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Understanding maritime transport route choice among Irish exporters: A latent class approach

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ABSTRACT

The reduction in the level of maritime connectivity between Ireland and mainland Europe has been the focus of concern for Irish exporters since the withdrawal of the United Kingdom from the European Union in January 2019. In a post-Brexit scenario, new proposals are being sought to address Ireland's reliance on the UK landbridge. Policy developments aimed at circumventing the potential negative impact of UK customs checks for Irish exports include the proposals by the European Commission to introduce new direct shipping routes connecting main ports in Ireland with Zeebrugge and Antwerp in Belgium, as well as with Rotterdam in the Netherlands. From a transport policy perspective, finding alternatives to Ireland's reliance on the land bridge over Britain is a strategic priority. A better understanding of shippers' route preferences from Ireland to continental Europe is an important aspect in the formulation and assessment of future policies on freight transport. The objective of this paper is precisely to contribute to this by providing an analysis of route choice behaviour from the perspective of the shipper. The paper presents an analysis of non-observable heterogeneity from the estimation of a Latent Class Model (LCM). Using data from an efficient stated preference (SP) experiment undertaken to model route choice between Ireland and continental Europe, results from this paper provide an understanding of the effects that the main transport attributes such as cost and transit time have within identified Irish shipper segments. The paper contributes to transport policy by offering a strategically relevant insight into the demand side for maritime transport services in Ireland.

1. Introduction

The potential reduction in the level of maritime connectivity between Ireland and mainland Europe has been the focus of concern for Irish exporters and policy makers since the start of the process of separation of the UK from the European Union (EU) or Brexit. The UK's legal and irrevocable exit from the EU came into effect on the January 31, 2020, with the start of a transition period in which a trade agreement is negotiated. This period will come to an end on December 31, 2020. In a post-Brexit scenario, with great uncertainties regarding the future relationship between the EU and UK, new proposals are being sought to tackle Ireland's reliance on the UK landbridge. According to recent reports, about 53 per cent of all Irish goods exported to continental Europe go via the Channel Tunnel between England and France (Lawless & Morgenroth, 2017), with approximately 150,000 Irish trucks and 3 million tonnes of goods travelling through the UK for export to the EU each year (IMDO, 2019).

As part of Europe's contingency plans to prepare for Brexit, the European Commission proposed a review of one of the EU's strategic transport corridors, the North Sea-Mediterranean Core Network Corridor (NSM Corridor), which formerly included the UK. Policy developments aimed at circumventing the potential negative impact of UK customs checks for Irish exports include the proposals by the European Commission to introduce new direct shipping routes connecting Dublin and Cork in Ireland with Zeebrugge and Antwerp in Belgium, as well as with Rotterdam in the Netherlands (European Commission, 2018a). These proposals have been complemented by significant steps taken forward by industry, with the provision of additional capacity on continental routes by key players such as Irish Ferries, Brittany Ferries and CLdN, with the MV Celine and the MV Laureline vessels introduced in

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2018 and 2019 respectively.

From a transport policy perspective, finding alternatives to Ireland's reliance on the land bridge over Britain is a key priority. A better understanding of shippers' route preferences from Ireland to continental Europe is an important aspect in the formulation and assessment of future freight transport policies. The objective of this paper is precisely to contribute to this by providing an analysis of route choice behaviour from the perspective of the shipper. Prior research on the implications of Brexit for international shipping routes from Ireland to mainland Europe suggests that in a post-Brexit scenario, the use of direct routes is likely to increase by up to 14% with respect to the current level (Vega et al., 2018). Given the high level of uncertainty around the EU-UK Brexit trade deal negotiations, the increase in the use of direct shipping routes to continental Europe is likely to be much higher. This paper extends and complements previous research by specifically addressing Irish shippers' preference heterogeneity when faced with route choice decisions.

With a relatively inelastic demand, the next best alternatives to the UK land bridge are not able to match the transit times that UK land bridge users have historically benefit from until now. The current study discusses this further and it complements previous analyses of the demand for shipping services with an examination of the supply side. There is now widespread agreement among industry, academia and policy makers that a significant part of export goods that up until now were being exported from Ireland into mainland Europe via the UK land bridge will inevitably start using new direct routes to the continent. A key question remains as to the extent to which these new direct services will be able to adjust to the existing requirements from customers used to highly competitive levels of service along the pre-Brexit UK land bridge route. In this sense, a major aspect to consider is the type of service offered – roll-on/roll-off (RORO) vs lift-off/lift-on (LOLO).[1] The levels of service offered by LOLO and RORO are different in terms of transit times and frequencies (see Section 2 for details). Therefore, the potential demand for each of these services will depend on how sensitive users are with respect to these attributes.

The objective of this paper is to shed light on this question by carrying out an analysis of non-observable heterogeneity from the estimation of a latent class model. Proposed by Greene and Hensher (2003), the latent class model is based on the idea that individuals belong to different segments or classes with identical preferences within classes. While latent class models are increasingly used in empirical transport studies, freight transport applications of these models are still limited in the literature. Applications of these models in freight transport research can be found in Greene and Hensher (2013), Massiani et al. (2007) and Román et al. (2017). Results from this paper provide a deep understanding of the effects that the main transport attributes have within each identified Irish shipper segment or class as well as to contribute to empirical applications on freight transport.

Using data from an efficient stated preference experiment undertaken to model route choice between Ireland and continental Europe, the results presented here provide policy makers with a quantitative and strategically relevant insight into the demand side for maritime transport services in Ireland.

Regardless of the effects that the different levels of service have on the demand for maritime transport, Brexit and the expected maritime freight route re-assignment away from the UK land bridge are likely to have implications for the structure of Ireland's freight transport supply to the continent, as well as for the entire Irish haulage sector. In fact, these expected changes are expected to have a deeper impact on Ireland's freight transport business model to mainland Europe. From a business model mainly based on road transport through the UK land bridge, to a model in which the transport connectivity is entirely maritime. In other words, Ireland's freight transport sector is facing a transition from a primarily road-based freight transport system with limited maritime involvement, to a fully integrated intermodal maritime system. The extent to which these new maritime direct services from Ireland to continental Europe are RORO or LOLO has important implications for Irish road hauliers and transport policy makers in general.

