price		0.25
Hinterland * Service Headway	0.63	0.50
Hinterland * FAS price	−0.4280	
BHB * Freight Price		−0.72
BHB * FAS Price		0.54
Scale parameter Nest Truck RP <sup>****</sup>		4.3000
Scale parameter Nest Truck SP <sup>****</sup>	1	1.3800
Scale parameter SP to RP <sup>****</sup>		1.8500
Null log likelihood [LL(0)] <sup>**</sup> :	−399.25	−16,824.87
Constants log likelihood [LL(c)] <sup>**</sup> :	−382.41	−16,568.40
Final log likelihood [LL] <sup>**</sup> :	−253.79	−8,032.68
Rho-square-bar [LL/LL(0)]:	0.339	0.522
Sample size:	288	23,427

\* Not significant at a 95% confidence level.

\*\* The models were estimated with different databases.

\*\*\* All constants are referred to the mode-port pair of Train to QQN.

\*\*\*\* Scale parameters Nest Train and RP have been normalised to 1.

## 5. Results and discussion

Table 4 shows the parameters' values for of the model for the SP and for the combined RP and SP choice data model. It can be seen that the difference between the models go beyond the scale parameter of SP to RP. The model combining SP and RP data accommodates some correlation between alternatives (nested parameters) and gives a different comprehension on the impact of the different variables and heterogeneity present in the study area. Eqs. (3)–(6) show the structure of the utility function for train

or truck to either port used for further simulations, which are the ones derived from actual choices of the consolidators and producers.<sup>2</sup>

$$U_{TrainQNN} = -0.0617 * headway_{TrainQNN} (1 + 0.496 * hinterland) - 0.401 * \ln(Time_{TrainQNN}) + 0.0275 * FAS_{QNN} * (1 + 0.537 * BHB) - 0.0624 * FreightPrice_{TrainQNN} * (1 - 0.722 * BHB + 0.248 * hinterland) \quad (3)$$

$$U_{TruckQNN} = 2.86 - 0.401 * \ln(Time_{TruckQNN}) + 0.0275 * FAS_{QNN} * (1 + 0.537 * BHB) - 0.0624 * FreightPrice_{TruckQNN} * (1 - 0.722 * BHB + 0.248 * hinterland) \quad (4)$$

$$U_{TrainBHB} = 2.45 - 0.0617 * headway_{TrainBHB} (1 + 0.496 * hinterland) - 0.401 * \ln(Time_{TrainBHB}) + 0.0275 * FAS_{BHB} * (1 + 0.537 * BHB) - 0.0624 * FreightPrice_{TrainBHB} * (1 - 0.722 * BHB + 0.248 * hinterland) \quad (5)$$

$$U_{TruckBHB} = 3.14 - 0.401 * \ln(Time_{TruckBHB}) + 0.0275 * FAS_{BHB} * (1 + 0.537 * BHB) - 0.0624 * FreightPrice_{TruckBHB} * (1 - 0.722 * BHB + 0.248 * hinterland) \quad (6)$$

Regarding RP + SP model results, the scale parameter for the subset SP alternatives was found to be statistically significant (95% confidence level) and greater than one, the normalised value for the RP data. This value suggests a lower variance for SP data than for RP. The scale parameters for the truck alternatives of the RP data were also statistically significant (95% confidence level) and greater than one, consistent with the theory.

The estimate model showed good overall fit (Rho-square of 0.522) and the signs for the parameters are compatible with microeconomic theory and previous assumptions. Estimated parameters for *Service headway*, *Logarithm of Time* and *Freight Price* were negative, indicating that the utility of mode-port alternatives decreases with increases in the number of days the cargo had to wait to unload at the port, travel time from the cargo point of pick up to the port and freight tariff. Increase in waiting time (*headway*) means adding more time to completing the shipping, resulting in an increase in the production cost. In the same way, increases in distance and freight tariff result in higher resource expenses that consolidators and producers have to incur. *FAS Price* parameter has a positive sign, the utility of mode-port alternative increases with increases in the soy price paid to producers and consolidators. This variable is seldom considered in other studies, even though its inclusion in port-choice models results in a better representation of consolidator and producer decision-making. Producers and consolidators make choices, trading off costs and benefits. They select the option that has the highest positive net value (highest utility value), as postulated by economic theory and behavioural decision theory.

The coefficient of *FAS Price* proved to be lower in absolute value than the one for *Freight Price*. During the SP survey, the interviewees stated that *FAS prices* were received approximately 10 days after the product arrived at the port, while the freight service had to be paid when the service was provided. This unbalance of the payment timing could cause cash flow problems. This might suggest trade-off between having less gross margin and receiving the payment sooner if sent by truck or gaining more money but being paid later, if sent by train.

