Panama Canal vs alternative routes: estimating a logit model for grains

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Abstract

Purpose – The purpose of this paper is to fit a logit model for dry bulkers transporting grains through the Panama Canal versus alternative routes destined to East Asia, originating on the US Gulf and East Coast. This is with the purpose of better understanding the attributes.

Design/methodology/approach – In this paper, grain transits both through the Panama Canal and alternative routes, which are examined, and a logit model is developed to explain the route decision from a carrier/vessel operator point of view.

Findings – Transit draft is the most important attribute in the route decision process for grains according to this study. Also, Panamax bulkers are the preferred vessel size into China, especially through the Cape of Good Hope route, impacting Panama Canal's market share for grains.

Research limitations/implications – This research used only a full year of grain traffic data approximating fiscal year 2018 (October 1, 2017 to September 30, 2018). Data will come mostly from the Panama Canal transit data and observations using IHS's Market Intelligence Network (MINT).

Originality/value – This paper is highly dependent on visual observations of grains vessels through alternative routes using AIS data from MINT software.

Keywords East Asia, Panama Canal, Logit model, Cape of Good Hope, US Gulf and East Coast, Dry bulker, Automated identification system (AIS), Grains

Paper type Research paper

1. Introduction

After the expansion of the Panama Canal on June 26, 2016, the waterway was able to attract larger ships such as containers, tankers, liquefied natural gas (LNG), liquefied petroleum gas (LPG), passenger and dry bulk vessels, among others, to take advantage of the economies of scale provided by the Neopanamax locks. In terms of the dry bulk segment, the goals of the Panama Canal system – including both the Neopanamax and the Panamax locks as a whole – were to consolidate coal traffic, recuperate iron ore flows, serve ballast transits and maintain market share for the grain movements, especially from the US East Coast and Gulf to Asia, the main grain route for the waterway. In the past two fiscal years, that is, fiscal years 2017 and 2018, the Panama Canal has witnessed an increase in coal and coke flows – including petroleum coke, reaching 23.0 million long tons in fiscal year 2018, very close to 23.9 million long tons registered in fiscal year 2013. The increase in coal and coke traffic is mainly due to the expansion of the interoceanic

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waterway[1]. On the other hand, iron ore has not been able to reach its highest numbers of the past 10 fiscal years because of Oldendorff¨s top off operation in Point Lisas, Trinidad, which loads ores from smaller feeder vessels into large Capesize ships drafting around 18 meters[2]. Those Capesizes head to Asia through the Cape of Good Hope. With regard to grains traffic, this has not recovered since the 52.3 million long tons record registered in fiscal year 2015 and has been on a declining trend – even with the expanded Canal – posting just 27.8 million long tons in fiscal year 2018.

Following declining movements of grains through the waterway between fiscal years 2016 and 2018, mirrored in the very important East Coast USA – Asia grain route but not in most of the other smaller routes[3] (Figure 1), the Panama Canal Authority is exploring the reasons for this decline in grains flows, especially grain traffic mostly through the Cape of Good Hope route as the main alternative bypass to the Panama Canal. What are the factors that negatively impact grain flows through the Panama Canal, the Neopanamax locks notwithstanding? Specifically, what are the most important attributes considered in the decision by a carrier/vessel operator to use either the Panama Canal route or alternative bypass routes for grains, assuming origination on the US East Coast and Gulf? Trying to answer the questions, this study will attempt to fit a logit model for dry bulkers transporting grains through the Panama Canal versus alternative routes destined to Asia, -specifically East Asia-, originating on the US Gulf and East Coast, pursuing to identify relationships with several explanatory variables, such as total Panama Canal costs, –including pure tolls and other charges-, transit draft, Canal Water Time, bunker price and timecharter rates. The answer to this question is key, given the importance of the grain flow to the dry bulk segment of the Panama Canal, which represents on average close to 40 per cent of total dry bulk cargo in the past 10 years and around 31 per cent of total dry bulks revenue in the same period. This paper aims to provide the first insights in the decision making process regarding market share for grains and the optimal utilization of the Panama Canal system. The ensuing logit model developed for this research could be used to understand the odds of grains vessel originating on the US Gulf and East Coast to East Asia transiting the Panama Canal and will be part of the discussion regarding future market share for grains at the waterway.

This paper will first review the past literature on discrete choice models applied to transportation research, then will describe the data for the study, later will include

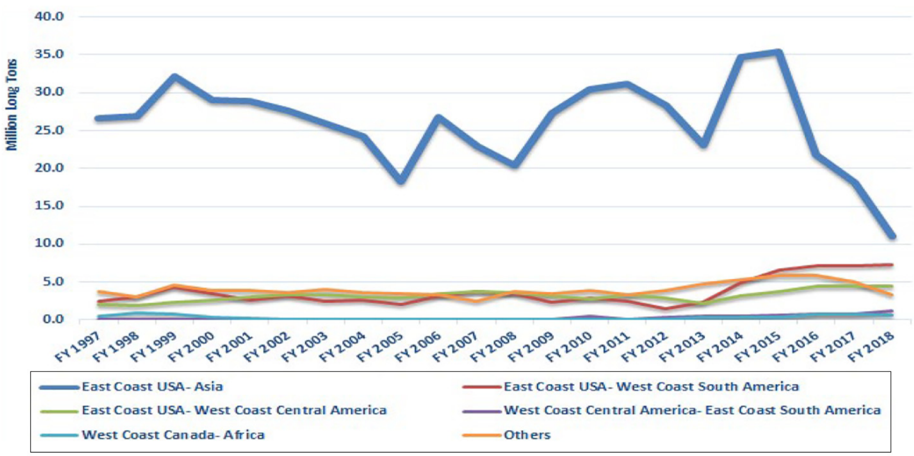


Figure 1.
Main grains routes through the Panama canal

Source: Panama Canal internal database descriptive statistics, assumptions and methodology, model specification assuming a carrier/vessel operator¨s perspective, and finally the discussions and conclusions focused upon the Panama Canal. From the beginning, the route choice for grains from the US Gulf and East Coast to East Asia involves either the Panama Canal or mostly the Cape of Good Hope as bypass route. For purpose of this study, we will analyze the traffic of grains from July 1, 2017 to September 30, 2018[4]. Data will come mostly from the Panama Canal transit data, visual tracking using IHS's Market Intelligence Network (MINT) and Panama Canal subscriptions.

Given our preference and because we are interested in calculating the probability of grains transits through the Panama Canal versus alternative routes – in this case our binary dependent variable is 1 if transiting the Panama Canal, 0 otherwise – the choice of a logit model is more appropriate compare to a Linear Probability Model to avoid the problem of unbounded probabilities. On the other hand, the logit has an easier interpretation than the probit model because logit is interpreted in terms of the log of odds ratio[5].

2. Literature review

Based upon our literary review, discrete choice models, especially logit and probit models, are widely used in the field of transportation studies, including mode of transportation and route choices. However, according to Shen and Wang (2012), the discrete logit model is the prevalent methodology in transportation research. In the case of modal choice of transportation, several studies can be mentioned dealing with binary choices between two alternatives, such as the works by Surbakti and Bombongan (2017), Manssour *et al.* (2013), Wojcik (2017), Guoqiang (2012) and Regianni *et al.* (1997). Those studies were related to the binary choice of ground transportation such as car/bus, rail/truck, bus/train or public/private transportation. In terms of models with more than two choices (multinomial), we may include the works by Manssour *et al.* (2013), Hussain *et al.* (2017) and Chang and Lu (2013). Most of these studies involves using survey data and publicly available transportation databases, and were performed to improve mobility, understand patterns of transportation and to project future demand for transportation modes.

