UNCERTAINTY OF MARITIME TRANSPORT DEMAND AND GRAIN TRADE: A GRAVITY MODEL ANALYSIS

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ABSTRACT

This paper investigates the seaborne trade flow using a gravity model approach. According to the theory of economics, the uncertainty of maritime transport demand is fundamentally caused by the imbalance between the supply and demand of seaborne transport. The supply of maritime transport capacity is the tonnage of vessels provided. The seaborne demand is derived from the commodities needing carriage by sea. Because the demand for maritime transport varies in response to the seaborne trade, the demand is inevitably affected by the world economy and the demand in fact changes quickly. On the other hand, it takes a long time to increase the supply of seaborne transport capacity. Therefore, in order to plan tonnage supply and avoid shortage or excess of transport capacity, predictions of demand for maritime transport service is more practical and important. Prior studies on maritime transport have been concerns on the supply side, but this study is on the demand side. This paper focuses on the grain trade which is one of the three major dry bulks transported by sea. A gravity model is developed by selecting variables, such as GDP, of 11 major grain trading countries over 11 years (1996-2006). The model is statistically good and the results provide managerial implications for the shipowners to allocate the capacity.

Keywords: Maritime transport, Gravity model, Grain trade, Bulk shipping

1. INTRODUCTION

The dry bulk market is just belonging to the economic areas that the price (freight rate) is determined by a balance between the supply (the transport capacity provided at each price) and the demand (the desires of transporting cargoes at each price). Because of the varying supply and demand, the freight rate is fluctuating from time to time. This paper will focus on the demand aspect of dry bulk market, and provide a method of demand forecasting, according to which the dry bulk carriers could lay plans for their future operation.

1.1 Brief description of recent bulk shipping market

During the year of 2008, the bulk shipping market suffered a cold winter. The collapse in dry bulk shipping rates was an unprecedented severity and was reflected by the Baltic Dry Index (BDI) apparently. According to the Baltic Exchange, the index is based on an assessment of the price of transporting the major raw materials by sea, including coal, iron ore and grain. Considering 26 major shipping routes which are measured on a per tonne and daily hire basis, the index is constituted by four different sizes of oceangoing dry bulk carriers, namely Handysize (10,000-40,000 DWT), Handymax (40,000-60,000 DWT), Panamax (60,000-100,000 DWT), Capesize (above 100,000 DWT). So the BDI is seemed as an indicator of the bulk shipping market. The Capesize can be further divided into VLBC (Very Large Bulk Carrier, over 200,000 DWT), ULBC (Ultra Large Bulk Carrier, over 300,000 DWT), and VLOC (Very Large Ore Carrier, over 300,000 DWT).

The BDI plummeted to 663 points on 5 December 2008, 94.4 percent down from 11,793 points hit on 20 May 2008, which is the all-time record high since the index was introduced in 1985. And the rates for Capesize, which is the largest ship of the four sizes of the vessels, were down 98.8 percent from the record $233,988 per day at 19,687 points set on June 5 to $2,773 at 858 points on 27 November, 2008.

It was said by Jeremy Penn, Chief Executive of the Baltic Exchange, that the Baltic Dry Index was now close to its all-time low in 1986 and, this time, the conditions were more extreme . These low rates were approximately close to operation costs combined by expenditure for vessels and fuel, and the salary for crews. And even, “zero rate” emerged in October 2008, under which freight rate, the earned revenue could hardly cover its voyage cost. Verified by a broker of far-east area, M.V. *Dong Sheng Ocean* had been chartered to Brownstone with “zero rate” in October 2008. The charterer only needed to assume fuel and port disbursement. To confront this violent situation, some companies even chose to refuse the honour long-term contracts agreed at the old, higher level of the freight rate. Some vulnerable shipping companies were in dire financial straits, and had no choice but declaration of bankruptcy. As to the big shipping companies, their share price fell more than 50 percent.

There are significant relationships between global economy and shipping. For example, not only when Europe and Japan were developing in 1960s, but also during the development of China and other Asian areas, the shipping entered into a booming era. The surge in economy produced large demands for seaborne trade, so that shipping market developed rapidly. It is similarly when economy is at low ebb. Now, the current collapse in shipping industry, to some extent, was resulted from the sudden financial crisis. Because of the economic contraction, the demand for transport capacity decreased dramatically. America and European Union’s demand for products provided by Asia declined, which further led to the reduction of the demand for raw materials. And the difficult situation was also influenced by the disagreement between Chinese steel mills and Brazilian ore producers (Companhia Vale do Rio Doce), which reduced the demand for transport. Besides, the large delivery quantity of newbuildings constructed a significant increase of transport capacity supply, which made the imbalance between supply and demand more acute. The intense softening of dry bulk freight rates was heightened by the new entering vessels. As a result shipping market was frozen around the world.