The alternative specific constants (ASC) for the RP data were significantly different from zero (95% confidence level). The constant for Train to QNN alternative was set to zero. The positive signs of the constants show that shippers are more likely to choose the truck mode, for both QNN and BHB, and the train to BHB over the train to QNN, all else being equal. BHB port might be more distant than QNN for many consolidators and producers in the study area. However, the price paid for soy in this port is usually higher than that paid in QNN, encouraging its choice. A comparison of the alternative specific constant values shows the current tendency to choose the truck alternative over the train.

*Shipment size* was supposed to affect shippers' behaviour via two channels: an indirect effect through railway availability and a direct effect. Thus, railway was considered as an available mode for RP data when it was used at least once in previous years and when the shipment size was above a minimum of 230 t (as explained in Section 4.2). This indirect effect was included in the final model presented in Table 4. The direct effect was tested including *Shipment size* as an explanatory variable, but this model did not present a good fit. The overall fit was lower (a likelihood ratio test showed no significant improvement in the goodness of fit) and the parameters estimated were affected by the inclusion of this variable. Thus, the direct effect was not included in the final model.

Due to the low number of interviewees of the SP survey and the lack of shipper characteristic from the RP data, no variables representing characteristics of the firms were included in the model. Preference heterogeneity was captured using a naïve approach (Marcucci and Gatta, 2012), by interacting attributes with location variables. Two dummy variables were included to categorize individuals in the sample regards location: *BHB* and *hinterland*. *BHB* represents the closest port, being one if BHB is the closest one. *Hinterland* signalled the areas where both ports hinterlands were in higher competition, taking the value of one if the difference in

<sup>2</sup> The utilities for the SP have the following form:

$$U_{traini}^{SP} = 1.85 * (ASC_{traini}^{SP} - 0.0617 * Hedway_i * (1 + 0.496 * Hinterland_i) - 0.401 * \ln(Time_i) + 0.0275 * FAS_i * (1 + 0.537 * BHB_i)) - 0.0617 * FreightPrice_i * (1 - 0.722 * BHB_i + 0.248 * Hinterland_i))'$$

$$U_{trucki}^{SP} = 1.85 * (ASC_{trucki}^{SP} - 0.401 * \ln(Time_i) + 0.0275 * FAS_i * (1 + 0.537 * BHB_i)) - 0.0617 * FreightPrice_i * (1 - 0.722 * BHB_i + 0.248 * Hinterland_i))$$

distances towards the ports was less than 50 km. This data was available in both datasets.

As shown in Eqs. (3)–(6), the interactions appear as a multiplier of the baseline value of the main effect, rather than as an adding formulation. This means that a positive value never changes the main effect sign and a negative only does so if greater than one. The results of the interactions act as a multiplier to expand or contract the main effect.

The interactions between *FAS Price* and *Freight price* with *BHB* show shippers around the port of BHB are more sensitive to changes in the *FAS Price*, but less sensitive to *Freight price* than shippers who are closer to the port of QQN. The parameters estimated suggest that the port of BHB attracts its natural hinterland (the closer regions) through price (the price at BHB is generally higher). The lower freight price importance diminishes the disutility of trucks, so a relative higher preference for this mode is shown.

The coefficients of the interactions between *Freight Price* and *Service Headway* with *hinterland* were positive suggesting that shippers located in areas where both ports compete are more sensitive to freight prices and headway than those located in other areas. The higher valuation for *Freight Price* shows part of the dynamics of an area that is under price competition between ports. The *Service Headway* valuation can be interpreted as the need for attending quickly to changes in price in order to take advantage of the business opportunity. Higher prices at the port are sometimes related to the exporter's need to fulfill unexpected shortages which should be covered rapidly.

Non-linear effects on utility function were tested using logarithmic and exponential transformations for the explanatory variables *Time*, *FAS price*, *Freight Price* and *Headway*. Studies developed show the importance of accounting for non-linear attributes' effects in the freight context (Gatta and Marcucci, 2016a; Marcucci et al., 2015). Most mathematical transformations were not statistically different from zero. However, the coefficient estimated for the logarithmic transformation of *Time* (*ln Time*) was significant, suggesting that travel time has less importance for higher values in the study area. This result reinforces the importance of truck in short distances, as the ones present at the study.