Related to vessel tracking, vessel movement data from AIS (Automated Identification System) is an important tool in the navigational and operational processing of vessels. AIS primary purpose is to facilitate voyages and to allow ships to be identified by others for safety and security reasons. On the other hand, a secondary use of AIS data has involved making AIS data publicly available on the Internet, such as a Marine Traffic tool[6]. AIS aggregated data includes ship name, position, speed and direction[7]. This information is global, searchable and could be displayed on a map through a computer screen. However, the most important characteristic, – from the point of view of a researcher–, is that this information can be stored and later retrieved. Tu *et al.* (2017) list commercial data providers and free data sources. Examples of studies using AIS data for visualization of trade patterns and for understanding it include Fiorini *et al.* (2016), Anderson and Ivehammar (2016) and Wu *et al.* (2017). These works, although very technical in terms of data collection, describe a procedure for displaying AIS data to obtain traffic density information and aim to achieve route optimization through route planning. Fiorini *et al.* (2016) explains that every 6 min the AIS transmitter sends information on vessel name, IMO number, vessel type, draft and destination, among others. These are important pieces of information to understand given that IHS's MINT, – our main tool for tracking dry bulkers with grains bypassing the Panama Canal for this study, is based upon global AIS network and permits real-time visualization of vessels plus historical positions[8]. The historical position allows to register origin and destination of ships, therefore the generation of vessel routes for our research.

Previous studies applied in the maritime transportation and involving route choices include the works by Schøyen and Bråthen (2011), Shibasaki *et al.* (2016), Shibasaki *et al.* (2017) and Shibasaki *et al.* (2018). Several of those investigations covered alternative routes to the Panama Canal, such as the Suez Canal and the Northern Sea Route, focus on the savings in terms of energy efficiency and applied the use of vessel movement databases for container, dry bulkers and LNG vessels. Specifically, both Shibasaki *et al.* (2016) and Shibasaki *et al.* (2017) applied an aggregated logit model to describe route choice behavior for container and dry bulk vessels, respectively. On the other hand, Wilson and Ho (2018) wrote about the historical commodity traffic through the Panama Canal and provided examples of voyage calculations for several market segments, including grains, comparing the Panama Canal with the Cape of Good Hope route. Finally, the work by Bai and Siu (2018) on a destination choice model for very large gas carriers (VLGC) originating on the US Gulf applied a logit model that is much related to the purpose of our study. In a nutshell, the literature review highlighted the widespread use of logit models in maritime transportation, emphasized the growing importance of AIS related data and tools in route choice models such as our research and brought home the usefulness of this type of investigation for the Panama Canal business. Therefore, following the same line of thought from past literature works, our paper will make a contribution to choice behavior by individual vessels, but will narrow down into the Panama Canal's main grain route: US Gulf and East Coast to East Asia. Hopefully, it could become the starting point for further research for other routes and vessel types for the Panama Canal, including the growing utilization of AIS information in route choice modelling.

3. Data for the study

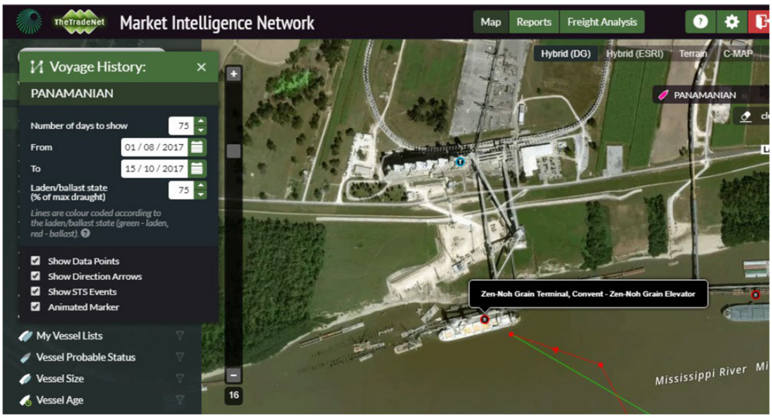
For the study, it was necessary to collect data for grains transiting the Panama Canal originating in the US Gulf and East Coast destined to East Asia, grain flows using alternative routes from the same origin and destination route and data on bunker prices and timecharters from Panama Canal subscriptions such as Clarksons[9]. Firstly, Panama Canal data was collected from internal data sets[10]. This data included, -but not limited to-, IMO number of the vessel, ship name, transit date, transit draft (converted to meters), Panama Canal costs (pure tolls + other income amount), summer loaded deadweight (DWT), Canal Water Time (CWT) as well as information related to the amount of cargo, cargo type description and vessel origin and destination (including ports). The information on cargo type, as well as the "Dry Bulk Cargo Type" and "Harmonized Code" fields, ensured the proper classification of grain transits through the waterway. At the same time, vessel origin and destination from Panama Canal data provided the information to select only transits from the US Gulf and East Coast to East Asia. With respect to grain transits in the route using the Neopanamax locks, only two transits were reported for these locks during the period, meaning 293 transits out of a total of 295 transits used the Panamax locks.

Secondly, data for grain transits bypassing the Panama Canal using mostly the Cape of Good Hope route was based upon live, regular visual tracking using IHS's MINT tool and Marine Traffic[11], cross-checked with information from vessel departures by port region from MINT. The visual observations of grains bypassing the Panama Canal in favor of alternative routes using MINT provided data on the ship name, IMO number, deadweight (DWT), departure date, transit draft and grain port of origin and destination but did not include any information about commodities or cargo tons. For purpose of the transit draft and port of origin and destination, it was necessary to do a complete tracking of each departing vessel out of the US Gulf and East Coast headed into East Asia to check transit draft and final route chosen (Figure 2). For example, most of the time MINT and Marine

Source: IHS Markit

Figure 2. Example of vessel tracking using Market Intelligence Network (MINT)

Traffic displayed Singapore as the final destination for grain-carrying vessels headed into East Asia and provided outdated draft information, therefore making necessary to follow up each vessel to assure the correct and updated information during the trip and afterwards using the historical tracking capability of MINT. Also, the final revision of port of origin and/or destination provided us with the final information to decide whether or not a dry bulker was transporting grains. In other words, MINT has a feature that allow us to identify the name of the grain elevators[12] (Figure 3). However, our current MINT subscription does not provide information about the cargo type or lot size of each shipment, especially for the case of alternative routes. On the other hand, official grain inspections for exports must be performed by the Federal Grain Inspection Service (FGIS), a part of the Grain Inspection Packers and Stockyards Agency (GIPSA), an agency of the US Department of Agriculture. GIPSA and private shipping agencies such as Blue Water Shipping clearly name and identify the approved and grain dedicated export elevators in the US, therefore providing



Source: IHS Markit

Figure 3. Example of export grain elevator identification using Market Intelligence Network (MINT)

comprehensive information and knowledge for the identification of dry bulkers with grains for our research. It is important to highlight that export elevators are operated by large grain traders such as Cargill, ADM, Zen Noh, CHS, Bunge and Louis Dreyfus.

Thirdly, both Panama Canal and alternative routes grain transits were assembled together into a unified database for this research, totaling 527 observations: 295 Panama Canal grains transits (56 per cent) and 232 bypass transits (44 per cent). It is important to mention that only one grain transit bypassing the Panama Canal used the Suez Canal, that is, out of a total of 232 bypass grains transits, 231 transits used the Cape of Good Hope route, meaning this is the main alternative bypass route for grains headed into East Asia. Also, all vessels using alternative routes involved Panamax vessels above 74,000 DWT and drafted at least 12.5 meters. Likewise close to 90 per cent of grain transits bypassing the Panama Canal, that is 207 transits, had China as the final destination[13]. In other words, the Panama Canal had a market share of 25.3 per cent of all dry bulkers transits with grains from the US Gulf and East Coast to China between July 1, 2017 and September 30, 2018. Finally, for the unified database we included weekly data on the price of IFO 380 cst Houston bunker price and 1-year timecharter for a 75,000 DWT dry bulk vessel from Clarksons, along with weekly Canal Water Time from Panama Canal internal database. As mentioned before, the period for the study covered grains transits from July 1, 2017 to September 30, 2018, with the purpose of also including the odds of wheat transits because the wheat marketing year runs from June 1 of the previous calendar year to May 31 of the next calendar year.