1.2 The need for forecasting demand

The sudden credit crisis was unpredictable and causing inevitable economic recession and demand depression. However, the continuously increasing supply of transport capacity has worsened this imbalance of supply and demand.

The dry bulk market kept booming with little fluctuation since the year of 2005, and the transport capacity seemed to be comparatively insufficient. Facing this prosperous market, many shipowners brought second-hand vessels and booked newbuildings to expand their fleets. However, the demand for transport capacity was overestimated, and the newbuildings were delivered in a large quantity from 2008, happened to the economic crisis. If the shipowners could assess the speed of increasing demand for transport capacity and reduce the newbuilding order, the current frozen situation of dry bulk market should have been mitigated.

So forecasting is important for shipping industry management. The shipowners should forecast demand in order to plan the supply of transport services required to meet that demand. The tactical or operational decisions could be made according to short-term forecasts. The operation strategy of the company should take the long-term forecast into consideration. Generally speaking, demand forecasting is so important to the parties operating in the market. However, mistakes always happen in the forecasting area. There is no absolute correction in forecasting, no optimum method that can guarantee accuracy. So this paper just aims to look for a general method which could forecast the demand for transport service by sea.

2. MARITIME TRANSPORT AND GRAIN TRADE

Supply and demand theory is one of the elementary theories in economics and is the foundation of many other advanced economic models. The initial supply and demand theory is developed based on the perfectly competitive market and is used to explain many phenomena in market economy. The supply refers to the quantity of some certain goods which the producers would like to provide at a certain price. Meanwhile, the demand indicates the amount of the specific goods that the customers are willing to buy at a certain price.

The supply and demand theory is similar in seaborne transport. The supply is constructed by the tonnage shipowners would like to provide, and the demand is derived from the cargoes shippers wish to transport by sea. The same as economics theory, supply and demand in shipping are linked by price in freight market which is the money paid by shippers to shipowners for the transport supplied. By the connection of freight rate, the seaborne supply varies according to the changes in demand for tonnage. The supply and demand functions have been well built up by Stopford (2009).

The supply function for an individual ship is a hockey stick shaped curve. The supply can be adjusted by changing the speed of this single ship. When the freight rate falls too low, the shipowner will choose to lay up the vessel. If the freight rate increases, the owner will break layup and operate the vessel at its lowest speed in order to save fuel. When the freight rate goes on rising, the ship will speed up to supply more transport capacity until reaching its highest speed. After reaching its full speed, a higher freight rate cannot simulate more transport capacity supplied by the single ship. So the supply of fleet shall be taken into consideration.

As to the demand aspect, it is derived from the world economy. The demand in shipping market is a result of the international trade of commodities which require to be hauled by sea. As the sea transport can satisfy the large amount of commodities, especially for the bulk commodities, there is hardly substituted transport mode. The shippers have no rational choices but transport by sea, even if the freight rate reaches a high level. As a result, the demand curve is almost vertical just as illustrated by Stopford (2009). The demand for shipping capacity is a derived demand arising from the commodities trade, which fluctuates in response to the commodities trade volume. All in all, the demand forecasting is very important and essential.

2.1 Demand in dry bulk shipping industry

Demand, in the dry bulk shipping industry, can be explained as the transport capacity shippers are willing to carry their goods. It is fundamentally driven by the world economy and commodities shipped around the world. As the dry bulk market is focusing on tramp, the demand for dry bulk transport service is mainly from the cargoes which are always traded in a large quantity including iron ore, coal, grain and other categories. Trading of these dry bulk commodities will fluctuate along with the economic growth of the different countries and areas. In order to make correct judgment about the demand for dry bulk transport capacity, the trading trend of these cargoes shall be considered first.

The three largest bulk commodities shipped around the world are iron ore, coal, and grain from year to year, which are essential to people's daily lives and to the global economy. The iron ore trade routes mainly start from Australia and Brazil, and mostly end in China and Japan. The important origin point of international coal trade is Australia. And the primary consumers of coal are from Far East and West Europe. As to the grain trade, the grain commodities dominantly are exported from US Gulf. And the destinations of the trades mainly are Latin America, Japan, Asia and Brazil.

Apart from iron ore, coal and grain, there are some other dry bulk cargoes take a minor percentage of the total dry bulk trades, which are, bauxite and aluminium, phosphate rock copper, sugar, fertilizers, scrap, cement, coke, pig iron, forest product, and steel product, etc. In the year of 2007, the volume of iron ore transported by dry bulk carriers was 782 million tonnes, and coal and grains were 772 and 304 million tonnes respectively. All the trading volume of the three commodities took 62 percent of the whole dry bulk trade. The percentages of volume of iron ore and coal traded in 2007 were both 26 percent, and the proportion of grains was a little small, 10 percent. As to the rest of the dry bulk trade, the minor bulks including more than 10 kinds of bulk cargoes represented only 38 percent of the whole dry bulk trade. As a result, if the demand of major three dry bulk commodities can be studied and predicted as precisely as possible, it will be convenient to judge the total demand of the dry bulk shipping market and useful for the market participators to make their operation plans.