### 5.1. Model analysis

The parameters estimated allow the computation of the willingness to pay (WTP) for one day less in inventory. *Service headway* relates to the moment in time that the consolidator's client received the shipment. This not only represents an extra inventory cost because of storing the goods an extra day (immobilised assets or cost of opportunity, for instance) but potentially could affect the cash flows of the company. Consolidators and producers have to wait up to one week after a shipment is received by the client to receive the payment. This implies that longer service headway results in delays for consolidators/producers being paid. Depending on cash flow requirements, this might cause financial problems. Although this can be planned to certain extent, the seasonality of harvest concentrates stock in a short lapse of time creating the risk of not being able to pay unexpected or close to harvest expenses. The seasonality effect also reinforces the impact of cost of opportunity, since they have to offer storage space in order to handle higher volumes. Thus, the WTP for frequency could be interpreted as the WTP to reduce days in inventory by one unit (similar as defined by Combes, 2013). The model results show that the WTP for one day less in inventory is 0.99 US\$/ton/day, significant to a 95% confidence level according to the delta method (Daly et al., 2012; Gatta et al., 2015). This measure is useful to convert a unit of inventory time into a monetary value that could be used in cost-benefit analyses associated to transport projects. Considering the interactions, the WTP for regions closer to BHB is 3.56 US\$/ton/day, those located in the mixed hinterland area is of 0.64 US\$/ton/day and the regions that satisfy both conditions is 1.88 US\$/ton/day (all significances tested by the delta method).

Since the effect of the *Travel Time* in the utility function is logarithmic, the WTP for saving an extra hour of travel depends on the travel time itself. Considering the average of the values of travel time in the study area, the WTP is of 1.49 US\$/ton/hour for the areas outside the mixed hinterland area and closer to QQN (significant by the delta method). For the other areas the values range between 1.43 and 2.05 US\$/ton/hour, but were not significant. These values are consistent with the values found in the literature. De Jong (2013) reported several values that ranged between 0.1 and 1.7 euro/ton/hour (0.2 and 2 US\$/ton/hour) and Larranaga et al. (2016) found ranges in the literature from 0.03 to 2.88 euro/ton/hour (0.1–3.4 US\$/ton/hour).

Although both WTPs estimated above refer to time intervals, they represent different issues. The most trivial difference is that the

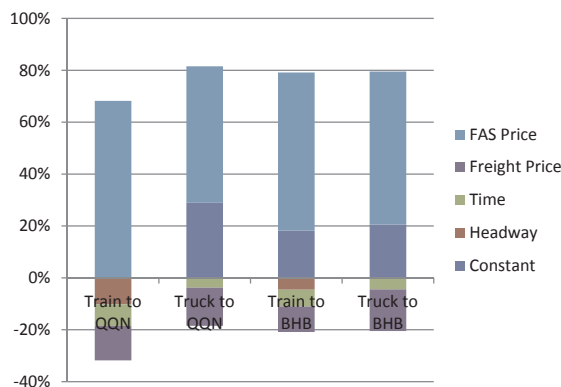


Fig. 6. Utility composition.

**Table 5**  
Direct and cross elasticities.

Variables		Elasticities					
		Train QQN	Truck QQN	Train BHB	Truck BHB	Train	Truck
Freight Price	Train QQN	−0.274	0.001	0.034	0.001	–	–
	Truck QQN	0.009	−2.077	0.009	0.910	–	–
	Train BHB	0.358	0.017	−0.058	0.017	–	–
	Truck BHB	0.009	2.146	0.015	−1.507	–	–
	Train	–	–	–	–	−0.020	0.017
	Truck	–	–	–	–	0.024	−0.021
Service headway	Train QQN	−0.909	0.004	0.117	0.004	−0.015	0.004
	Train BHB	0.862	0.032	−0.178	0.032	−0.037	0.032

time intervals are very different in size, with the headway ranging between 0.5 and 32 days and the travel time between 1.20 and 10.45 h. Another interpretation could be related to the different level of decisions for the two variables. While inventory in this case is related with cash flow and stock planning, travel time has a link with operational issues and compliance with clients' arrangements.