4. Descriptive statistics, assumptions and methodology

4.1 Descriptive statistics of data

The following statistics provide a quick glimpse of the data used for this study and represent the first insights about the decision making by carriers/vessel operators in selecting a particular route for grains from the US Gulf and East Coast to East Asia. Here, we include the average vessel size, transit drafts and total canal costs for the full sample data, Panama Canal route and alternatives, as well as statistics for weekly data for bunker price and 1-year timecharter between July 1, 2017 and September 30, 2018 (Tables I and II). These statistics, plus the results from the logit model, are important inputs for the conclusions and possible recommendations out of this research.

In terms of vessel sizes, we noticed that grain flows from the US Gulf and East Coast to East Asia using alternative bypass routes to the Panama Canal- mainly the Cape of Good Hope- preferred Panamax ships in the DWT range between 70,000- 79,999 DWT and 80,000- 89,999 DWT (Figure 4). On the other hand, grains transits through the Panama Canal concentrated mostly on Supramax (50,000- 59,999 DWT), Ultramax (60,000- 64,999 DWT) and, to a lesser extent, on Panamax ranges (70,000- 79,999 DWT and 80,000- 89,999 DWT – Figure 5)[14]. Larger ships on the longer alternative route are key in terms of economies of scale and greater revenue from the carrier/vessel operator¨s point of view. Also, given the fact that close to 90 per cent of alternative route transits had China as final destination, this may be an important preliminary attention getter in terms of Panama Canal strategy. Concerning bunker price and timecharter, both variables presented an upward trend during the research period (Figures 6 and 7), depicting a relatively constant recovery path from their lowest point during the time frame of the investigation.

According to our statistics collected for the study of the US Gulf and East Coast to East Asia route, the monthly grouped data for dry bulkers with grains reflects the seasonality of the grain trade from the USA (Figure 8). When the new crops are harvested in the USA, exports of grains peak between September and February of the marketing year[15], then tapers off for the rest of the marketing year, coinciding with the beginning of the competing

	Full sample	Panama Canal Route	Alternative route
Number of transits	527	295 (56%)	232 (44%)
Vessel size – DWT			
Mean	69,941	61,945	80,107
Standard deviation	11,524	9,196	3,055
Highest/lowest value	93,249/29,231	83,610/29,231	93,249/74,117
Transit draft – meters			
Mean	12.60	11.83	13.58
Standard deviation	0.95	0.43	0.28
Highest/lowest value	14.30/5.82	13.72/5.82	14.30/12.50
*Total canal cost**			
Mean	$211,459.40*	$187,249	$242,244*
Standard deviation	$32,145.75*	$22,526	$2,626*
Highest/lowest value	$250,331/$99,983*	$245,074/$99,983	$250,331/$236,936*

Sources: MINT and Panama Canal. Processed by authors; *includes theoretical tolls for alternative routes vessels

Table I. Descriptive statistics for grain transits: full sample, Panama canal and alternative routes

Variable	Statistics
Weekly IFO 380 cst Houston (S/ton)- mean/standard deviation	$366.24/$53.94
Highest/Lowest Value	$447.50/$255.00
Weekly 1-year timecharter 75 K Panamax ($/day)-mean/standard deviation	$12,476.75/$1.065.02
Highest/Lowest Value	$14,500/$9,850

Source: Clarksons

Table II. Descriptive statistics of weekly bunker price and one-year timecharter (07/01/2017 to 09/30/2018)

South America grain harvest[16]. Regarding the imports of grains by China from the USA – especially soybeans, a similar seasonality occurs: China imports lots of grains from the USA between September and February of the marketing year, then importing to a nil as a consequence of the new South America crop (Figure 9). In both cases, however, the Panama Canal market share reaches its lowest values at the high of the US grains exporting season for the period of the study, a fact to keep in mind during the evaluation of recommendations for the grain trade.

Finally, we are including statistics related to the main Chinese grains imports terminals with transits both through the Panama Canal and alternative bypass routes (Table III), given the fact that close to 90 per cent of panamax vessels bypassing the Panama Canal were headed to a Chinese terminal. The table yields summarized information regarding the vessel sizes that calls at each Chinese terminals, as well as information about the geographical location of each of them. This is important complementary information to better understand the Chinese grain port system and for future research.

4.2 Assumptions and methodology for the study

Because this study is assuming the point of view of a carrier/vessel operator time chartering a dry bulker for business, the main attributes to consider for our logit model will include Panama Canal cost (pure tolls + other income amount)[17], Canal Water Time (CWT), bunker price (IFO 380 cst Houston), 1-year timecharter for a 75,000 DWT dry bulker and

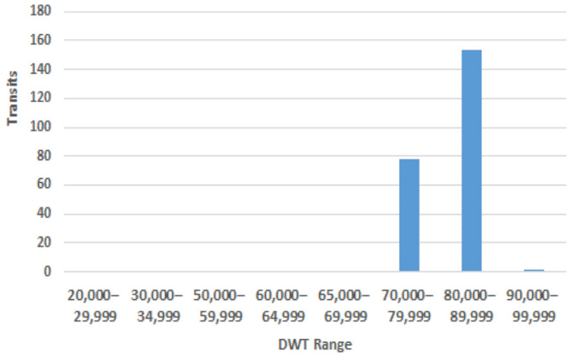


Figure 4.
Alternative routes grain transits by DWT ranges

Source: MINT. Ranges from Clarksons. Processed by authors

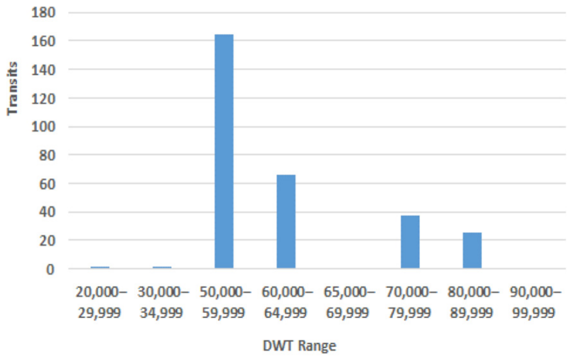


Figure 5.
Panama canal grain transits by DWT ranges

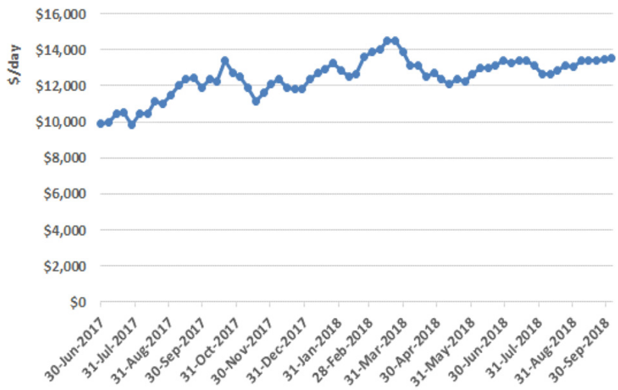
Source: Panama Canal. Ranges from Clarksons. Processed by authors

draft for both Panama Canal and Alternative Route transits. Based only upon voyage calculations, the higher the fuel price and timecharter, the higher the cost of transiting the longer, alternative bypass route, therefore favoring the shorter Panama Canal route – *ceteris paribus*. Also, the higher the Canal Water Time, that is, the higher the summation of waiting time before transit plus the actual transit time, the most likely a dry bulker will try an alternative bypass route to the waterway. With this in mind, we assumed the use of IFO 380 cst Houston as the bunker reference for the US Gulf and East Coast given the availability of this price in our subscriptions and because it is a good bunker price reference for the region. In terms of the value of time for a carrier/vessel operator, the use of timecharter, in this case 1-year timecharter for a 75,000 DWT Panamax dry bulker, is assumed given that all real transits using alternative routes in our study involved Panamax vessels above 74,000 DWT. This timecharter information is readily available in our subscription with Clarksons.