2.2 Grain Trade

Grains, which are using to provide human food directly and feed to animals, can be subdivided into cereal grains (or cereal) and oilseed. Usually, the shipping related statistics data only mention cereal grain which comprises wheat and coarse grain. Coarse grain normally includes maize/corn, barley, sorghum, oats, rye, millet, triticale and mixed grain. Wheat, with highly scattered dispersion at 30 percent of the whole acreage under cultivation all over the world, is the most important crop and the largest single commodity of all these types of grains. And the production of wheat takes 28 percent of the total grains. Maize/corn following wheat produces the second largest seaborne trading volume. To some degree, it is because both wheat and maize can thrive in a variety of growing conditions. Apart from wheat and maize, rice is also an important grain which is dominating in human diets in East and South Asia.

On one hand, some countries do not have enough cultivated lands or just crop failures happened so that the domestic grains can't feed up their people. On the other hand, because of developed cultivating technology and abundant plowed lands, agricultural surpluses exist in some other countries. As a result, the agricultural trade happens. Although grains (and other bulk commodities) are also transported by other transport modes (e.g. rails), only the seaborne trade is considered in this study.

According to the statistics issued by International Grains Council (IGC), the dominant producers and exporters are Argentina, Australia, Canada, EU and USA. And the USA is the largest one, whose export volume is even higher than other four major exporters as a whole. On the import side, the main countries are Japan, Mexico, South Korea, Egypt, Brazil, Algeria, Taiwan, Indonesia, and Turkey and so on. All the import countries scatter to Europe, Asia, Mid East, South America, Central America and Africa. The European Union used to be the traditional major exporter, however, in crop year of 2007/08, it has become a net importer with 27.6 million tonnes importing and 15.7 million tonnes exporting, respectively. Apart from European Union, Japan, Mexico, South Korea and Egypt are the countries with more than 10 million tonnes grain importing per crop year. And Japan is the only country which always imports a large amount of grain exceeding 20 million tonnes.

IGC collects fifteen major grain trade shipping routes to calculate the Grain Freight Index. The fifteen routes represent the main grain trade flows. Five of the routes start from USA, and two each of the remaining routes from Argentina, Australia, Canada, European Union and Black Sea respectively. The vessel types used to carry grains are also adequately represented by the Grain Freight Index: ten of the routes are calculated by Panamax freight rate, and the rest are Handy freight rate. Currently, 50-60 percent of grains are carried by Panamax vessels, and the others are transported by Handy.

As the grain trading tonnage has not grown as quickly as iron ore and coal, it has been less important in the overall dry bulk seaborne market. Although grain is grouped with iron ore and coal as the three major bulk commodities, it is fundamentally a different business. The latter connects closely to scheduled industrial operation, whereas grain is an agricultural commodity. Seasonal trade is the distinctive feature of grain carriage. Usually, the grain seaborne of South America and North America is concentrating in April to May and September to October every year. Furthermore, grain trade is considerably impacted by quite unpredictable events, such as drought, flood, other bad weather and insect pests. Not predominately affected by the business cycles as other raw materials, the demand for grain seaborne trade is difficult to predict. So the purpose of this paper is studying on forecasting the seaborne demand produced by grain trade. Furthermore, the cereals are the main part of grains and take a large proportion of the whole international grain trade so that the following analysis will focus on the cereals seaborne trade and choose the demand for cereals carriage by sea as the core object.

3. LITERATURE REVIEW

The theoretical foundation of gravity model evolves from Newton's Law which explains the gravitational force (F_{ij}) between two objects *i* and *j*, and can be expressed as:

$$F_{ij} = G\frac{M_i M_j}{r_{ij}^2} \qquad (i \neq j) \tag{1}$$

such as the gravitational force is proportional to the masses of the objects M_i and M_j and inversely proportional to the squared distance between them (r_{ij}). *G* is the gravitational constant equalling to 6.672×10^{-13}.

Usually, the Newton's Law can be transformed into terms of natural logarithms, expressed by "ln", so that the multiplication in Equation (1) is changed to addition and the division becomes subtraction. The equation can be expressed as:

$$\ln F_{ij} = C + \ln M_i + \ln M_j - 2\ln r_{ij} \tag{2}$$

where *C* is a constant which equals to ln*G*. And the whole equation has been transformed to linear relation.