The paper is structured as follows: Section 2 describes the research context in terms of the characteristics of the transport corridors under study and the policy debate around Ireland's transport dependency on the UK land bridge. Section 3 presents the data sources and model specification, followed by the estimation results in Section 4. Section 5 concludes with discussion and policy implications.

2. Research context: transport policy, supply and demand of maritime freight transport services

Great Britain has historically accounted for a large proportion of RORO volumes between Ireland and continental Europe. Cargo movements have relied on the UK landbridge network for its competitive and efficient service, with high levels of reliability and security. According to the Irish Exporters Association, two-thirds of their members use the UK landbridge to access continental markets (IEA, 2017). The Economic and Social Research Institute (ESRI) estimates that 53 per cent of Irish exports to all countries other than the UK use the UK land bridge (Lawless & Morgenroth, 2017). With the recent withdrawal of the UK from the European Union, Ireland faces a considerable level of uncertainty regarding the potential impact that the future development of the UK/EU trade relationship may have on its own connectivity with mainland Europe, with further implications for the supply and demand of maritime freight services from/to Ireland.

From a European policy perspective, the focus has been on reviewing the Trans-European Transport Network (TEN-T) policy route alignment of core strategic network corridors. The objective of this review is to prevent a severe interruption of Ireland's connectivity with continental Europe as result of Brexit. The European Commission published specific proposals on Trans- European Networks for the design of new maritime routes to link Ireland with the continental part of the North Sea-Mediterranean corridor or NSM corridor.[2] The objective is to improve transport connections within the island of Ireland, and to meet growing trade requirements via Ireland's ports. Specifically, the European Commission's proposed regulation involves adjusting the NSM corridor's route by adding new maritime links between the Irish core ports of Dublin and Cork and the NSM corridor's ports of Zeebrugge and Antwerp in Belgium, and the port of Rotterdam in the Netherlands (European Commission, 2018a).

From a more general policy perspective, the European Commission published a Contingency Action Plan (European Commission, 2018b, p. 890) that highlights a number of key issues in preparation for the UK withdrawal from the EU, including transport, as well as a package of contingency measures in case of a no-deal withdrawal of the UK from the European Union. In line with these contingency plans, the Irish government has also announced the publication of a series of legislative measures to address future challenges in the case of a no-deal Brexit scenario (Government of Ireland, 2019). Such a situation may come into effect if the EU and the UK are not successful in agreeing a trade deal after the transition period and therefore, revert to trading on World Trade Organisation (WTO) commercial terms.

From a maritime supply perspective, Ireland largely relies on feeder,

[1] LOLO and RORO acronyms refer to the way products are loaded and unloaded from vessels. The first category includes those traffics that are lift on/lift off using cranes (containers) while the second includes those that roll on/off the vessel using their own wheels (self-propelled cargo such as cars, tractors) or handling equipment of the terminal.

[2] The NSM corridor includes links between Belfast, Dublin and Cork with Zeebrugge, Antwerpen and Rotterdam on the island of Ireland and links in Great Britain from Glasgow and Edinburgh in the north to Folkestone and Dover in the south.

rather than direct deep-sea container services to connect its ports to European and global container networks. While these short-sea container services are important means of trade with third countries, Ireland's trade with the UK and France has historically used RORO services (European Commission, 2018a). Table 1 shows the tonnage of goods forwarded through Irish ports by RORO and LOLO services in the 2010–2018 period. While RORO services account for over 90 per cent of unitised shipments to Great Britain, this proportion is significantly smaller in the case of EU destinations with only about 20 per cent of unitised maritime shipments using RORO. Fig. 1 shows Ireland's maritime transport supply, which has remained relatively stable over the last decades.

Table 2 shows the levels of service in terms of transit time and frequency for the identified direct routes to North of France, Netherlands and Belgium, differentiating by the type of service, RORO or LOLO. Most of tonnage forwarded through LOLO direct connections is to continental Europe (EU). A further breakdown of direct routes to mainland Europe by type of service is presented in Table 2. This table shows that while there are significant differences across routes, the levels of service for LOLO are largely poorer in terms of transit time and frequency than those for RORO. Overall, Tables 1 and 2 are consistent with the results from a recently published report by the Irish Maritime Development Office (IMDO) that concludes that while the transit time for shipments to continental Europe through the UK land bridge is about 20 h, it can take up to 40–60 h for direct RORO and direct LOLO services respectively (Breen et al., 2018). However, transit times and frequencies along these direct routes tend to respond to the requirements from major intercontinental routes, as in most cases these are feeder services connecting to major container routes, among them one of the most important ones in the world stretching from Hamburg along the German, Dutch and Belgian North Sea coast and through the English Channel to the open sea.

From a demand perspective and given the forthcoming difficulties in transporting goods from Ireland to continental Europe via the UK land bridge, exporters are inevitably going to consider using direct routes to the continent. The question remains are to whether direct services will be able to adjust to the existing demand requirements. In this sense, a major determinant is the type of service offered – LOLO or RORO - as the potential demand for each of these services will depend on how sensitive shippers are to transit times, frequencies and other freight transport attributes. The ultimate choice of type of service for transporting goods along direct routes will be a major determinant for the competitiveness of Irish exports.

Potential changes in the demand for direct freight services are likely to also have an effect on the Irish haulage sector business model and structure. Previous research on the Irish haulier sector suggests that haulage operators have a relatively low bargaining power compared to other transport providers (Vega & Evers, 2016). The Irish haulage market has been described as a quasi-perfect competition market brought about by a large fragmented supply base mainly operated by small haulage companies offering transport services primarily based on price competitiveness (Vega & Evers, 2016). Overall, Ireland's haulage industry is very competitive, and profit margins are low. Road freight operators are deemed to be price takers rather than price makers (Aylward & O'toole, 2007).

Increasing demand for direct services is expected to transform the traditional Irish freight transport business model based on the use of road transport to export goods to the continent - with two short maritime crossings to/from the UK - into an entirely maritime intermodal freight transport business model. The extent of the impact on the Irish road haulage sector as a result of these changes in demand will depend on the growth of market share by type of direct services offered – RORO vs LOLO. In the case of a new maritime intermodal business model based on LOLO, the effect on the road haulier could be extensive, as they would no longer be the main transport provider and their role would be limited to haulage activities at loading ports. Recent developments from the supply side suggest that this case would be unlikely as growth in direct continental services are primarily in the RORO/ROLO market. According the latest reports, both RORO and LOLO markets maintained steady growth in 2019. However, there has been a twofold increase in growth in the Irish RORO market in 2019 compared to the Irish LOLO market. This has been largely driven by an increase in trade between Ireland and the EU, i.e. direct RORO services to the continent from Dublin & Rosslare. This market segment has averaged 8.4% growth in 2019 adding approximately 4000 RORO units each quarter in 2019 (IMDO, 2019).