Further explaining our selection of independent variables, the choice of bunker prices is based upon voyage cost calculation by a vessel operator in the route decision process, and it

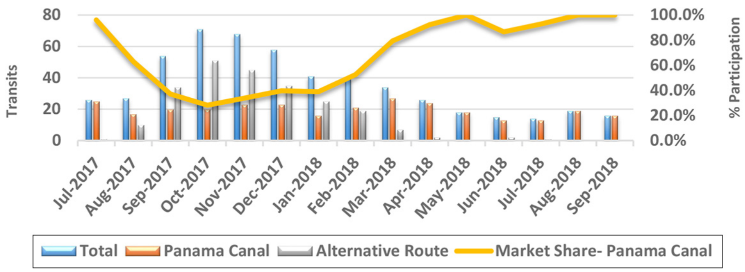
Source: Clarksons

Figure 6.
Weekly IFO 380 cst Houston



Source: Clarksons

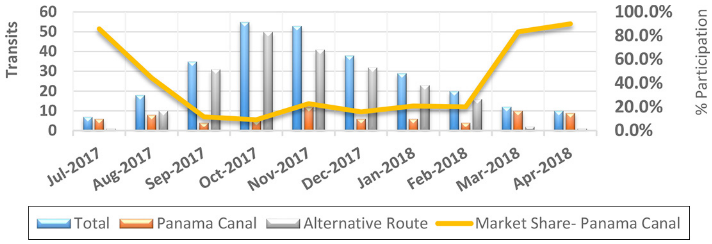
Figure 7.
Weekly 1-Year Timecharter for 75,000 DWT Bulker



Source: Mint. Processed by authors

Figure 8.
Monthly total dry bulker grain transits

is an important component of total voyage cost that must be taken into consideration. On the other hand, timecharter represents the hiring cost per day of a vessel during a trip, which represents the opportunity cost of a vessel in terms of time that must be considered in a voyage calculation. Likewise, Canal Water Time represents time at Panama Canal¨s water and a proxy for congestion: the higher the Canal Water Time before time of departure from origin port, the higher the possibilities of delays at the Panama Canal in favor of alternative routes, therefore it is an important consideration in the decision whether or not to transit the Panama Canal. At the same time, transit draft represents a proxy for the amount of cargo by a grain vessel. The higher the draft, the higher the amount of cargo a grain vessel is transporting. The draft component is critical, especially when draft is greater than 12.04 meters, the maximum draft allowed at the Pananamax Locks. If draft is greater than 12.04 meters, grain vessels will need to consider either the Neopanamax locks or the alternative route. Finally, transit cost through the Panama Canal needs to be included in the analysis to check whether Panama Canal tolls are an important factor in the voyage route decision.



Source: Mint. Processed by authors

Figure 9.
Monthly total dry bulker grain transits to China

Table III.
DWT Ranges in main Chinese grains terminals- Panama canal and alternatives (representing about 85% of total Panama canal and alternative routes)

Port	Region	No. of arrivals	Highest/lowest DWT
Laotangshan	Center	30	84,860/ 60,498
Tianjin	North	22	83,416/ 52,454
Qingdao	North	21	87,306/ 56,155
Nansha	South	17	82,986/ 55,618
Guangming	Center	15	83,480/ 55,303
Dalian- Beiliang	North	14	83,448/ 63,250
Shanghai	Center	14	74,456/ 58,518
Fangcheng	South	12	93,249/ 75,700
Longkou	North	12	84,790/ 74,483
Dongguan	South	11	81,600/ 54,881
Nantong	Center	11	80,204/ 55,541
Rizhao	North	10	82,774/ 63,414
Tienshan	South	10	84,808/ 63,507
Xinsha	South	10	83,690/ 74,716
Xiuyu	Southeast	8	82,177/ 74,133
Xingang	South	7	81,533/ 52,382
Chiwan	South	6	82,025/74,117
Lianyungang	North	6	82,171/ 75,395

Source: MINT

In general terms, assuming a carrier/vessel operator n at time t faces j mutually exclusive destinations, then the carrier/vessel operator chooses the destination with the highest utility, that is, the alternative bearing the highest attractiveness[18]. The utility level from a destination choice j at time t for carrier/vessel operator n can be determined by the following utility function:

$$U_{tjn} = V_{tjn} + \varepsilon_{tjn} \tag{1}$$

where V_{tjn} is deterministic, known to the researcher from both observed attributes of the destination X_{tjn} and observed attributes of the decision maker S_{tjn} (Chang and Lu, 2013 and Bai and Siu, 2018). V_{tjn} is called representative utility and is denoted by $V_{tjn} = f(X_{tjn}, S_{tjn})$. On the other hand, ε_{tjn} is not observable; therefore, the carrier/vessel operator destination choice cannot be predicted with certainty, and it is a random component of a carrier/vessel operator's utility function for destination choice j at time t. According to Chang and Lu (2013), representative utility is assumed in a linear and additive function such that:

$$U_{tjn} = \sum_{k}^{N} \beta_k X_{tjnk} + \varepsilon_{tjnk} \tag{2}$$

where X_{tjnk} is the k^{th} observed attribute of destination j at time t for carrier/vessel operator n. The term β_k represents the coefficient of the k^{th} observed attribute X_{tjnk}.

The odd that a carrier/vessel operator n at time t chooses destination j given k attributes is:

$$P_{tjn} = \frac{e^{V_{tjn}}}{\sum_{n=1}^{n} e^{V_{tjn}}} \tag{3}$$

In this research, given that i represents an individual transit, our logit model will take the following general form:

Name of the OMS charge	Amount
PCSOPEP charges	$525.00
Safety and security charge	$1,000.00
Line handling services	$2,600.00
TVI inspection	$118.00
Tugboat services	$17,000.00
Total	$21,433.00

Source: Panama Canal

Table IV. Basic components of other marine services (OMS) for neopanamax locks

Fix portion (DWT)	Variable portion (cargo tons)	Total pure toll	OMS	Total canal cost
$204,302	$17,522	$221,824	$21,433	$243,257

Source: Panama Canal

Table V. Example of components of total Panama Canal cost – Neopanamax locks

$$Ln\frac{Pi}{1-Pi}V_i = \alpha + \beta X_i \Rightarrow Ln\frac{Pi(Canal\,grain\,transit)}{1-Pi(Canal\,grain\,transit)} = \beta_{1+}\beta_2 Z_{2+\ldots+}\beta_k Z_k \quad (4)$$

or

$$Ln\frac{Pi\,(Canal\,grain\,transit)}{1-Pi\,(Canal\,grain\,transit)} = Intercept + Panama\ Canal\ Cost + Bunker\ Price + 1\ Year\ Timecharter + Draft + Canal\ Water\ Time \quad (5)$$

where:

Pi (*Canal grain transit*) = probability of Panama Canal grain transit;

1 – *Pi* (*Canal grain transit*) = *probability of no Panama Canal grain transit (alternative route*).