This gravity concept as a causal model now is applied extensively in many areas other than spatiality. By replacing the dependent variable named F_{ij} and the independent variables nominated M_i, M_j and r_{ij} with others, the equation, if it works, can be used to explain other phenomena and make predictions.

Carey (1858) first introduced the gravity concept into human interaction and suggested "*gravitation is here (social phenomena), as everywhere else in the material world, in the direct ration of the mass and in the inverse one of the distance*", the gravity model has been testified adoptable in other areas. For instance, the gravity models have applications in transport studies. The initial attempt in transport was a study on movements of the Austrian state railways (*Lill, 1889*), whose result was then taken over by highway engineers to forecast road traffic. Apart from road transport, the aviation also involved. The first record was evaluation of the air traffic flow between two communities (*Harvey, 1951*). And this model is more valuable than other econometric model approach that it is able to forecast demand even on new routes (*Doganis, 2002*). Compared with other forecasting techniques, the gravity model as one of causal techniques will provide better and more accurate forecasts when using to forecast airline passenger.

More popularly, the gravity models were applied in international trades. Based on the economic sizes of and the distance between two countries, the model was able to predict the bilateral trade flows (*Isard, 1954*). Other studies adopted gravity model to evaluate the influences of mutual trade agreements on international trade. The international lending's effect of bilateral international trades was also testified by the models with inducting the real lending value as dependent variable, and GDP, population, trading value, area and other ten factors as independent variables (*Rose and Spiegel, 2004*). Following that, the causal gravity model assessed the policy of free trade agreement between Switzerland and US impacting on economic structure and multilateral trade patterns. And the result was that "*bilateral trade is positively related to the joint GDP of the partner countries and negatively related to the distance between them*" (*DeRosa and Gilbert, 2006*).

However, most of the existing gravity model literature on international trade have focused on all traded commodities as a whole, rather than agricultural products oriented, even in many cases, agricultural trade has been excluded from the estimation. In recent years, the object of gravity research has diverted to agricultural commodities. By making oil seeds, wheat and durum as research subject and incorporating GDP, GDP per capita, Distance, Contiguity, Landlocked and Common Language as independent variables, the extended gravity model analyzed how effective the regional trade agreements promote multilateral free trade (*Grant and Lambert, 2005*). Besides, the impacts of technical regulations on agricultural trade were also detected by gravity concept (*Schlüter, 2005*).

Previous research and literature showed that gravity models as a forecast method with high popularity in many research areas have developed for many years and are applicable to international trading and transport areas. It is more useful and accurate in forecasting than qualitative methodologies. As the model has been an empirical success, the gravity model will be tried to apply to and focus on the international cereal trade in this paper.

4. GRAVITY MODELS OF CEREAL TRADE

The trade flow is the predicting subject, and usually, the value of annual cereal trade is chosen as the objective function, namely dependent variable. After determination of the modelling target, the causal modelling starts from identifying and selecting the factors (independent variables) which will be assessed to forecast the dependent variable. Then the paper will discuss whether the gravity model with these variables is proper to forecast the cereal trade.

4.1 Basic gravity model of cereal trade

According to the solid theoretical foundations, this paper will start from the basic gravity model of trade which is based on the distance between countries and the interaction of the countries' economic sizes usually expressed by GDP.

4.1.1 Gross Domestic Product (GDP)

Economic theory suggests that the demand for commodities will be affected by the level of personal income. Gross domestic product (GDP) is the production value assessed by the resident institutional units of the country in monetary term. As to the whole country, it is the measure of national income and output of the country's economy. To some degree, GDP indicates the country's wealth and how rich the country is, which cursorily reflects the international purchase power of the country as a whole. Here, as a good measure of a country's income levels, GDP is introduced to assess the relationship between income of the country and how many cereals the given country wants to purchase. So the country with a higher GDP is expected to import more cereals from foreign countries.

4.1.2 Distance

Distance is the basic variable participating in gravity models of trade which usually represents the transport costs. It shall be grouped as the impedance variable and will be, to some extent, an obstacle to trade between two countries. So it is expected that the longer distance between two countries, the less trade flowing between them.

After the factors which may affect the cereal trade flow have been decided, the modelling processes to the core phase – construction of the mathematical expression. The gravity model equation of cereal trade with two independent variables is expressed as:

$$F_{ij} = C \cdot \frac{GDP_i \times GDP_j}{D_{ij}} \qquad (i \neq j) \tag{3}$$

where *i* and *j* denote export and import countries and the variables are defined as:
F_{ij} denotes the value of cereal trade flow from country *i* to country *j*;
C represents the constant;
GDP is the real GDP of countries indicating the economic sizes;
D_{ij} donates the distance between country *i* and country *j*.