3. Data and methodology

3.1. Data collection

Data for this analysis was collected by the authors as part of a wider study into the analysis of maritime freight transport demand from Ireland to continental Europe.

Prior to the data collection process, the research team carried out in-depth interviews with exporters and freight transport service providers to understand the composition of the maritime transport supply and demand along several transport corridors of interest. These were 15 qualitative interviews with key industry representatives, which provided the research team with valuable information that was later used to identify main service attributes and their initial levels of service. These initial levels were then presented to participants in the choice experiments. Table 3 shows the attributes and levels considered in the SP choice experiment.

The data collection regarding the SP choice experiment was carried out in two phases. First, two pilot exercises were conducted for a sample of 15 companies. This allowed for the estimation of preliminary models to obtain parameter priors required in the construction of the final choice experiments. A source of concern for the research team was to provide as much realism as possible for the respondent in the experimental design phase. To achieve this, the Cost variable was selected from a catalogue of 30 possible cost levels according to the actual cost reported by the respondent. This resulted in 30 individual choice experiments being constructed for the study. N-gene software (ChoiceMetrics, 2009) was used to build the efficient designs for a multinomial logit specification.

In a second phase, the research team carried out interviews with the logistics and supply chain managers of 50 Irish-based export companies of non-refrigerated goods[3] to continental Europe (France, Belgium, Netherlands and Germany). Interviews were carried out by specialised transport interviewers and efforts were made to ensure that respondents were the relevant decision makers. That is, respondents were directly responsible for the management of transport shipments within the organisation. Additional efforts were made to confirm that the commercial terms or incoterms were relevant to this study.[4] Companies were selected by a simple random sample of business directories provided by state business development organisations including the Enterprise Ireland, the Irish Exporters Association, and IDA Ireland.[5]

The structure of the sample reflected the composition of the Irish exporting manufacturing sector, according to the latest statistics from

[3] The refrigerated shipments were excluded as these have very different timeline requirements and costs, and would not be comparable to the rest of the sample.

[4] Companies that specifically indicated that chose an incoterm under group E – EXW (Ex Works) – or F - Free Carrier (FCA), Free Alongside Ship (FAS) and Free on Board (FOB), as these incoterms place most of the transport responsibility on the buyer (importer).

[5] Enterprise Ireland is the Irish government agency responsible for the development and growth of Irish enterprises in world markets. IDA Ireland is the Irish state agency responsible for attracting and encouraging investment into Ireland by foreign-owned companies.

Table 1
Tonnage of goods forwarded through Irish ports, LOLO and RORO, 2010–2018, '000 Tonnes.

'000 Tn	Great Britain			EU		
	Roll-on/roll-off traffic	*Lift-on/lift-off traffic*	*TOTAL*	*Roll-on/roll-off traffic*	*Lift-on/lift-off traffic*	*TOTAL*
2010	4920	226	5146	588	2395	2983
2011	4877	248	5125	638	2526	3164
2012	4756	346	5102	606	2446	3052
2013	4872	302	5174	647	2464	3111
2014	5138	519	5657	695	2282	2977
2015	5758	662	6420	756	2434	3190
2016	6128	604	6732	755	2605	3360
2017	6409	570	6979	756	2706	3462
2018	6482	302	6784	835	2996	3831
% Total						
2010	95.61%	4.39%		19.71%	80.29%	
2011	95.16%	4.84%		20.16%	79.84%	
2012	93.22%	6.78%		19.86%	80.14%	
2013	94.16%	5.84%		20.80%	79.20%	
2014	90.83%	9.17%		23.35%	76.65%	
2015	89.69%	10.31%		23.70%	76.30%	
2016	91.03%	8.97%		22.47%	77.53%	
2017	91.83%	8.17%		21.84%	78.16%	
2018	95.55%	4.45%		21.80%	78.20%	

Source: Central Statistics Office (CSO) of Ireland, Statistics of Port Traffic.

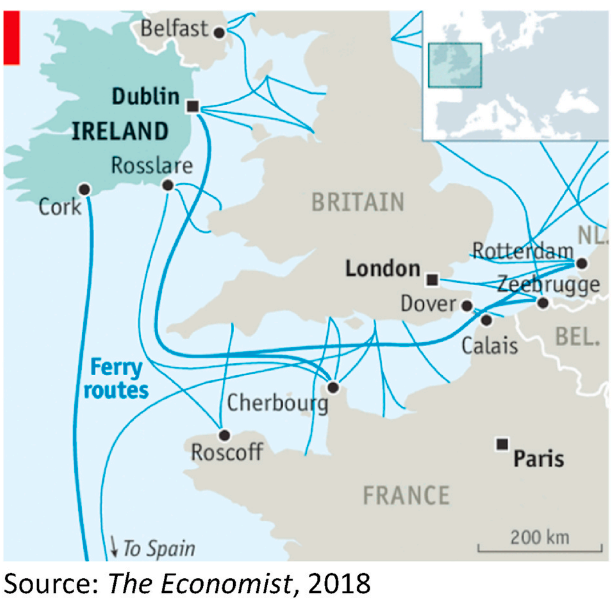

Fig. 1. Maritime transport routes from Ireland to the UK and North Continental Europe
Source: *The Economist*, 2018.

the Central Statistics Office of Ireland. The largest number of active enterprises are found under 'basic and fabricated metal products', representing 21% of the total, followed by 'Furniture and other manufacturing' with 13.4% of the total number of active manufacturing enterprises (Central Statistics Office, 2017). The sample used in the analysis is mainly composed by Small and Medium Enterprises (SMEs) (56%), employing less than 250 persons. Again, this reflects the structure of the manufacturing sector in Ireland. On this regard, the Central Statistics Office reports that the number of SMEs in Ireland accounts for 99.7% of active enterprises, 68% of persons engaged, 50.3% of turnover and 46.2% of gross value added (GVA) (Central Statistics Office, 2017).