Here Panama Canal Cost, Canal Water Time, Bunker Price, 1Year Timecharter and Draft are the main covariates to explain the odds of grain transits through the Panama Canal from the US Gulf and East Coast to East Asia.

To fit a logit model for the purpose of estimating the odds of grain transits through the Panama Canal compared to alternatives, it was necessary to build a unified database with the main explanatory variables listed above. For the case of Panama Canal cost, this information was easy to obtain from Panama Canal databases, including the few grain transits using the Neopanamax locks. However, for dry bulkers with grains bypassing the Panama Canal and drafting more than 12.04 meters TFW (Tropical Fresh Water),- therefore potential users of the Neopanamax locks-, it was necessary to calculate a theoretical Panama Canal cost using the Panama Canal toll calculator for all dry bulkers carrying grains[19]. Dry bulkers with grains transiting the Neopanamax locks, -having draft greater than 12.04 meters-, are assessed tolls based upon a fixed portion (based upon DWT- representing around 92 per cent of pure tolls), a variable portion (based upon cargo tons transported in metric tons – representing close to 8 per cent of pure tolls) and other Panama Canal charges/ other income amount (OMS). MINT provided DWT data for these transits; therefore, we could calculate the fixed portion of pure tolls. However, it was necessary to calculate the theoretical metric ton of grain cargo for the variable portion because our current MINT subscription does not provide information on cargo type and amount.

4.2.1 Calculation of theoretical grains cargo tons for bypass transits. For calculating the theoretical metric ton of grain cargo bypassing the Panama Canal, we estimated a theoretical vessel utilization rate for dry bulkers with grains as a function of a vessel's DWT, using the following regression based upon grains transits data through both the Panama Canal as Panamax and the very few transits through the Cape of Good Hope in which we obtained information about grain type and metric ton amount[20]:

$$\begin{aligned} &Dry\,Bulker\,utilization\,rate = 1.0309 - 0.0000034\,DWT \\ &\text{s.e.} \quad (0.1225)\ (1.56\,\mathrm{x}\,10^{-6}) \\ &t\text{–statistics} \quad (8.414192)(-2.15437) \\ &R^2 = 0.0707\ \text{Adjusted}\ R^2 = 0.0554\ \text{Observations} = 63 \end{aligned} \quad (6)$$

With this regression, we calculated the theoretical utilization for dry bulkers with grains bypassing the Panama Canal by multiplying DWT by its estimated parameter (−0.0000034 x DWT) plus the estimated parameter for the constant term (1.0309). Then, this theoretical utilization is multiplied by the dry bulker¨s DWT to obtain the theoretical cargo amount in metric tons. Although this regression slightly underestimates the theoretical metric tons of cargo for the variable portion of pure Panama Canal tolls in the Neopanamax locks and presents a low R^2, this is the most objective way to try to estimate metric tons of grains cargo given this lack of information and taking into consideration that the variable portion of pure tolls is only around 8 per cent of total pure tolls[21]. Once we have both dry bulkers's DWT and the theoretical metric tons of grain cargo, we can plug both values into the Panama Canal's toll calculator for dry bulkers carrying grains in the Neopanamax locks and obtain the total pure toll amount for each bypassing dry bulker on the list.

4.2.2 Assumptions on other marine services. We assumed a minimum other Panama Canal services (OMS) of $21,433.00 -no booking included- for dry bulkers transiting the Neopanamax locks, which is added to pure Canal tolls to obtain total Panama Canal costs for each dry bulker bypassing the Panama Canal with grains[22]. The components of the minimum OMS for the Neopanamax locks are the following:

As an example, the final theoretical Panama Canal cost for an 81,964 DWT dry bulker transiting the Neopanamax locks with 58,846 metric tons of grains will be the following:

4.2.3 Mapping of bunker price, timecharter and canal water time with the departure date. Because it is virtually impossible to find the real value of timecharter or bunker price for each dry bulker with grains in our study, we assumed the use of weekly Houston IFO 380 cst bunker price and weekly 1-year timecharter for 75,000 DWT dry bulker from Clarksons as a proxy for the real bunker price and timecharter. Likewise, we use weekly Canal Water Time as an explanatory variable impacting the decision to use the waterway. These weekly data were matched with MINT¨s departure date for the grain vessel bypassing the Panama Canal. For example, if a departure date for a bypassing vessel from the US Gulf was October 19, 2017, then the corresponding weekly data for bunker, timecharter and Canal Water Time was the week of 15-21 October 2017 from Clarksons' timeseries data corresponding to week 18 (Table VI).

Similarly, we matched grains transit dates through the Panama Canal with the weekly Houston bunker price, weekly 1-year timecharter from Clarksons and Canal Water Time, but subtracting 7 days to take into consideration the average time it takes for a grain vessel to arrive from the US Gulf and East Coast to Panama. For example, if a transit date through the Panama Canal was December 22, 2017, we subtracted 7 days, that is December 15, 2017 becomes the theoretical departure date from the port of origin. This theoretical departure date was matched with the Houston bunker, timecharter and Canal Water Time information of the week of December 10-16, 2017 for a specific transit. In a nutshell, overall, we are

Table VI. Example of weekly bunker price and timecharter assignment from Clarksons data into individual grain transit

Vessel name	Departure date (US Gulf)		Week (Clarksons)	Week no.	Weekly IFO 380 cst Houston price	Weekly 1-year Timecharter 75 K DWT Panamax
Star of Sawara	Oct. 19 2017	→	15-21 Oct. 2017	18	$312.50/ton	$13,375/day
Key Evolution	Dec. 15 2017	→	10-16 Dec. 2017	26	$348.50/ton	$11,900/day

Source: Clarksons. Processed by authors assuming the departure date from the origin port as the "fixing" date for bunkers, 1- year timecharters and Canal Water Time for the unified database.

4.2.4 Draft assumption for the study. As the "official" draft for the study, we assumed both MINT¨s most updated transit draft for dry bulkers bypassing the Panama Canal and the registered transit draft for grain vessels transiting the interoceanic waterway from Panama Canal transit information. In this research, transit draft is a continuous explanatory variable similar to total Canal cost, bunker price, timecharter and Canal Water Time.

5. Model specification, results and discussions

The logit model for this study follows the approach of previous works related to route choices, taking into consideration the advantages of this modelling technique. In our case, and from a carrier/vessel operator¨s point of view, we assumed that each individual carrier/vessel operator is faced with a choice of two routes: the Panama Canal route and alternative bypass routes which is mostly through the Cape of Good Hope as per our collected data. For our paper, we include the following attributes for our logit model:

$$Log\frac{Pi\,(\text{Canal}\,grain\ stransit)}{1-\,Pi\,(Canal\,grain\ stransit)} = \beta_1 + \beta_2\text{Draft} + \beta_3\text{Transit cost} + \beta_4\text{Time charter} + \beta_5\text{Bunker} + \beta_6\text{Canal Water Time} + \varepsilon \tag{7}$$

where the β^{s} represent the estimates for our attributes or explanatory variables. Using our continuous explanatory variables, here we include the following logit models, where Models 1-4 and 6-8 are bids to fit a logit model rescuing as many attributes as possible after disregarding statistically insignificant and wrong-signed attributes. Finally, we obtained model 5 as the best logit model as per our aforementioned explanatory variables. In general, signs were as expected from most of our attributes, except Canal Water Time (*CWT*). On the other hand, the only statistically significant explanatory variable- in addition to the intercept- is transit draft (Table VII). The other attributes are consistently not statistically significant through Models 1-8.