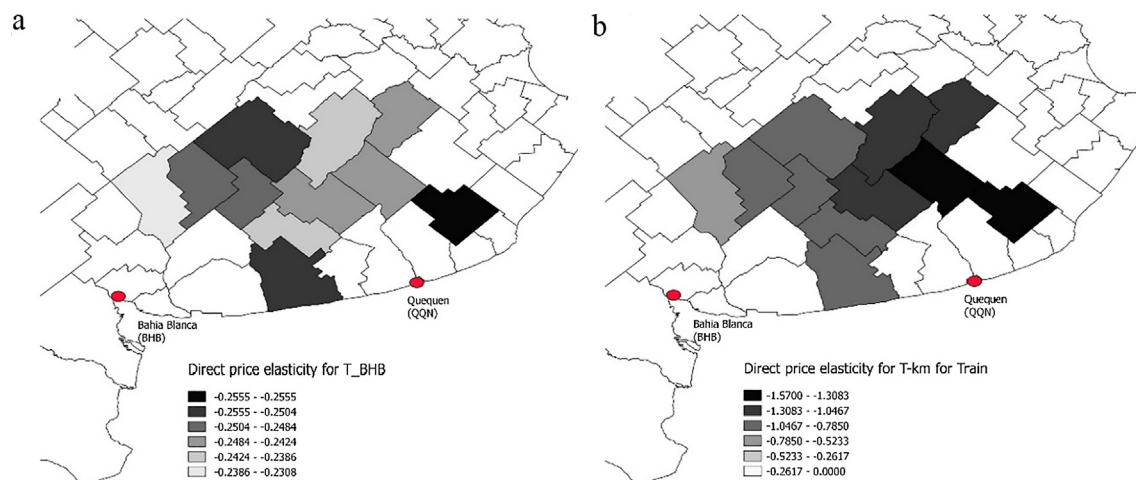
Given the limitation of direct interpretations of parameters estimated from discrete choice models, behavioural contrasts were made through other outputs such as the utility function estimation presented in Fig. 4 and elasticities for the different attributes. Fig. 6 shows the different utility functions computed with the variables in the mean values in the study area.

*FAS price* is the most influential variable. This variable accounts for around 60% of the utility function. Regarding variables with negative impact (disutility), *Freight price* is the most important, accounting for 40% of the disutility of rail. For truck mode alternatives, *Freight price* stands for approximately 80% of it.

The direct and cross elasticities of mode-port choice probability with respect to *Service headway* and *Freight Price* were computed aggregating individual choices through sample enumeration technique (see Eqs. (3) and (4) in Section 2, for direct and cross-elasticities). Elasticity values confirm the variables' impact obtained through the utility function estimation (Fig. 6). Comparison of direct and cross elasticities for mode-destination choices showed interesting results, as shown in Table 5.

First, truck mode turned out to be relatively elastic with respect to truck freight price (elasticity absolute value between 1.507 and 2.077) and train mode proved relatively inelastic with respect to train freight price (absolute values between 0.058 and 0.274). The pure modal elasticities showed to be relatively inelastic: −0.020 for train and −0.021 for truck. The empirical results are not conclusive: some studies suggest that train is more elastic than truck mode (Abdelwahab, 1998; Beuthe et al., 2001), while others concluded the opposite, similar to the present study (Hensher et al., 2013; Luk and Hepburn, 1993; Larranaga et al., 2016).

Second, freight price elasticities suggest that consolidators and producers are likely to change the port of delivery but not the transport mode after price increases. An increment in the truck freight price to QQN port by 1% could diminish up to 2.08% of the market share of the truck to QQN and increase by 0.91% the market share of the truck to BHB, but the chosen mode is still truck (cross elasticity value is 0.009). In the same way, an increment in the truck freight price to BHB port by 1% could decrease by 1.51% the market share of the truck to BHB and increase by 2.15% the market share of the truck to QQN. Cross elasticity is equal to 0.015 suggesting that they still tend to choose truck. Similar behaviour can be observed with the train mode. Direct elasticities values for the train to QQN and BHB are equal to 0.274 and 0.058 respectively, and cross elasticity in relation to truck mode is close to zero. This supports the interpretation of the higher impact of freight price in mixed hinterland areas.