Computer-assisted telephone interviewing (CATI) were conducted and consisted of two blocks of questions. The objective of the first block was to obtain information on the characteristics of the company and its most typical (reference) shipment for the maritime transport corridor under study. The second block corresponded to an efficient stated preference experiment (Rose & Bliemer, 2004, 2008 and, 2009; Rose et al., 2008) with 12 scenarios during which the interviewee had to choose between its current alternative through the UK land bridge -status quo- and an unlabelled hypothetical alternative defined in relation to this status quo.

3.2. Methodology

The attributes considered in the experiment were transport cost (in euros per shipment) and transit time (hours) between the Irish port of departure and the continental European port of entrance,[6] frequency of the maritime service –measured by the number of waiting hours with respect to the preferred departure hour- and delays –characterised both by the probability of suffering significant delays and the absolute magnitude of these delays when they took place. The hypothetical alternative to the status quo was defined as more competitive in terms of cost in 3 out of the 4 levels considered, but always worse in terms of transit time and frequency. From the three levels considered for delays, one corresponded to the level of service currently reported, one to a deterioration and one to an improvement. As the probability of suffering delays and its magnitude were defined through two different attributes, the level of delays of the hypothetical alternative could be better in terms of the probability of suffering delays but worst in the magnitude and vice versa, thus covering all possible casuistry. Both the selection of the attributes and the attribute levels considered in the stated preference experiment were based on knowledge obtained through previous research (Breen et al., 2015; Vega & Evers, 2016), qualitative interviews and the pilots carried out prior to the experiment previously described. A more detailed description of the questionnaire, fieldwork and descriptive statistics can be found in Vega et al. (2018).

The selection of the attributes in the study is in line with the literature on freight transport choice modelling, where the basic attributes – transport cost and transit time - are complemented with research and context specific attributes on the level of service provided. Literature reviews in the area of freight transport choice modelling can be found in Floden et al. (2017), Tavasszy and y de Jong (2014) and Feo et al. (2011) and Cullinane and Toy (2000) among others, while Raza et al. (2020), Mathisen and Hanssen (2014) provide interesting reviews specific to

[6] Note that the cost and the transit time variables refer to the port-to-port. The experiment was carried out under the assumption that the destination port in both alternatives was the same, similarly to the port-to-door segment…

Table 2
Levels of service of RORO and LOLO direct routes to North of France, Netherlands and Belgium.

IRISH PORT	EU PORT		TYPE OF SERVICE	NO OF SHIPPING LINES IDENTIFIED	FREQUENCY Dep. per week	TRANSIT TIME hours
DUBLIN	ROTTERDAM	NETHERLANDS	RORO	2	4	44
			LOLO	7	2	61
			% LOLO/RORO	350%	46%	139%
DUBLIN	ZEEBRUGGE AND ANTWERP	BELGIUM	RORO	1	2	40
			LOLO	3	1	53
			% LOLO/RORO	300%	67%	132%
DUBLIN	CHERBOURG AND LE HAVRE	FRANCE	ROPAX	1	3	22
			LOLO	2	1	70
			% LOLO/RORO	200%	33%	318%
CORK	ROTTERDAM	NETHERLANDS	RORO	1	2	72
			LOLO	6	2	83
			% LOLO/RORO	600%	75%	115%
CORK	ANTWERP	BELGIUM	LOLO	2	0.88	48
CORK	ROSCOFF AND LE HAVRE	FRANCE	ROPAX	1	2	15
			LOLO	2	1	45
			% LOLO/RORO	200%	50%	300%
ROSSLARE	CHERBOURG	FRANCE	RORO	1	3	18
WATERFORD	ROTTERDAM	NETHERLANDS	RORO	1	2	48
			LOLO	1	2	120
			% LOLO/RORO	100%	100%	250%

Source: authors' own elaboration from publicly available data obtained from shipping companies and port authorities operating relevant routes in 2019.

Table 3
Attributes and levels considered in the SP choice experiment.

Attribute	Definition and unit	Alternative A (Land bridge UK)	Alternative B (Direct)
Cost	• Cost of the IRL port - EU port transport section • Euros/Shipment	Catalogue of 30 possible cost levels	−30%, −20%, −10%, +10%
Transit time	• Transit time between the IRL port and the EU port • Hours	16	+8 h, +20 h, +32 h
Probability of delays	• Probability of suffering a significant delay. • Percentage	5	−2 percentile points, current level, +2 percentile points
Delays duration	• Hours of delay with respect to the initially agreed delivery time.	5	- 2 h, current level, + 5 h
Service frequency	• Waiting hours with respect to the preferred departure hour.	4	+8 h, +20 h, +32 h

intermodal freight transport.

Among the attributes included in discrete choice applications for freight transport, frequency is of special interest in cases when the choice set includes the assessment of intermodal transport chains subject to fixed schedules and comparatively low levels of frequency (Kim et al., 2017). On this regard, both road and intermodal transport services differentiate in terms of flexibility, understood as the ability to adjust to last-minute changes in the level of service. Compared to the other attributes typically included in freight transport choice modelling, flexibility can be difficult to capture, as its definition may contain several dimensions and its valuation is subject to greater subjectivity. Arunotayanun and Polak (2011) introduce flexibility through indicators such as the time of departure or the responsiveness to problems. Zotti and Danielis (2004) opted to introduce it as a discrete variable indicating either a high or low level of flexibility of the service.

The level of reliability in the terms and conditions of delivery is also considered a key determinant of modal choice. This is particularly important for shipments with a relatively high value and subject to inventory optimisation policies or just-in-time production systems (Shams et al., 2017). On this regard, the availability of real-time tracking systems can be crucial to freight forwarders and shippers, as they allow for a more efficient process of incident management. Still, not many studies have included this attribute in their models and in those where this was included, there was limited evidence that these were indeed relevant (Arencibia et al., 2015; Lammgård & Andersson, 2014).

In addition to the selection of attributes, a critical aspects in freight transport choice modelling is how to capture preference heterogeneity. Different behavioural patterns can be defined by identifying individual preferences based on the socioeconomic characteristics of decision makers. These preferences can be studied by modelling heterogeneity either exogenously or endogenously. The former can be analysed by the researcher either by specifying interaction terms between socioeconomic characteristics and modal attributes (Ortúzar & Willumsen, 2011) or by specifying random parameters and estimating a so-called Mixed Logit model (Train, 2003). In both cases, the distributions of those parameters are tested by the researcher (e.g. with the normal, log-normal or the triangular distribution. When heterogeneity is modelled endogenously, it means that it is not observed by the researcher and therefore estimated using Latent Class models, which do not require functional form specification (Greene & Hensher, 2003). In this paper, modal choice behaviour is analysed using these latter models.