Taking logs of both sides of Equation (3), the basic gravity concept is translated into terms of natural logarithm:

$$\ln F_{ij} = \alpha + \beta_1 \ln GDP_i + \beta_2 \ln GDP_j + \beta_3 \ln D_{ij} \qquad (i \neq j) \qquad (4)$$

Now, the gravity concept of cereal trade is expressed into linear equation with a log-log model.

Equation (4) is the assumption of the gravity model of cereal trade from the empirical gravity model of international trade. After the functional specifications between the dependent variable and the independent variables have been determined, the correction of the mathematical expression for this relationship has to be tested. In other words, the empirical data of the trade shall be used to identify whether the model works or not, and if yes, how well the equation works.

4.1.3 Model testing and adjusting

In order to test the applicable level of the gravity model for cereal trade, a large quantity of the cereal trade data have to be collected first. Although this is not a time series model, this study will take an 11-year-period data (1996-2006) as a sample so that ensures the data scale as abundant as possible, and further make sure that the model result is not accidental.

Taking the data availability and coherence into consideration, the objective countries will be chosen from the major exporter and importer list. Besides, as the data of European Union as a whole is hard to keep data consistent (some variables data given as EU-15, others as EU-25 or EU-27), some major European countries will also be picked out as the objects. However, due to the unavailability of data, some main trading countries cannot be included in this study, just like Argentina as main exporter and Egypt as main importer. As a result, thirty-five counties including United States, United Kingdom, Australia, Canada, Brazil, China, Finland, France, Germany, South Korea Japan, Russia and South Africa have been selected.

According to Equation (4), the value of cereal trade flow F_{ij}, the GDP of the target countries and the distance D_{ij} between two countries should be collected and organized. The cereal trade data in US dollars are from the Comtrade database of the UN Comtrade website. When the trade flow happens between country *i* and country *j*, it is very rare to find that the import value reported by *j* equals exactly to export value from the version provided by *i*. Usually, it is caused by the different parties of reporting for different purpose or the difference of reporting periods in different countries. This paper only considers the export value reported by each country. The GDP data in billion US dollars are taken from the *OECD.StatExtracts* databases of *Organisation for Economic Co-operation and Development* (OECD) website. The last variable of the basic gravity model assumption distance (D_{ij}), which is taken from the *Centre d'Etudes Prospectives et d'Informations Internationales* (CEPII). Distance is calculated following the great circle formula which uses latitudes and longitudes of its official capital. All the data collected shall be organized into one Excel file (Refer to **Table 2**) and then transformed to natural logarithm term which can be analyzed by computer software.

SPSS (Statistical Product and Service Solutions) is a leader in predictive analytics technologies and widely used for statistical analysis in social science and also by market analysts, survey companies, marketing organizations and others. Apart from statistical analysis, the software is able to manage data and output analyzed results into different format. This study has chosen SPSS v.13.0 as the analysis tool. As only numerical data make sense to the SPSS statistical analysis, the country name shall be designated a number to be represented.

The assumed gravity model of cereal trade in natural logarithm term, if works, has linear relationship as Equation (4) expresses. SPSS Linear Regression Analysis is used to specify the nature of the relation between variables, which can test whether the variables in logarithm terms in Equation (4) have this linear relationship. By choosing ln*Trade* as Dependent and ln*GDP_Ex*, ln*GDP_Im* and ln*Distance* as Independent(s), the SPSS regression analysis program gets the result as indicated in **Table 1**.

Table 1 – Results of basic gravity model by SPSS analysis

Independent variables	**Coefficients**	**Sig.**
Constant	-23.121	0.000
ln*GDP_Ex*	1.210	0.000
ln*GDP_Im*	.573	0.000
ln*Distance*	-1.489	0.000
R Square	0.315	

From the **Table 1**, the "*R* Square" is equivalent to *0.315*. In statistics, the "*R* Square" provides an indicator to measure how well future outcomes are likely to be predicted by the model. And in the linear regression case like as Equation (4), the value of "*R* Square" varies from *0* to *1* and represents the proportion of variability in ln*Trade* that may be attributed to some linear combination of the variables on the right side of the equation. It is commonly used to describe the overall fitness of the estimated model. "*R* Square" equalling to *1* indicates that the equation is with perfect linear relation, while equalling to *0* means there is no linear relation at all between the dependent and independent variables. Now, the value of "*R* Square" in this case is *0.315*. In other words, only *31.5* percent of the variation can be explained by the explanatory variables, which is moderate.