As part of our evaluation we performed a Hosmer–Lemeshow test for assessing goodness of fit of logit regression Models 1-8. From this test, we found that model 1 had the highest *Pseudo* R^2, therefore we performed likelihood ratio tests to compare the goodness of fit between Model 5 against Models 1, 6 and 7. The likelihood ratio test results indicated that adding CWT, transit cost, timecharter and bunker to the model did not result in a statistically significant improvement in model fit. We also assessed the sensitivity and specificity of Models 1-8, performed an assessment of variable impact by model, an assessment of the variance inflation factors per model and an assessment of the variance inflation factors per model.

Regardless of the model, the variable draft always turned out to be statistically significant. Even though Model 5 did not have the highest *Pseudo* R^2, it has a value of 0.94760, a pretty high value. When performing the ANOVA test of the models, only Models 1 and 5 were significant. After evaluating the goodness of fit in each of the eight models, only Models 5 and 6 were fairly good fits, but being aware of the limitations of the Hosmer–Lemeshow test, we conducted the likelihood ratio test to each model. The results showed that adding bunker, *CWT*, transit cost and timecharter did not statistically improved model fit. Therefore, the variable draft is the only covariate included in Model 5.

Finally, an assessment of the model sensitivity and specificity was conducted. From the results, each one of the models was able to decently predict the no-transit probabilities but did quite poorly on assessing transit probabilities. Model 5 is regarded as the best model because of its fairly high *Pseudo* R^2. Also, the Hosmer–Lemeshow test regarded model 5 as one of the

Table VII. Logit models testing different attributes

Variable- Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept - β_1	91.0182*** (22.8479)	97.4350*** (23.6522)	102.3466*** (23.7958)	112.9738*** (15.7690)	110.327*** (14.815)
Transit Draft- β_2	−6.1108*** (1.8355)	−5.3383*** (1.5483)	−5.3116*** (1.5262)	−9.1072*** (1.2768)	−8.723*** (1.162)
Transit Cost- β_3	−0.0001254 (0.0001)	−0.0001638 (0.0001)	−0.0001608 (0.0001)	–	–
1 Year Timecharter- β_4	0.0008487 (0.0010)	0.0005280 (0.0006)	–	–	–
Bunker Price- β_5	0.0112375 (0.0276)	–	–	–	–
Canal Water Time- β_6	0.0287 (0.0409)	0.0392 (0.0349)	0.0544 (0.0289)	0.05245 (0.0294)	–
Log-likelihood	−10.0545	−14.4016	−14.6863	−17.4747	−18.9440
Mc Fadden Pseudo R^2	0.972187	0.96016	0.95938	0.95166	0.94760
AIC	32.109	38.803	37.373	40.949	41.888
			527 observations		

Notes: Standard errors in parenthesis; ***at 0.001 significance level

(*continued*)

Table VII.

Variable- Coefficient	Model 6	Model 7	Model 8
Intercept - β_1	106.9076*** (15.3383)	107.1338*** (15.1675)	106.8209*** (14.9195)
Transit Draft- β_2	−9.2090*** (1.4076)	−9.2103*** (1.3983)	−8.7588*** (1.2021)
Transit Cost- β_3	–	–	–
1 Year Timecharter- β_4	0.0007297 (0.0006)	0.0007591 (0.0005)	–
Bunker Price- β_5	0.0016823 (0.0176)	–	0.01143 (0.0159)
Canal Water Time- β_6	–	–	–
Log-likelihood	−18.0113	−18.0158	−18.6790
Mc Fadden Pseudo R^2	0.95018	0.95017	0.94833
AIC	44.023	42.032	43.358
		527 observations	

models with best fit, and the likelihood ratio test evidenced that adding extra variables different from draft did not improve the model fit in terms of statistical significance.

To address the possibility of our dataset being a panel data, the following panel data logistic regression was attempted for the individual, time and two-way effects using R:

As we can see from the R results, the standard errors diverge, and the probabilities display unusual results. Furthermore, the response and the explanatory variables were not monitored over time (in time series format) nor individual effects were studied; therefore, we concluded that we were not dealing with a panel data and/or that performing panel data logistic regression would not generate adequate results.

As a matter of fact, very few Panamax dry bulkers transit the Neopanamax locks because of the low chances of securing a reservation to transit as a Panamax Plus drafting more than 12.04 meters as per the maximum draft of the Panamax locks[23]. In general, dry bulkers with grains headed into East Asia try to take advantage of economies of scale- and the possibilities of higher voyage revenue and profit- by filling vessels up to maximum load, depending on the port of origin and destination. At the same time, the difficulty to clinch a transit spot in the Neopanamax locks- most Panamax Plus dry bulkers wait to nail down a transit slot without a reservation- discourage grain traffic through the Neopanamax locks in favor of the alternative route and may explain the negative sign of transit draft and perhaps translates into a high

Maximum likelihood estimation. BFGS maximization, 258 interaction. Log Likelihood: −14.95457. 5 free parameters

	Estimate	Std. error	*t*-value	Pr (>t)
Intercept	93.5397	Inf	0	1
Dataset$Canal Cost	−0.0001	Inf	0	1
Dataset$Draft	−5.3521	Inf	0	1
Dataset$Bunker	0.0073	Inf	0	1
DatasetTimecharter	0.0008	Inf	0	1

Table VIII.
Individual effect

Maximum likelihood estimation. BFGS maximization, 258 interaction. Log Likelihood: −14.95457. 5 free parameters

	Estimate	Std. Error	*t*-value	Pr (>t)
Intercept	93.5397	Inf	0	1
Dataset$Canal Cost	−0.0001	Inf	0	1
Dataset$Draft	−5.3521	Inf	0	1
Dataset$Bunker	0.0073	Inf	0	1
DatasetTimecharter	0.0008	Inf	0	1

Table IX.
Time effect

Maximum likelihood estimation. BFGS maximization, 258 interaction. Log Likelihood: −14.95457. 5 free parameters

	Estimate	Std. Error	*t*-value	Pr (>t)
Intercept	93.5397	Inf	0	1
Dataset$Canal Cost	−0.0001	Inf	0	1
Dataset$Draft	−5.3521	Inf	0	1
Dataset$Bunker	0.0073	Inf	0	1
DatasetTimecharter	0.0008	Inf	0	1

Table X.
Two way

statistical significant attribute, meaning that, as a dry bulker is fully loading with grains and approaching the maximum draft allowed at the Panamax locks, the greater is the risk of being overdraft for the Panamax locks, therefore increasing the odds of considering alternative bypass routes from the US Gulf and East Coast to Asia[24]. Likewise, if a grain importer plans on shipping a large amount of grains, say, 68,000+ metric tons of grains from the onset to take advantage of economies of scale and because of inventory management, this cargo amount derives into a draft larger than 12.04 meters of the Panamax locks, therefore decreasing the odds of grains transits through the Panama Canal in favor of the alternative route. In this case, the larger amount of cargo and higher voyage profit compensate the use of the longer alternative bypass route compared to a shipment with fewer amount of cargo, for example, 60,000 metric tons, through the Panamax locks at 12.04 meters. Additionally, even though bunker price and time charter turn out to be not statistically significant in our research approach, voyage cost intuition will tell that the decision to use a longer bypass route such as the Cape of Good Hope may hinge on those voyage cost variables. From Model 5 as our fitted logit model, -8.723 is the impact of the draft variable on the log of the odds of transiting the Panama Canal. From the estimated coefficients for the intercept and draft, we have the following specification to estimate probabilities of Panama Canal transits:

$$P_i = \frac{1}{1 + e^{-(\beta_{1+}\beta_2 X)}} \Rightarrow P_i = \frac{1}{1 + e^{-110.327+8.723\,Draft}} \tag{8}$$