The latent class model assumes that various segments or classes of individuals can be identified to explain heterogeneity in preferences (Greene & Hensher, 2003). Class heterogeneity is defined by an observable vector of characteristics that varies across classes, that is, the perception of the different attributes described above differs across the identified classes. In addition, the latent class model allows considering non-compensatory behaviours within each class. This means that each identified class can consider a different set of attributes in the choice process, which implies that class or segment identification in the sample is carried out endogenously. Alternatively, within each class the vector of characteristics that each class identifies is common to all the individuals in that class, that is, there is homogeneity in the preferences of the individuals that form the same class. The standard estimation procedure for this model is maximum likelihood.

A detailed account of the econometric development of the model can be found in Greene and Hensher (2003), the basic assumption is that individuals can be implicitly sorted into a set of exogenously defined Q classes. Unobserved heterogeneity is captured by these classes through the estimation of a parameter vector for each class. The central behavioural model is a Multinomial Logit model (MNL) for discrete choice among J_i alternatives, by individual i observe in T_i choice situations:

$$P_{it|q}(j) = Prob(y_{it} = j|class = q) = \frac{exp(\beta_q x_{it,j})}{\sum_{j=1}^{J_i} exp(\beta_q x_{it,j})} \quad (1)$$

where y_{it} represents the choice made by individual i in choice situation t, $x_{it,j}$ is the attribute vector of alternative j for individual i in choice situation t; and b_q is the vector of unknown taste parameters in class q. The contribution of individual i to the likelihood would be the joint probability of the sequence $y_i = [y_{i1}, y_{i2}, ..., y_{it}]$ is:

$$P_{i|q} = \prod_{t=1}^{T_i} P_{it|q} \quad (2)$$

The prior probability for class q for individual i will be the following expression:

$$H_{iq} = \frac{exp(\theta_q z_i)}{\sum_{q=1}^{Q} exp(\theta_q z_i)} \; q = 1, \ldots, Q, \; \theta_q = 0 \quad (3)$$

where z_i is a vector of observable characteristic to explain the class membership and q_q is a vector of unknown parameters. θ_q are normalized to 0 to allow the model identification. Thus, the likelihood for individual i is the expectation (over classes) of the class-specific contributions is:

$$P_i = \sum_{q=1}^{Q} H_{iq} P_{i|q} \quad (4)$$

The posterior probability for class q for individual i can be obtained as well as the posterior estimate of the individual parameter vector (see Greene and Hensher (2003) for details). Class membership can be defined exogenously either when an alternative specific constant is specified in the utility function or through relevant socioeconomic variables that increase the probability of belonging to a class. The latter case can offer interesting results from a transport policy perspective. In this paper, two socioeconomic variables are shown to increase the probability of belonging to Class 1. Details are presented in Section 4.

In the field of freight transport, latent class models are still relatively limited compared to their counterparts in passenger transport. Table 4 shows some key applications of latent class models in freight transport discrete choice analysis, with details on the attributes included in the experiment as well as the variables in the class membership function.

4. Estimation results

The five attributes defined by the stated preference experiment are considered in the estimation process. The definition, unit and expected signs are shown in Table 5. Two socioeconomic variables are also included and defined as dummy variables. The first socioeconomic variable is SME and it indicates whether the company interviewed is a small and medium enterprise or not. The second socioeconomic variable is TOP3 and it represents whether the firm outsources transport operations to a road haulier directly (=1) or they outsource transport to a freight forwarder (=0). These two socioeconomic variables are defined as class segmentation variables, that is, they increase the probability of belonging to Class 1.

Several models were estimated to obtain the best latent class model considering different number of classes. In addition, various specifications of the utility function were also estimated in order to consider other variables as well as the modal attributes. It was decided the latent class model with two classes shown in Table 6 that was best model[7] based on the information criteria (less value of BIC criteria) and coherence, in terms of significance of explanatory variables and expected sign. The analysis was carried out using NLOGIT 6.0 (Greene, 2016). The utility specification of each alternative is the following expression:

$$V_{LB} = \theta_C cost + \theta_T time + \theta_D delays\ (\%) + \theta_{DM} delays(M) + \theta_W wait$$

$$V_{DS} = \theta_C cost + \theta_T time + \theta_D delays\ (\%) + \theta_{DM} delays(M) + \theta_W wait$$

where V_{LB} is the utility function of LandBridge UK alternative and V_{DS} is the utility function of direct service alternative.

Results show that there are two distinct classes that value transport attributes differently. While Class 1 values the two fundamental maritime transport attributes of Cost and Transit time, Class 2 puts the emphasis on the quality of service. Overall, estimates show expected signs despite the fact that not all of them are significant.

Class 1 is characterised by firms that consider Cost and Transit Time when choosing their maritime freight transport route to mainland Europe. In this case, the class probability is 63.90%. Alternatively, Class 2 includes firms that take into account the three level-of-service variables included in the study - Transit time, Delays (in hours) and Waiting time - with a 36.10% class probability. Moreover, if the firm is an SME or it outsources transport operations to a road haulier – relative to outsourcing it to a freight forwarder or carrying out its own transport operations - the probability of belonging to Class 1 increases.

The variable Delays (%), measured as a percentage of shipments that suffer a significant delay, is the only non-significant variable in both classes. Note that, as Kurri et al. (2000) and Konstantinues et al. (2020), the variable related to shipment delays was considered in the study in two attributes: first, as a percentage of shipments that suffer a significant delay (Delays %) and second, as the number of hours of delay once these take place (Delays M). The idea was to deepen our understanding of the role that the variable related to shipment delays played in transport decisions. Overall, results show that what seems to be relevant for the decision maker of Class 2 is not the probability of experiencing delays, but the extent of these delays when they occur (in hours). Given that the probability of suffering delays is implicitly assumed in the Delays (M) attribute, it is difficult for the researchers to assess whether the non-significance of the Delays (%) variable is due to a failure by the respondent to isolate both notions of delays.