**Fig. 7.** (a) Price direct elasticity for train to BHB; (b) Price direct ton-km point elasticity for train.

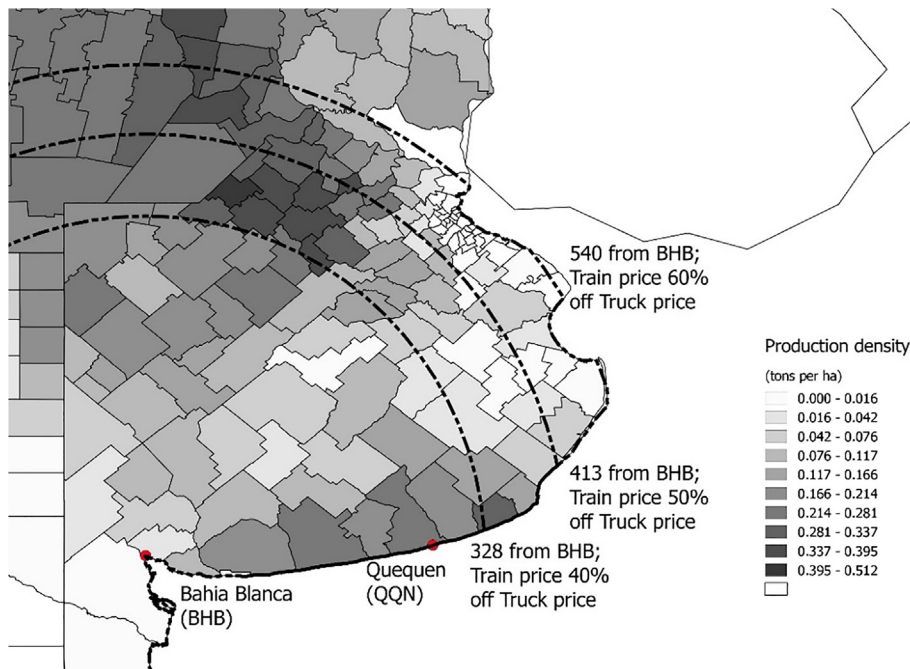


Fig. 8. Iso-utility curves for train to BHB.

Third, mode-port choice probability is not very sensitive to train headway changes. An increase in the train headway to QQN port by 1% diminishes by 0.91% the market share of the train to QQN and increases by 0.117% the market share of the train to BHB (cross elasticity near zero). Still, an increase in the train headway to BHB by 1% decreases by 0.178% the probability of choosing the train to BHB and increases by 0.862% the probability of choosing the train to QQN.

For a better understanding of consolidator and producer behaviour in the different districts (located at different distances from the delivery port) regarding freight price changes, the direct elasticity for train mode was computed for each district using a naïve approach to aggregate them. Fig. 7a presents the train to BHB freight price elasticity for transported tons in the different districts and Fig. 7b shows the freight price elasticity for transported ton-km by train (both ports). The train freight price adopted corresponds to 60% of the truck tariff, relation estimated from RP data assuming service headway of 10 days. Fig. 7a shows two distinct areas, one that is further away from BHB and out of the mixed hinterland area and the other, which meets any of those requirements. The elasticity for the train to BHB values increase with the distance to the port within both areas. The effect on ton-km, shown in Fig. 7b, shows the same trend independent on these conditions. Districts closer to BHB port are less elastic than ones that are more distant because the freight price has a lower impact on the utility function. Districts more distant to BHB port tend to change the delivery port with increases in the train freight price to BHB. The same results are valid to QQN port and are in line with those obtained by Beuthe et al. (2001).

The competitiveness of train and truck modes can be analysed through indifference curves (iso-utility curves), based on consumer choice theory. Indifference or iso-utility curves connect all possible combinations of variables that show the same level of utility. As utility function depends on distance to the port (by its impact in time and cost) and on the location (through the locational dummy variables) it is useful to determine the iso-utility distance for each port, which represents the distance at which the utilities of train and truck are equal. Fig. 8 illustrates iso-utility curves and distance for train and truck modes to BHB port, where each mode is equally attractive. Three iso-utility curves are presented in Fig. 8, considering three different train freight prices: (i) 40% off the truck tariff (iso-utility distance is 328 km), (ii) 50% off the truck tariff (iso-utility distance is 413 km), and (iii) 60% off the truck tariff (iso-utility distance is 540 km). All situations correspond to a headway service of 10 days (obtained from RP data).

Fig. 8 shows that iso-utility distance rises with increases in the train freight price, showing that the competitiveness of train and truck varies depending on the freight price of both modes. For a train freight price 40% of the truck tariff, the iso-utility distance is 328 km, suggested as a reason for the lack of train market share in Argentina by Schnepf et al. (2001). Incidentally, at this distance, the port of BHB starts to compete with the port of Rosario. Though, for more expensive train freight price (60% of the truck price) the iso-utility distance increases to 540 km, showing that the train alternative to BHB port loses competitiveness. The same analysis was performed for QQN port, obtaining significantly higher distances than for BHB.

The competitiveness of the ports can be analysed through analysis of the ports' hinterland. The port's hinterland refers to the area that it serves, both for imports and for exports, measured by the difference in distances to each port where the utility to BHB was equal to the utility of QQN. This distance was computed equalising the utilities of both ports (QQN and BHB). The result of this analysis shows that for the same FAS price offered in each port, the nearest one is chosen. An increase of 5% in the FAS price at BHB results in an increase in 84 km of the hinterland distance if only truck is available and 113 km if both modes are available. Probably,