Besides the difficulty of a Panamax Plus vessels to secure a transit slot through the Neopanamax locks, it is very important to take into consideration the pre-approval process and the physical requirements for Panamax Plus bulkers to be eligible to transit the Neopanamax locks[25]. For example, from a subset of 505 dry bulkers with grains that transited both the Panama Canal and alternative routes, of which the Panama Canal had previous inspections and transits records, a total of 434 vessels with grains, roughly 86 per cent of Panamax dry bulkers, did not comply with the requirements to transits the Neopanamax locks as Panamax Plus. It meant that only 71 transits (14 per cent) of the total subset qualified as Panamax Plus eligible to transit the Expanded Canal. This eligibility may be an important deterrent for Panamax vessels trying to transit the Neopanamax locks as Panamax Plus. Even further, of the total number of vessels that bypassed the Panama Canal, 232 total transits, only 40 vessel transits (17 per cent) were suitable for a Panamax Plus transit status. Still, even with this low percentage, the following issue remains: 40 potential Panamax Plus transits – representing close to $9.6m in potential toll revenue (40 × $242,244) – ended up taking alternative bypass routes such as the Cape of Good Hope. Again, the answer to this question may lay on the difficulties for Panamax Plus bulkers to fetch a transit reservation for the Neopanamax locks.

6. Implications and conclusions

This study attempted to fit a logit model with several attributes trying to explain the declining movements of grains through the Panama Canal between July 1, 2017 and September 30, 2018, especially in the very important East Coast USA- Asia grain route, the Neopanamax locks notwithstanding. This paper carefully reviewed past literature mostly related to the use of discrete choice models applied to the field of transportation, including mode of transportation, route choices and, notably, vessel movements from AIS because of our utilization of IHS¨s MINT as the main tool for tracking dry bulkers with grains bypassing the Panama Canal. This is probably one of the few opportunities in which specific real vessel movements were listed and cross-checked, allowing the recording of vessels origin and destination to generate a shipping route. GIPSA and Blue Water Shipping provided the information to identify the approved and grain dedicated export terminals in the USA for the vessel tracking of our research.

Although the literary review covered papers in which alternative routes to the Panama Canal were considered, or destination choice models with timeframes before and after the expansion of the Panama Canal were encompassed, perhaps there is no research related to the Panama Canal applying direct real Canal data on tolls, transit draft and Canal Water Time and applied to a particular route and commodity. Moreover, the construction of the final database for the logit model required extra work and creativity to map weekly bunker, timecharter and Canal Water Time data with quasi daily observations such as transit draft and total Panama Canal cost. Additionally, it was necessary to create a calculation for theoretical grains cargo tons of dry bulkers bypassing the waterway.

Because this analysis assumed the point of view of a carrier/vessel operator chartering a dry bulker to transport grains, the initial logit model attempted to include attributes directly related to the Panama Canal such as Canal Water Time, total Canal cost and transit draft; and attributes that are key to a voyage cost calculation, namely bunker price and time charter rates. At the end we arrived at a final logit model (Model 5) in which transit draft was the only statistically significant explanatory variable explaining the odds of dry bulkers with grains transiting the Panama Canal or else. Given the expected negative sign of the transit draft attribute, this implies that, as a dry bulker approaches the maximum draft allowed at the Panamax locks, the overdraft risk for using the Panamax locks increases, raising the odds for the alternative bypass routes because of the difficulty of a Panamax Plus vessel to secure a transit through the Neopanamax locks. At the same time, the negative sign of the draft variable and the estimated coefficients of Model 5 entail a higher odd of fewer grains transits through the Panama Canal with large grain cargo load, most likely as transit draft approaches 13 meters for vessels trying to take advantage of economies of scale and maximizing profit. Furthermore, the pre-approval process and the physical requirements for potential Panamax Plus vessels attempting to transit the Neopanamax locks may also be an important deterrent working against the waterway. Also, panel data logistic regression was attempted for the individual, time and two-way effects for the possibility of our dataset being a panel data.

Additional research is required related to this particular study, including grain movements before the time period of this study – if data is available – and in the near future. As the case may be, different attributes could also be explored such as vessel arrivals at the Panama Canal or vessel backlogs, assuming this information is readily available. Further, the logit methodology and goodness of fit tests of this study could be applied to other commodities, routes or vessel types. In terms of data description, the preliminary descriptive statistics provided useful initial information regarding the vessel sizes involved in the grain trade, especially for grains headed into Chinese ports. From the beginning the statistics suggested a high participation of grain transits from the US Gulf and East Coast to East Asia mainly through the Cape of Good Hope, especially grain cargo into China. More importantly, the data analysis shows the lowest market share for Panama Canal grains during the peak of the US grain exporting season, a fact worth extra attention by the Panama Canal Authority in evaluating market share for grains. The paper also provided comprehension on the particular grain terminals in China, which is a useful knowledge to better understand the vessel size flows into China.

To increase the participation of grains through the waterway, especially headed into China, the Panama Canal Authority may need to consider increasing daily transit capacity in the Neopanamax locks given the preference for the use of Panamax vessels for this trade as a consequence of the economies of scale of using relatively larger ships. This may need to take into account the rest of the transit mix through the Neopanamax locks, namely container, LNG, LPG and other vessels, as well as understanding present traffic at the Panamax locks. The toll paid by the different vessel types in the Neopanamax locks is an important consideration in the final traffic mix decision for these locks. Also, if migration into larger vessel size increases the traffic through the Neopanamax locks for key market segments, the Panama Canal may need to take a second look at the contribution of the Panamax locks. Any decision will require a careful analysis based on commodities, lot size and alternative sources. Once more, the comprehensive data developed for the study and the information extracted from it provided the first useful insights for any future decision or analysis related to the grain trade through the Panama Canal.

Notes

1. The fiscal year for the Panama Canal runs from October 1 to September 30.
2. This is Oldendorff's Web page explaining top off operation in Trinidad, available at: www.oldendorff.com/pages/transshipment/trinidad
3. "East Coast USA" here includes East Coast and US Gulf regions.
4. This time span corresponds to a fix, single US marketing year for wheat (June/May), corn, sorghum and soybeans (September/August) and closely approximates a single fiscal year of the Panama Canal.
5. See J. Hilbe, *Practical Guide to Logistic Regression,* CRC Press (2016) and Klieštik, T *et al.*, "Logit and Probit Model used for Prediction of Financial Health of Company", *Procedia Economics and Finance*, Vol. 23, pp. 850-855 (2015). Also, for comparison purpose only, the robustness of our logit model was higher than a probit one (using our data) in terms of AIC, BIC and pseudo R^2.
6. Available at: www.marinetraffic.com/en/p/expand-coverage
7. Available at: www.aishub.net/
8. Available at: www.marketintelligencenetwork.com/
9. Shipping Intelligence Network Timeseries, Clarksons.
10. The information comes from the Panama Canal¨s Datamart, linking both cargo and transit databases and cross checking origin and destination with information from IHS¨s Market Intelligence Network (MINT) for certain origins and destinations.
11. Available at: www.marinetraffic.com/en/ais/home/centerx:−91.2/centery30.4/zoom:4
12. The USDA-GIPSA (US Department of Agriculture- Grain Transportation, Packers and Stockyards Administration) provides a list of authorized US grain export elevators/terminals that helps to identify grain exporting terminals in the USA.
13. There were a few transits to Vietnam, Thailand and Indonesia, Also, there were transits ending up in Saudi Arabia and Spain originally headed into China. These were consequences of the beginning of the trade war between the USA and China.
14. Because Supramax and Ultramax vessels may register 32 meters beam size, they are considered Panamax vessels in terms of Panama Canal's size classification.
15. The US marketing year for most of the grains and soybeans, except wheat, runs from September to August. The US marketing year for wheat is from June to May.
16. Brazil's marketing year for soybeans runs from February to January.
17. "Other income amount" is also called "other marine services" (OMS).
18. Regarding period *t*, the time span for the study is from July 1, 2017 to September 30, 2018, corresponding to the US marketing year for wheat, soybeans and other grains.
19. Available at: https://peajes.panama-canal.com/ppal.aspx