Table 7 presents the characteristics of each class according to the characteristics of the shipper and the reference shipment. In this regard, firms in Class 1 are mostly SMEs that handle the shipments with the lowest unitary value. This is in line with what would be expected, as the lower the unitary value of shipments, the greater the relative importance of the transport cost on the overall price of the products (Beuthe & Bouffioux, 2008; Konstantinus et al., 2020). In terms of their traffic with the UK, firms in Class 1 outsource their transport operations mainly to road hauliers and to some extent to freight forwarders. Regarding their export destinations, companies under Class 1 export most of their goods to Germany and France, and to a lesser extent to the Netherlands. Conversely, companies in Class 2 tend to be larger firms (>250 employees) that export a more balanced range of goods in terms of unitary value and destination. Regarding their traffic with the UK, shippers under Class 2 outsource their transport operations mainly to freight forwarders.

Table 8 shows the direct and cross elasticities for the land bridge and the direct maritime service alternatives respectively. The direct elasticity represents the percentage change in the probability of choosing the alternative when marginal changes in the attributes of that

[7] The Horowitz test (Horrowitz, 1982) has been applied and the hull hypothesis is rejected, the true model is the latent class model.

Table 4
Applications of latent class models in freight transport.

AUTHOR (YEAR)COUNTRY	DECISION MODELLED	No. CLASSES	VARIBLES INCLUDED IN CLASS PROBABILITY FUNCTION	ATTRIBUTES INCLUDED IN THE SP EXPERIMENT
Zotti and Danielis (2004) Italy	Choice between the current road transport alternative and 2 hypothetical intermodal alternatives	2	None	Cost Time Punctuality Loss & Damages Frequency Flexibility Mode
Massiani et al. (2007) Italy	Choice between two types of freight transport service	2	Location of the firm within an industrial cluster JIT techniques adoption	Cost Travel time Punctuality Damage and loss
Puckett and Rasciute (2010) Australia	Choice between 3 transport services (current and 2 alternatives defined in relation to the current SQ).	2	TRANSPORTERS' MODEL: Years in a similar role Scheduling by transporter Scheduling by receiver of goods Litres of fuel used on RP trip N° of years of partnership Sender of the goods paid for shipment Routing by sender of goods Combined all cost measures SHIPPERS' MODEL: Subsidiary of larger firm Years in a similar role Proportion of business for transporter Hours available to meet delivery N° of delivery locations Combined time measures Combined cost measures Ignored all waiting times Ignored all on-time probabilities Ignored all fuel costs Ignored all distance-based charges	Free-flow time Slowed-down time Waiting time at destination Probability of on-time arrival Fuel cost Distance based charges
Arunotayanunand Polak (2011) Indonesia	Choice between small truck, large truck and rail	3	Commodity value Use of container Frequency of delivery Commodity type	Cost Time Service quality Service flexibility
Feng et al. (2013) Netherlands	Truck drivers route choice	2	Size of truck	Congestion Road category Road pricing Road bonus Urban area Parking/restaurant facilities
Greene and Hensher (2013) Australia	Choice between 3 transport services: current and 2 alternatives defined in relation to the current SQ.	2	Freight rate	Total cost Total transit time On time delivery No variable charge dummy
Hyun-han Kim et al. (2017) New Zealand	Choice betwewn road/rail/SSS if FLC and between rail/road own account/road hired if LCL	3 FCL and 4 LCL	None	Cost Time Reliability (no delays) Risk of losses and breakages Frequency
Román et al. (2017) Spain	Choice beteween road and an intermodal (maritime/rail) alternative	5	None	Cost Transit time Delays (magnitude) Frequency
Konstantinus et al. (2020) Southern Africa Development Community	Choice between road and a hypothetical SSS alternative	2	Type of product (raw, semi-finished and finished)	Transit time Transport cost Reliability> Extent of delay Frequency

alternative are considered. Direct elasticities are expected to be negative for all attributes. The direct elasticity expression is as follows:

$$\varepsilon_{jj} = \frac{\left(P_j^1 - P_j^0\right) \Big/ P_j^0}{\left(X_j^1 - X_j^0\right) \Big/ X_j^0} \quad (5)$$

where P_j^1 and P_j^0 represent the probability of choosing to transport alternative j (landbridge or direct service) after and before considering a marginal increase in attribute X_j. The cross elasticity represents the percentage change in the probability of choosing the alternative when marginal changes in the attributes of the other alternative are considered. A positive sign is expected for all cross elasticities. The cross-elasticity expression is the following:

Table 5
Variables considered in the estimation.

ATTRIBUTES	DEFINITION	UNIT	EXPECTED SIGN
COST	Cost of the IRL port – EU port transport section	Euros/ Shipment	Negative
TIME	Transit time between the IRL port and the EU port	Hours	Negative
DELAYS (%)	Probability of suffering a significant delay	Percentage	Negative
DELAYS (M)	Hours of delay with respect to the initially agreed delivery time	Hours	Negative
WAIT	Waiting hours with respect to the preferred departure hour	Hours	Negative
SME	1 if the number of employees is less than or equal than 250	Dummy	
TOP3	1 if the firm outsources transport operations to a road haulier directly	Dummy	

Table 6
Estimation results, MNL and LCM.

Attribute	MNL		Class 1		Class 2	
	Estimate	*t*-test	Estimate	*t*-test	Estimate	*t*-test
Cost	−0.00296	−6.93	−0.0035	−5.13	−0.0015	−1.00
Transit time	−0.03786	−6.04	−0.0296	−3.65	−0.0589	−3.17
Delays (%)	−0.09347	−1.12	−0.1094	−1.02	−0.0142	−0.05
Delays (M)	−0.08891	−2.47	−0.0533	−1.23	−0.3211	−2.12
Wait	−0.02216	3.86	−0.0086	−1.11	−0.0697	−3.18
Membership class	–	–	0.6390		0.3610	
Class Probability						
Constant	–	–	−1.3934	−1.41	–	–
SME	–	–	1.8892	2.07	–	–
Top3	–	–	1.8809	1.94	–	–
McFadden Pseudo R2	0.0606		0.2811			
Final Log Likelihood	−357.6444		−299.00125			
Observations	600		600			
Individuals	50		50			
AIC[a]	–		1.0500			
BIC[a]	–		1.1673			
HQIC[a]	–		1.0956			

[a] Standardised by number of observations.

$$\varepsilon_{jk} = \frac{\left(P_j^1 - P_j^0\right) / P_j^0}{\left(X_k^1 - X_k^0\right) / X_k^0} \tag{6}$$

The elasticities[8] are obtained for each class and only for those attributes that were significant. As expressions (5) and (6) represent elasticity values at the individual level. Values are calculated at the individual level and aggregated by sample enumeration (Ortúzar & Willumsen, 2011). All elasticities are less than one (in absolute value) which indicates that the demand for the given alternative is relatively inelastic. This means that a given change in one of the attributes results in lower than proportional changes in the choice probability.