However, in the "Sig." (Significance) column of **Table 1**, the values are *0.000*. In statistics, "Sig." judges the statistical significance of variable. The higher the "Sig." value, the less probability the equation are and the less significant the variables are. In usual, *0.05* is the limit of the acceptable "Sig." value. If the value for "Sig." is higher than *0.05*, the predictive assumption will be violated. Conversely, the independent variable is useful in predicting the dependent variable when the level of significance is below 0.05. According to **Table 1**, all the

"Sig." values are only *0.000* so that the variables on the right side of the Equation (4) would be concerned as causes of the variable on the left side.

As a result, although the assumed gravity model of cereal trade does not work perfectly as the "*R* Square" value is *0.315*, the selected variables of *GDP* of exporters and importers and distance between countries are highly related to the cereal trade flow. In order to improve this model, other related factors shall be added to the model.

4.2 Extended gravity model of cereal trade

The basic features and results of the gravity model have been described in the previous section which involves *GDP* indicating countries' economic sizes and the distance between countries. As each specific commodity has its own distinct characteristic of demand, other factors impacting on cereal trade shall be taken into consideration and included in an expanded version of the model.

4.2.1 GDP per capita

GDP per capita (*GDPPC*) is a similar concept with GDP which also indicates the income level. However, the different aspect is that the *GDPPC* is the production value of the country (GDP) allocated to every resident. It can be seemed as the judgment of individual wealth of the country. For two countries, the country with a higher GDP may, however, have a lower *GDPPC*. Though *GDPPC* has similar function with GDP, this study still involves this factor.

4.2.2 Population and population growth rate

Cereals are the consumptive commodities which provide human beings with energy and nutrition. Human beings as the major part consuming cereals bring the primary demand for cereal grain. On one hand, the population size of a country will affect the cereal consumption; on the other hand, the population can represent the productive forces. So the population of countries shall be considered in this paper, and also the population growth rate which also will affect the cereal consumption or the productive forces.

4.2.3 Exchange rate

Exchange rate is the worth of one currency specified by another one. Usually, it reflects the country's transaction demand for money and is highly correlated to the level of business activity and GDP of the country. And it also captures the price effects of commodities. Generally speaking, settlement by US dollars is the international trade practice, so the exchange rate here means the currencies' value per US dollar.

4.2.4 Area

The precondition of cereals cultivating is fertile soil. Under current technical situation, it is still a crucial condition of the quantity one country can produce. It is important for a country to decide whether it can afford the domestic demand for cereals by itself; otherwise it has to export from other countries. Meanwhile, if a country has abundant earth to grow crops and the produced cereals cannot be consumed inside the country, it is possible to export the overstock.

Taking these factors above which are related to cereal trade in different degree into consideration, the basic gravity model can be expanded as:

$$\begin{aligned}\ln F_{ij} &= \alpha + \beta_1 \ln GDP_i + \beta_2 \ln GDP_j + \beta_3 \ln GDPPC_i + \beta_4 \ln GDPPC_j \\ &+ \beta_5 \ln Pop_i + \beta_6 \ln Pop_j + \beta_7 \ln Pgrowth_i + \beta_8 \ln Pgrowth_j + \qquad (i \neq j) \qquad (5) \\ &\beta_9 \ln ER_i + \beta_{10} \ln ER_j + \beta_{11} \ln Area_i + \beta_{12} \ln Area_j + \beta_{13} \ln D_{ij}\end{aligned}$$

where *i* and *j* denotes exporters and importers respectively and the variables are defined as:
F_{ij} denotes the value of cereal trade flow from country *i* to country *j*;
GDP is the real GDP;
GDPPC is the GDP per capita;
Pop is the population;
Pgrowth means the population growth rate;
ER indicates the exchange rate;
Area is the area of the countries;
D_{ij} donates the distance between country *i* and country *j*.

4.2.5 Model testing and adjusting

The data of exchange rate (vis-à-vis the US dollar), population of the countries, population growth rate are collected from *OECD.StatExtracts* database and of OECD website. And the areas of the countries are taken from CEPII website. Together with the GDP and distance collected already, all the data are organized into one Excel file (**Table 2**).

However, the original data of these variables are measured by different levels of units. The value of GDP is measured in billion US dollars; however the GDPPC and the cereal grain trade are measured in US dollars. In order to facilitate the following calculation, all the units of data are transformed to the same level, US dollars. Besides, the unit of population is also changed from thousand persons to persons. Then, according to the specifications of Equation (5), all these data shall be changed into natural logarithmic scale for further analysis. After that, the software of SPSS can be used to analyze these data again. Bearing in mind that the populations of some countries decreased during several years, so the value of population growth rate may be negative which cannot be transformed as logarithm term. These items will be invalid for the SPSS to analyze and shall be deleted from the dataset. After kicking out the invalid data, the data details are illustrated in **Table 2**.