20. This was information from news outlets about grains cargo rejected by China because of the trade conflict with the USA.
21. Although the estimated R^2 for the dry bulker utilization rate is very low, but with statistically significant coefficients for DWT and intercept, this estimation is the most objective way to try to calculate the cargo amount of vessels bypassing the Panama Canal, given the fact that cargo information is needed to calculate the variable portion of the theoretical toll amount that a panamax plus vessel (bypassing the Panama Canal in real life- we don¨t know the cargo amount) will pay for using the Neopanamax locks. Nonetheless, the variable portion of toll is only 8% of total amount compared with the fixed portion (92%) represented by the DWT of a dry bulker.
22. Depending on the vessel transit circumstance, OMS charges may be larger (i.e. extra tugboats services needed). Also, many times, the Neopanamax locks require a reservation/booking, extra fee that must be added to total Canal costs.
23. Panamax Plus vessels: All Panamax vessels authorized for TFW drafts greater than 12.04 meters (39.5o feet) up to 15.24 meters (50.00 feet) and approved for transit through the new locks. Source: NT Notice to Shipping N-1-2019, pg. 10. Also, dry bulkers with grains compete with other vessel types that pay higher tolls for a transit slot in the new locks.
24. The amount of grain cargo intake depends on the lot size a grain importer "fixes", depending on consumption, inventory management and previous planning, then resulting in the route choice decision.
25. A key requirement for Panamax Plus and Neopanamax bulkers includes adequate chocks and bits for towing and mooring at the Neopanamax locks. NT Notice to Shipping N-1-2019, pp. 38-46.

References

Anderson, P. and Ivehammar, P. (2016), "Dynamic route planning in the Baltic sea region- a cost- benefit analysis based on AIS data", *Maritime Economics and Logistics*, Vol. 19 No. 4, pp. 631-649.

Bai, X. and Siu, J. (2018), "A destination choice model for very large gas carriers (VLGC) loading from US Gulf", paper presented at the 26th International Association of Maritime Economists 2018 Conference (IAME), 11-14 September, Mombasa.

Chang, M. and Lu, P. (2013), "A multinomial logit model of mode and arrival time choices for planned special events", *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 10, pp. 710-727.

Fiorini, M., Capata, A. and Bloisi, D. (2016), "AIS data visualization for Maritime spatial planning (MSP)", *International Journal of e-Navigation and Maritime Economy*, Vol. 5, pp. 45-60.

Hussain, D., Mohammed, A., Salman, A., Rahmat, R. and Borhan, M. (2017), "Analysis of transportation mode choice using a comparison of artificial neural network and multinomial logit model", *Journal of Engineering and Applied Sciences*, Vol. 12 No. 5, pp. 1483-1493.

Manssour, A., Alhodairi, A.M. and Rahmat, R. (2013), "Modeling a multinomial logit model of intercity travel mode choice behavior for all trips in Lybia", *International Journal of Civil and Environmental Engineering*, Vol. 7 No. 9, pp. 636-645.

Manssour, A., Alhodairi, A.M. and Rahmat, R. (2013), "Modeling of intercity transport mode choice behavior in Lybia: a binary logit model for business trips by private car and intercity bus", *Australian Journal of Basic and Applied Sciences*, Vol. 7 No. 1, pp. 302-311.

Regianni, A., Nijkamp, P. and Tsang, W.F. (1997), "European freight transport analysis using neural networks and logit models", TI Discussion paper, No. 97-032/3, Tinbergen Institute, Amsterdam, pp. 5-9.

Schøyen, H. and Bråthen, S. (2011), "The Northern sea route versus the Suez Canal: cases from bulk shipping", *Journal of Transport Geography*, Vol. 19 No. 4, pp. 977-983.

Shen, G. and Wang, J. (2012), "A freight mode choice analysis using a binary logit model and GIS: the case of cereal grains transportation in the Unites States", *Journal of Transportation Technologies*, Vol. 2 No. 2, pp. 175-188.

Shibasaki, R., Azuma, T. and Yoshida, T. (2016), "Route choice of containership on a global scale and model development: focusing on the Suez Canal", *International Journal of Transport Economics*, Vol. 43 No. 3, pp. 263-288.

Shibasaki, R., Azuma, T., Yoshida, T., Teranishi, H. and Abe, M. (2017), "Global route choice and its modelling of dry bulks carriers based on vessel movement database: focusing on the Suez Canal", *Research in Transportation Business and Management*, Vol. 25, pp. 51-65.

Shibasaki, R., Kanamoto, K. and Suzuki, T. (2018), "Port-basis global LNG trade and shipping route competition: estimation from vessel movement database", paper presented at the 26th International Association of Maritime Economists 2018 Conference (IAME), 11-14 September, Mombasa, Paper provided directly by the authors.

Surbakti, M. and Bombongan, C. (2017), "Characteristics of modal choice preference between bus and train from medan to Kuala Namu airport", *IOP Conference Series: Material Science and Engineering*, Vol. 180 No. 1.

Tu, E., Zhang, G., Rachmawati, L., Rajabally, E. and Huang, G.B. (2017), "Exploiting AIS data for intelligent marine navigation: a comprehensive survey from data to methodology", *IEEE. Transactions on Intelligent Transportation Systems*, Vol. 99, pp. 1-24.

Wilson, W. and Ho, J. (2018), "Panama canal", in Blonigen, B. and Wilson, W. (Eds), *Handbook of International Trade and Transportation*, Edward Elgar Publishing, pp. 628-657.

Wojcik, S. (2017), "The determinants of travel mode choice: the case of lodz", *Bulletin of Geography. Socio-Economics Series*, Vol. 44 No. 44, pp. 93-101.

Wu, L., Xu, Y., Wang, Q., Wang, F. and Xu, Z. (2017), "Mapping global shipping density from AIS data", *Journal of Navigation*, Vol. 70 No. 1, pp. 67-81.

Further reading

Bluewatershipping.com (2019), "Blue water shipping port maps", available at www.bluewatershipping.com/portmaps.php (accessed 5 April 2019).

Clarksons Research Databases (2019), "Shipping intelligence network timeseries",

Hilbe, J. (2016), *Practical Guide to Logistic Regression*, CRC Press, Boca Raton, FL.

Hub for the Americas (2019), "Oldendorff web page", available at: www.oldendorff.com/pages/transshipment/trinidad (accessed 1 July 2019).

Klieštik, T., Kočišová, K. and Mišanková, M. (2015), "Logit and probit model used for prediction of financial health of company", *Procedia Economics and Finance*, Vol. 23, pp. 850-855.

Panama Canal Authority (2019), "NT notice to shipping no. N-1-2019", available at: www.pancanal.com/eng/op/notices/2019/N01-2019.pdf, p. 10 and pp. 38-46.

USDA-GIPSA (2017), "Export port grain facilities", available at: www.gipsa.usda.gov/fgis/oversight/2017ExportPortGrainFacilities.pdf (accessed 15 January 2019).

USDA-FGIS (2017), "Registered grain exporter¨s directory", available at: www.ams.usda.gov/sites/default/files/media/2017RegisteredGrainExporterDirectory.pdf (accessed 15 April 2019).

USDA-FGIS (2017), "Exporter", available at www.ams.usda.gov/sites/default/files/media/2017ExporterFacilities.pdf (accessed 5 April 2019).

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