Overall, firms under Class 1 are very sensitive to changes in cost. The marginal effect of cost reductions along direct routes on the estimated demand is very similar to the marginal effect of cost increases along the UK landbridge route, i.e. 0.702 vs. 0.796. However, in terms of transit times, Class 1 firms are more sensitive to improvements in transit times along direct routes than deteriorations in transit times along the UK landbridge. This has implications in terms of the expected impact of custom check points on transit times and the potential effect of faster services along direct routes.

Conversely, firms in Class 2 are very sensitive to improvements in the level of service – delays and frequencies – along direct routes and less sensitive to reduced levels of service - transit times, frequencies and delays – along the UK landbridge. These firms are likely to be less sensitive to the effect of Brexit over the current service supply along the landbridge. In other words, a decline in the level of service derived from Brexit is likely to have a lower impact on modal shift than an improvement in the actual level of service along the direct routes.

Results from Table 8 are in line with the elasticities reported by Vierth et al., 2017 in their extensive review of factors influencing firms' modal choice. However, they need to be taken with caution. The nature of the choice experiment presented here implies that there may be some level of status-quo bias, which is a well-documented phenomenon in individual decision making (Ben-Akiva et al., 1991; Meyerhoff & Liebe, 2009). From this perspective, the direct a cross elasticities outlined

Table 7
Class characterisation by socio-economic variable.

	Class 1		Class 2		Total Sample	
	TOTAL	%	TOTAL	%	TOTAL	%
Firms	32	64%	18	36%	50	100%
Index of Unitary Value (IUV)						
IUV LOW (<50 €/kg.)	28	88%	10	56%	38	76%
IUV HIGH (≥50 €/kg.)	4	13%	8	44%	12	24%
Size of the enterprise						
if the number of employees is less than or equal than 250 (SME)	25	78%	7	39%	32	64%
if the number of employees is greater than 250	7	22%	11	61%	18	36%
Traffic with United Kingdom	22	69%	12	67%	34	68%
if the firm carry out their own transport operations	2	6%	2	11%	4	8%
If the firm outsources transport operations to a freight forwarder	19	59%	14	78%	33	66%
If the firm outsources transport operations to a road haulier directly	20	63%	5	28%	25	50%
Main destination						
France	8	25%	5	28%	13	26%
Germany	15	47%	7	39%	22	44%
Belgium	2	6%	2	11%	4	8%
Netherlands	6	19%	4	22%	10	20%
Other destinations	1	3%	0	0%	1	2%

Table 8
Direct and cross elasticities.

Direct Elasticity	Landbrigde MNL	Class 1	Class 2	Direct Service MNL	Class 1	Class 2
Cost	−0.451	−0.796	–	−0.411	−0.702	–
Time	−0.080	−0.097	−0.056	−0.181	−0.215	−0.126
Delays (%)	−0.062	–	–	−0.060	–	–
Delays (M)	−0.588	–	−0.096	−0.523	–	−0.103
Waiting Time	−0.012	–	−0.017	−0.076	–	−0.092
Cross Elasticity	**Landbrigde**			**Direct Service**		
	MNL	**Class 1**	**Class 2**	**MNL**	**Class 1**	**Class 2**
Cost	0.411	0.702	–	0.451	0.796	–
Time	0.181	0.215	0.126	0.080	0.097	0.056
Delays (%)	0.060	–	–	0.062	–	–
Delays (M)	0.523	–	0.103	0.588	–	0.096
Waiting Time	0.076	–	0.092	0.012	–	0.017

[8] The elasticity measure is weighted by the probability of the alternative and it is not computed at the sample means of the attributes.

above should more accurately be considered as natural lower limits for elasticities.

Overall, the estimation results presented above provide a further insight into the demand side for maritime transport services in Ireland. This is relevant in the context of the potential reconfiguration of strategic maritime routes from Ireland into mainland Europe. The wider implications of these are discussed in the next section.

5. Discussion and policy implications

With the recent withdrawal of the UK from the European Union, there is an increasing agreement among industry, policy makers and academia that there will be significant structural changes in the way Ireland will export its goods to Europe in the future. On December 31, 2020, the Brexit transition period comes to an end and the additional customs and other checks on goods going to, from or through the UK will come into place. This is expected to bring delays and congestion to the UK landbridge for trade goods with continental Europe. There is a great level of uncertainty regarding whether there will be a trade agreement adopted through UK/EU negotiations. Depending on the outcome of negotiations, the potential impact of Brexit on the Ireland's demand for shipping services to mainland Europe may vary significantly. While the UK landbridge is still the most preferred alternative for most exporters, many will inevitably start using new direct routes to the continent.

This research has identified two different types of exporters, depending on their valuation of key transport attributes such as cost, transit time and level of service – frequency and delays – and has provided a quantitative insight into how changes in these attributes will impact exporters' demand for maritime transport services. On the one hand, exporters under Class 1 are fundamentally driven by cost and transit times and would be likely to switch routes from the UK land bridge to direct services with increases (reductions) in the cost of the land bridge (direct services) and improvements in transit times along direct routes. One the other hand, exporters classified under Class 2 are mostly concerned about attributes related to the level of service such as frequency and delays. Initiatives aimed at improving these attributes along direct routes would have a significant effect in increasing the demand for direct services among Class 2 exporters.

A key question remains as to the extent to which new direct services will be able to adjust to the existing requirements from customers used to highly competitive levels of service along the pre-Brexit UK land bridge route. In this sense, a major determinant is the type of service offered – roll-on/roll-off (RORO) vs lift-off/lift-on (LOLO). Section 2 showed that the levels of service offered by LOLO and RORO differ in terms of transit times and frequencies. Therefore, the potential demand for each of these services will depend on how sensitive users are with respect to these attributes, which is precisely what we have reported in the paper and the main contribution of the research.