Table 2 – Original data description

	Name of columns	Units	Mean	Minimum	Maximum	Std. Deviation
1	Year	/	/	1996	2006	/
2	Exporter	/	/	/	/	/
3	ID_Ex	/	/	1	35	/
4	GDP_Ex	US dollars	1E+012	2E+010	1E+013	2E+012
5	GDPPC_Ex	US dollars	26,099.6239	2,126	78,138	8,838.7916
6	Population_Ex	Persons	64,461,114.68	430,000	1,312,979,000	141,726,639.3
7	Pgrowth rates_Ex	Annual growth in percentage	0.6292	0.01	2.15	0.43815
8	Exchange rate_Ex	Per US dollar	69.0318	0.081	1,817.264	285.122577
9	Area_Ex	km2	1,842,810	2,586	9,970,610	3,366,879
10	Importer	/	/	/	/	/
11	ID_Im	/	/	1	35	/
12	GDP_Im	US dollars	1E+012	7E+009	1E+013	2E+012
13	GDPPC_Im	US dollars	26,254.8777	2,126	5,2047	7,814.6576
14	Population_Im	Persons	50,256,444.58	269,000	1,312,979,000	100,484,042.2
15	Pgrowth rates_Im	Annual growth in percentage	0.6043	0.01	2.15	0.43132
16	Exchange rate_Im	Per US dollar	67.9881	0.152	1817.264	265.204614
17	Area_Im	km2	1,351,200	30,528	9,970,610	2,910,881
18	Trade	US dollars	3E+007	112	4E+009	2E+008
19	Distance	km	4,455.605	56	19,857	4,861.829
Year: 1996 – 2006						
Number of countries: 35						
Number of columns: 19						
Number of observations: 4,177						

Table 2 shows the case summary which is analyzed by SPSS. It illustrates the nature of each variable and also the maximum and minimum values. In this dataset with total 19 columns and 4,177 rows of data, the largest cereal value (*US $3,528,345,174*) was the trade from USA to Japan in 1996. The largest GDP is from USA of 2006. However the biggest GDPPC is from Luxembourg of the same year. The longest distance is between Spain and New Zealand, namely 19,857 kilometres.

In order to keep the consistent of the data analyzed in basic and expanded gravity model and make sure the correction of the results, the new dataset should be processed to the basic gravity model analysis again. The value of "R square" is *0.342* and "Sig." of all the variables are equivalent to *0.000*. The overall result is acceptable and still need to be improved. Now all the variables can be assessed by SPSS v.13.0.

Table 3 – Results of expanded gravity model with original population growth rate

Independent variables	**Coefficients**	**Sig.**
Constant	-19.886	0.000
ln*GDP_Ex*	0.739	0.000
ln*GDPPC_Ex*	0.809	0.000
Pgrowth rates_Ex	-0.618	0.000
ln*Exchange rate_Ex*	-0.124	0.000
ln*Area_Ex*	0.708	0.000
ln*GDP_Im*	0.759	0.000
ln*GDPPC_Im*	-0.761	0.000
Pgrowth rates_Im	0.301	0.007
ln*Exchange rate_Im*	0.127	0.000
ln*Area_Im*	-0.183	0.000
ln*Distance*	-1.798	0.000
R Square	0.439	

The extended gravity model of international cereal trade present the SPSS results in **Table 3**. The value of "R Square" increases to *0.439*. And the "Sig." value of *Pgrowth rates_Im* decreases to *0.007* which is acceptable, whereas the values of other variables are all *0.000*. This result shows that these variables are highly significant and the ln*Trade* depends much on these variables. The gravity model has been improved by using the original values of population growth rates.

Now the "*R* Square" has been improved to *0.439*, still at a low level compared with *1*, the largest value of "*R* Square". However, it cannot say that this model does not work. Generally speaking, the higher "*R* Square", the closer the estimated regression equation fits the sample data (*Studenmund, 2006*). A high "*R* Square" can often be acquired in time series data because of the significant time trends on both sides of the equation. However, in this case, these are cross-sectional data without regard to differences in time. The "*R* Square" is often low because the observations differ in ways that are not easily quantified. According to previous studies on gravity equation of international trades between countries, the results of "*R* Square" is ranged from *0.39* to *0.59* (*Debaere 2002*, referring to Appendix 7) which is deemed acceptable. Now in current situation, an "*R* Square" of *0.439* might be considered as a good fit.

As this gravity model of cereal trade fits the sample data to some degree, the following part of this paper will focus on identifying the variables that have significant impact on the cereal trade.