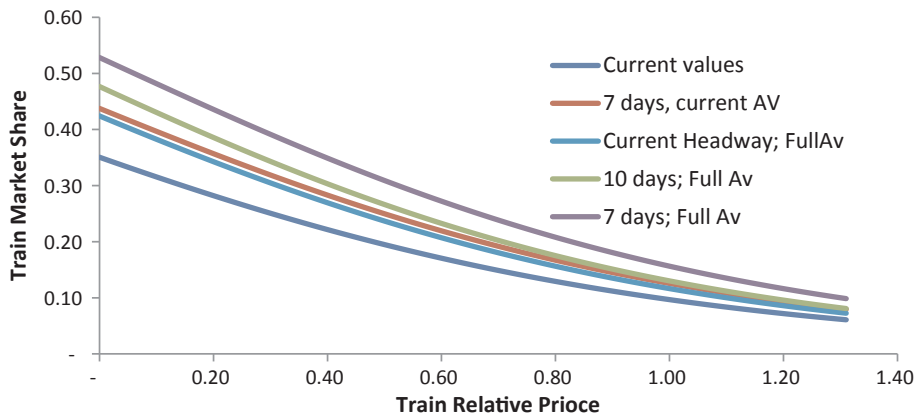


Fig. 9. Train market share for different prices and headways.

different port deficiencies are included in FAS price penalisation and internalised that way. Increases in the FAS price at QQN were also computed, resulting in 16 km if only truck was available and 18 km if both modes could be used. However, increases in the FAS price of this port are not common because QQN is a relatively small port with many operational difficulties, which are reflected in the FAS price. The difference in these values reflect the strong preferences for the port of BHB.

## 5.2. Policy implication

Regarding policy applications of the model, two of them have been highlighted. First, it can be used as a tool for prioritising investments by the government and the private sector. Concerning port policy, the model can estimate the impact of changes in toll charged in the Paraná River, the improvement of an existing port, or the evaluation of a new port. All of these actions can be modelled by changes in the FAS price. Although the variable is linked to international prices, it also reflects port costs and other difficulties exporters might experience. Because of this, the difference in FAS prices between ports can be used for modelling. Toll payments are used in the Parana River (which, for instance, contains the Rosario port complex) to pay for drought maintenance works. In the case of port improvements, such as the case for QQN port, the new FAS price should contemplate the operational improvements the investments would bring. In addition, it can analyse the impact of different toll levels on river traffic flows. A similar approach can be used when considering a new port by assuming the FAS price of a nearby port and considering additional expenses (such as pilotage and tolls).

Railroad infrastructure has deteriorated over the last few decades, having part of the network dismantled or unsuitable for train circulation. In order for the train to recover market share, investments are needed. The tools provided by the model can evaluate investment impacts and can identify the most influential ones considering a budget restriction.

The model developed shows some level of compatibility to the models used by the Ministry of Transport of Argentina to simulate operator's cost. Based on this, different impacts of the not yet implemented "Open Access" policy can be addressed. By forecasting transport volumes and expected gross revenue for operators, different scenarios can be evaluated in order to simulate different ways to remunerate the infrastructure, improve the general level of service offered by the rail system and determine the minimum level of service in the less profitable lines.

Different scenarios were simulated to predict market shares from the application of different policies. A baseline scenario, a 7-day headway with current availabilities, a current headway with full availability, a 10-day headway with full availability and a 7-day headway with full availability were analysed. Aggregate choice probabilities to forecast market shares were computed for each zone within the study area according to the volume of soy production and the relative value of the train and truck tariff, which was considered constant for all locations. The probability of each mode was estimated as a weighted mean of probabilities by the zones production. Fig. 9 presents the expected market share of the train mode for the four scenarios evaluated. The pricing variable used was the train relative price (Train Price/Truck Price).

Fig. 9 shows that even when the train freight price is 0%, the truck still transports goods. This result is due to the fact that, in short distances, the gross margin difference does not compensate for the delay in receiving payment. The figure also shows that when both modes have the same freight price, the train still has some market share because of the benefits of larger shipments and handling. However, improvements in the level of service result in an increase in train demand, even with the same freight prices as the truck. Simulation results suggest that investments for increasing the service headway combined with freight price reduction and increased availability are the most effective measures to encourage train demand in the south of Buenos Aires province.

Based on the simulation results, we estimated the gross potential remuneration for different pricing policies and level of service for the railroad operator, as shown in Fig. 10. The optimal pricing strategy for train mode, for all scenarios studied, corresponds to approximately 70% of the truck tariff. This value is higher to the current pricing, suggesting that there is room for higher pricing that