Regardless of the effects that increasing costs or transit times have on the demand for maritime transport services, the expected maritime freight route re-assignment that has been identified in previous research (Vega et al., 2018) is already happening with increases in capacity along continental routes by key industry players (IMDO, 2019). A recent report by the IMDO on Ireland's maritime connectivity concluded that there is enough capacity on existing continental (direct) services to accommodate displaced landbridge traffic (IMDO, 2020). Additional infrastructure funding has already been directed to Irish ports to accommodate increases in demand to mitigate congestion associated with new customs check points delays. However, there is an over-reliance on Dublin Port[9] for connectivity with the UK remains a challenge in this context. Further development of other strategic ports along Ireland's East coast is expected to assist in reducing congestion in Dublin and facilitating new routes to continental Europe (Seanad Special Committee, 2019).

The wider implications of a potential further increases in demand for direct services relate to the transformation of the traditional Irish freight transport business model based on the use of road transport to export goods to the continent - with mainly two short maritime crossings to/from the UK - into an fully integrated intermodal maritime freight transport system. This impact on the structure of Ireland's freight transport supply to the continent will also have deep implications for the Irish haulage sector and for Ireland's transport policy in general.

In particular, the impact on the Irish road haulage sector as a result of these changes in demand will depend on the growth of market share by type of direct services offered – RORO vs LOLO. In the case of a new maritime intermodal business model based on LOLO, the effect on the road haulier could be extensive, as they would no longer be the main transport provider and their role would be limited to haulage activities at loading ports. Recent developments from the supply side suggest that this case would be unlikely as growth in direct continental services are primarily in the RORO/ROLO market, as indicated in Section 2.

On this regard, the discussion focuses on the transport option promoted from a RORO perspective and whether this is accompanied or unaccompanied.[10] Previous research has acknowledged that the option of accompanied RORO requires less organisational and structural changes for the traditional transport provider or road haulier, allowing for a gradual integration into Short Sea Shipping (SSS). In fact, the transition from a traditional road haulier business model to an unaccompanied intermodal RORO transport provider requires deep adjustments in terms of fleet, staff and logistics management at the destination (see López-Navarro & Rodríguez-Artola, 2010; López-Navarro et al., 2013 for a detailed review of the process of adjustment from traditional road hauliers to SSS). The cost associated with these adjustments can be particularly high for small to medium road hauliers. Despite this, studies have shown that in the medium to long-term, greater cost effectiveness is obtained in unaccompanied RORO (Setra, 2007; Valenciaport Foundation, 2005). Therefore, in the case of severe transport restrictions across the UK land bridge, transport providers would be expected to gradually move away from accompanied RORO services. According to the results obtained by López-Navarro et al. (2013), the establishment of long-term relationships between international road transport providers and shipping companies is a crucial aspect to ensure an efficient transition from an accompanied to unaccompanied transport model.

The development of maritime services between Turkish ports and the port of Trieste during the 1990s offers an interesting analogy with the discussion here. Started in 1987 by the Turkish State Merchant Shipping Company, the initiative was later expanded by the non-profit Turkish International Transport Association (UND). In 1992, the UND with the direct financial support of its members - road and transport hauliers – decided to independently manage several Ro-Ro vessels on the above routes. The initial idea was to avoid the border crossing into Bulgaria, which resulted in long and uncertain journey times, and to bypass the dangerous Yugoslav territory by sea. While the service was initially set up to overcome the loss of competitiveness by Turkish exporters to Germany as a results of the Balkan wars, the increasing success of the service allowed the UND shipping companies to broaden their services, which currently offers seven services between Turkey and the ports of Trieste and Bari (Italy), Patras (Greece) and Toulon (France). The unique aspect of these new Ro-Ro services - where the ultimate owners were the road hauliers - is that they evolved from accompanied to unaccompanied

[9] Over 90% of all trade with the UK transits via Dublin Port.

[10] Accompanied freight goods are transported to and from the ferry the same driver, generally providing a faster and more flexible service. In contrast, unaccompanied implies that the freight goods are dropped off by the driver at the domestic port and travel by ferry to the destination port where a different driver collects the goods to the final destination. Unaccompanied RORO is generally more competitive over longer distances and it is currently the predominant type of service offered in direct routes from Ireland to continental Europe.

Ro-Ro services over time. Thus, improving cost effectiveness and overall competitiveness due to economies of scale.

Regardless of the increased cost effectiveness that unaccompanied RORO services would bring to road hauliers over time, there are significant economies of scale associated with the size of the transport provider (Valenciaport Foundation, 2005). Given the predominance of small and medium road hauliers in Ireland, it is expected that the road transport providers that will benefit the most from this new freight transport business model will be the larger operators. This imbalance in the impact of these effects across freight transport operators constitute a key challenge for national and European transport policy makers and the future of the indigenous haulage industry in Ireland. Policy initiatives such as the Ecobonus/Marebonus in Italy (see Med-Atlantic Ecobonus project, 2014-EU-TM-0544-S for details), which includes supports for industry and cargo consolidation across small operators, can be effective on this regard. The most recent reports from the IMDO indicate that since the outbreak of the Covid-19 Pandemic and the imposition of travel restrictions, there has been a noticeable shift in the Ro/Ro sector to the unaccompanied mode (IMDO, 2020).

Overall, this research presents a further quantitative and strategically relevant insight into maritime freight transport demand in Ireland. The paper aims at informing policy makers of the potential implications and challenges ahead of a changing freight transport business model both for exporters and transport operators. The level of uncertainty associated with the UK/EU trade deal negotiation process may result in unforeseen effects beyond the variables considered in this analysis. Further research would be needed to assess future scenarios with more detailed data from the demand side, including sectoral effects, and industry-specific analysis from the supply side. From a transport policy perspective, finding alternatives to Ireland's reliance on the UK land bridge is a key priority. A better understanding of shippers' route preferences from Ireland to continental Europe is an important aspect in the formulation and assessment of future transport policy at the national and European level.

CRediT authorship contribution statement

Amaya Vega: Funding acquisition, Conceptualization, Project administration, Methodology, Investigation, Writing - original draft, Writing - review & editing. **Maria Feo-Valero:** Data curation, Methodology, Conceptualization, Investigation, Formal analysis, Writing - review & editing. **Raquel Espino:** Investigation, Formal analysis, Software, Methodology, Writing - review & editing.

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