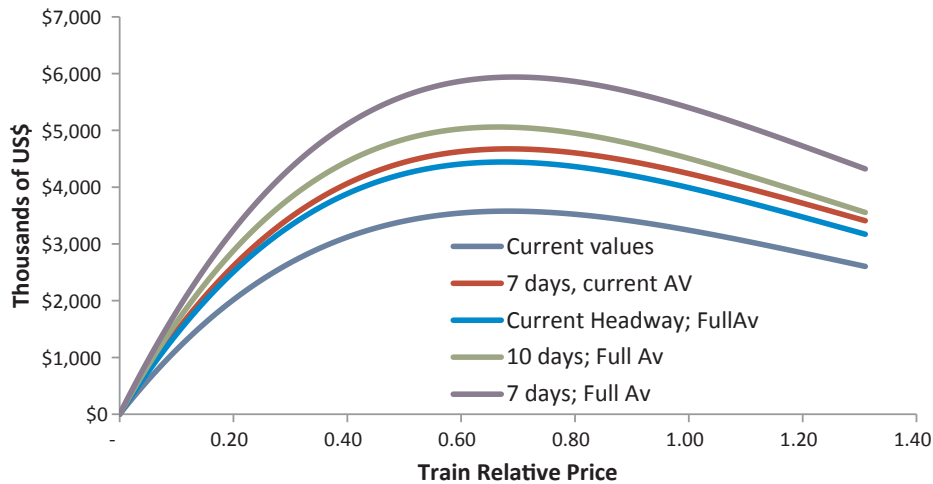


Fig. 10. Gross income potential for train.

could justify further investments. Analysing the headway service, Fig. 10 shows that higher expected gross revenue could be achieved with lower service headway. In the same way, increasing the availability of the railroad has a similar effect in the gross income than improving the current service to a 7-day headway. This may suggest that investments in availabilities and quality of service could improve the profit of the rail system and be a target for public and private investment policies.

## 6. Conclusion

This paper analysed the decision-making process for soy transport in the south of Buenos Aires province. The study set out a more general modelling approach than frequently used, examining jointly the choice of port and mode. Discrete choice models were estimated to analyse consolidator and producer behaviour, combining stated preference and revealed preference data.

A SP survey where respondents could freely allocate their cargo between alternatives was carried out, although later on discretised for modelling. The good response by consolidators to this type of variables suggests that the alternatives were not perfect substitutes. This suggests the exploration of other modelling approaches that standard discrete choice modelling, opening the possibility of other frameworks to be applied. The RP data was constructed by merging individual movements of grain into shipments considering the number of the order, the origin of the goods and the date of transport. This method can be used in other databases in order to estimate the original shipment size. This is particularly relevant in the context where consistent and systematic data is not available.

Combining both sources of data allowed the analysis of all shippers (consolidators and producers), and the identification of behavioural responses to port and mode choice situations not presented in the current market, especially as regards the availability of the railway. SP data were drawn from a stated choice experiment conducted with consolidators, which assumed that the rail network was renovated and is available for all shipments. SP responses showed a tendency for choosing train over truck mode, indicating a possible trade-off between modes if the service conditions were appropriate. RP responses, however, evidenced a strong preference for truck choice over train for shipments to both ports. This tendency is mainly due to two reasons: (i) RP data reveals the current situation, showing the imbalance between both different transport modes, and (ii) RP data includes information about shipments performed by consolidators and producers – cargo sent directly to the port – modelling implicitly part of the supply chain choice. The estimation of models with SP and RP data sources complemented the strengths of both sets of data obtaining a more comprehensive model, a better understanding of the trade-offs between ports and modes and a broader view of the supply chain choice.

The estimated nested models showed a satisfactory overall fit and the signs for the parameters are consistent with microeconomic theory and previous assumptions. The results support the hypothesis made, regarding the need to jointly model mode and port and not just a mode choice model. Service headway, FAS price, freight price and the (logarithm of) travel time to the delivery port were key elements to explain port and mode choice.

Parameters estimated indicated that the utility of mode-port alternatives decreases with increases in the number of days the cargo had to wait to unload at the port, (logarithm of) travel time from the cargo point of pick-up to the port and freight tariff. However, the utility of mode-port alternative increases with increases in the soy price paid to producers and consolidators. Including this variable, obtained a better representation of consolidator and producer decision-making. These parameters model the reasons for transporting goods and show that consolidators and producers chose the option that has the highest positive net utility value, as postulated by economic and behavioural decision theory, although, FAS price is seldom included in other studies.

The fact that the FAS price was valued less than the freight price could suggest a trade-off between the gross margin received and

the timing of the payment. This cash flow relationship has not been sufficiently investigated but it is a relevant issue in a context of high inflation and low credit availability.

The estimated parameters were used to compute the WTP for an increase in one day of the service headway, which corresponds to 0.99 US\$/ton/day. In the particular context of soy in Argentina, the service headway is related to the time soy spends in inventory and therefore this WTP for an increase in the headway could be interpreted as a WTP for a day less in inventory. This interpretation would be useful in cost-benefit analyses associated with transport projects, by converting a unit of inventory time into a monetary value.

Regarding the WTP for time savings, this depends on the travel time itself since this variable had a non-linear effect on the utility. The value for the mean was 1.49 US\$/ton/hour, which was consistent with the values found in the literature. Differences between these WTP values, although both refer to time intervals, could be related to the level of decision involved. While travel time tends to be an operational issue, service headway is more related to a planning sphere.

Direct and cross elasticities values of mode-port choice probability with respect to FAS price and Service headway, being Freight price is the most important. Comparison of direct and cross elasticities showed interesting results: (i) truck mode was relatively elastic with respect to truck freight price, and train mode proved to be relatively inelastic with respect to train freight price (ii) freight price elasticities suggest that consolidators and producers are likely to change the port of delivery but not the transport mode after price increases, (iii) mode-port choice probability is not very sensitive to train headway changes.

The direct elasticity for train mode computed for each district showed freight price elasticity values increase with increases in the distance to the port. Districts closer to a port are less elastic than ones that are more distant. Districts more distant to a port tend to change the delivery port with increases in the train freight price. For the mode-port specific elasticities, it can be distinguished two areas analysing the elasticity: the areas of mixed hinterland or close to BHB and the ones that did not satisfy any of those conditions.

The competitiveness of train and truck modes was analysed through indifference, based on consumer choice theory. The utility function depends on distance to the port, so the iso-utility distance for each port was computed, which represents the distance at which the utilities of train and truck are equal. The curves illustrated that iso-utility distance rises with increases in the train freight price, indicating that the competitiveness of train and truck varies depending on the freight price of both modes. For a train freight price of 40% of the truck tariff, the iso-utility distance is 328 km. Though, for a more expensive train freight price (60% of the truck price) the iso-utility distance increases to 540 km, showing that the train alternative to BHB port loses competitiveness. Iso-utility distances for QQN port were significantly higher than for BHB.

Comparing the hinterland of the ports with same price FAS, the two ports are divided almost equally into zones of influence. Nevertheless, when FAS price difference appears, the distances start to be significant in favour of BHB.

The model results can affect policymaking and infrastructure investment priorities. First, improving accessibility to the railway for all producers and consolidators would increase the railway market share. Second, the improvement of service headway and reliability through investment in railroads and rolling stock has shown a great potential to motivate modal shift. Finally, it may focus investment towards the railway to BHB since it has a greater potentiality of transporting more products than the railway to QQN.

Simulation results for the current scenario and for alternatives considering different availabilities and headways suggest that it is difficult to achieve important modality shifts only by reducing the train freight price. Investments for increasing the service headway combined with the freight price reduction and higher availabilities of the train are the most effective measures to encourage train demand in the south of Buenos Aires province. Service headway is related with inventory costs and may influence financial performance of the consolidator. The optimal pricing strategy for the train operator, for all scenarios studied, corresponds to approximately 70% of the truck tariff. Higher expected income could be achieved with higher service headway and greater availabilities. These results suggest that investments in availabilities and quality of service could improve the profit of the rail system and be a target for public and private investment policies. All these conclusions are particularly relevant for the design of an “Open Access” policy for the railroad.

To avoid QQN losing too much of its hinterland, and thus increasing the total amount of overall transported ton-km in the study area, actions towards the improvement of its operations could be implemented. By increasing its reliability, FAS price penalisation could be avoided. Carrying out maintenance to the draught, improving protection against waves and terrestrial access are some measures that could be targeted to boost the reliability and port operations.

Future research could involve the development of discrete–continuous extreme value models to explain other margins of shipping choice, since they show that for the case of mode-port choices the alternatives may not be perfect substitutes. This econometric approach could handle multiple discreteness, such as cargo percentage allocations for the various choice alternatives.

In addition, an expanded model applicable to the rest of the country, or to the Rosario port region, that might include shipment size choices and inventory decisions could become very useful for global policy study. Finally, a focused study on the economic and social viability of investing in railroad operability could be an interesting input for designing investment priorities, developing transport infrastructure, and to shape new policies oriented to increase rail market share in Argentina.

## Acknowledgements

The authors thank the CAPES and CNPq for its support through research grants, the Lastran for support during the research process and to the under-secretary of cargo planning of the Ministry of Transport of Argentina for the data and support. Additionally the authors thank Mariano Tapia for the logistic support during the field study. The authors are indebted to the referees and editors for their comments that improved the substance and readability of the paper.

## Appendix A. Abbreviations used

Table A1 shows the abbreviations used in the paper.

**Table A1**

List of abbreviations.

Abbreviation	Meaning
ASC	Alternative Specific Constant
BHB	Port of Bahía Blanca
D	Distance
FAS	Free Alongside Ship; Price paid to producers at the port
FOB	Free On Board; Price of the product after loading it to the ship
FP	Freight Price
MNL	Multinomial Logit
NL	Nested Logit
QQN	Port of Quequén
RP	Revealed Preference
SP	Stated Preference

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