5. MANAGEMENT IMPLICATIONS AND LIMITATIONS OF THE GRAVITY MODEL

5.1 Implications of Gravity Model

This study on gravity model of grain cereal trade aims to provide a method to forecast the demand for dry bulk transport volume. The cereal grain trade amount creates the part of demand for dry bulk transport volume. And the cereal grain trade can be estimated by the expected fluctuation of some economic indicators and other indices, for example, the GDP, GDPPC, exchange rate, population, and so on. These indicators have been introduced as the dependent variables of the cereal trade gravity model and usually will be anticipated and reported by the countries' authorities or some research institutions. And in the long run, the economic indicators can be expected according to the economic development. By overall consideration of these various factors, the cereal grain trade amount can be predicted, so that the variation of seaborne demand derived from cereal trade can be expected.

5.1.1 Fleet size decisions

After estimating the demand for dry bulk transport capacity, the plan of fleet supply can be worked out accordingly. As previously discussed, the demand for fleet or tonnage is quickly responding to economic situation and commercial market. However, as a result of long-time shipbuilding, the seaborne supply cannot be adjusted in accordance with the changed demand immediately. With the estimating results of the cereal trade gravity model, the decision makers can take steps to avoid shortage of seaborne supply or mitigate excessive bulk transport capacity.

The decision makers control or influence the supply of ships, which can be categorized into four groups: shipowners, shippers/charterers, the bankers and the various regulatory authorities (*Stopford, 2009*). Their decisions will affect each other and mutually impact on the shipping market. Although there are four types of decision makers, the influence of shipowners are the most primary and direct one. The actions of bankers and regulators will indirectly affect the dry bulk transport supply by pushing the shipowners' operations. Bank loan is the common financing method to build new vessels. When the freight rate is high, the requirements of applying for bank loan are easier to achieve, which will stimulate the shipowners to order new vessels. And in a poor market, bankers will exert the financial pressure on the shipowners and make them scrap the old ships. The regulatory authorities mainly consider from the safety and environmental aspects and usually the regulations will decrease the transport capacity of the fleet. Their decisions may not be affected by the seaborne demand.

The gravity model is more helpful to shipowners and shipper who can maximize their revenue and minimize the costs by working out operation planning in response to the results of the cereal trade gravity model.

As the primary decision makers, shipowners' decisions will affect the seaborne supply directly. According to the result of gravity model, shipowners may choose to order new ships or scrap old ones in the long-term, and arrange maintenance planning or decide when to lay up tonnage in the short-term. For example, if the cereal trade is expected to be prosperous according to the gravity model and will raise the seaborne demand, the shipowners may order new vessels or arrange maintenance in advance to avoid maintain the vessels in a booming market, which is depending on the extent of increased demand. And the shipowners may postpone the maintenance within the scope of regulation permission when the demand is forecast to decrease. So the shipowners will fully utilize their transport capacity and earn more profits.

Shippers will become shipowners when they charter in vessels to carry commodities. Usually, the shippers will not buy ships to carry cereal grains. It is because that the freight generally accounts for only a small proportion of material costs. The shippers will not be tempted to buy vessels themselves in order to save transport cost. However, the shippers still wish to save transport cost by chartering vessels in at a low freight level. Not like iron ore and coal which usually are transported under a charterparty enduring a long period, grains are seasonal agricultural commodities and commonly carried during a comparatively short period. If it is estimated by the gravity model that the cereal trade will boom and the dry bulk seaborne demand will increase, the shippers may choose to agree the charterparty earlier so that they can avoid a high freight after the market has been overheated.

5.1.2 Fleet allocation decisions

The dry bulk carriers are operated in tramp market which usually has no fixed routes. So there are no necessities for dry bulk shipowners to plan operation routes and to decide how many vessels are allocated on each route. However, before signing a time charterparty, the shipowners still need to consider whether the carrier can collect cargoes on its returning voyage. According to the estimation of cereal trade gravity model, the shipowners can choose the charterers whose destination country may have abundant cereals to export. So the shipowners may avoid ballast voyages and reduce their voyage costs.

5.2 Limitations of the cereal trade gravity model

The gravity model of cereal trade has been tested by SPSS and verified some relations between cereal trade and other variables. However, as an uncertain area, forecasting methods often have some limitations. So does the gravity model of cereal trade.

5.2.1 Short forecasting period

According to the gravity model, the estimation of cereal trade value is depending on the availability of other variables. Except for the certain value of distance between countries and the area of countries, other independent variables in the gravity model of cereal trade are changeable. In order to predict the cereal trade by this model, the variables such as GDP of exporters and importers, population and exchange rate vis-à-vis US dollar shall be estimated first. And the estimated results will affect the accuracy of the model. Furthermore, even if these variables have been precisely reckoned, the forecast period will be short. It is because the expected values of the variables, for example the GDP, are usually issued by relevant government authorities only one year in advance. As a result, the cereal trade can be predicted just of the next year.

5.2.2 Inconsistency of measurement unit between trade and shipping

In the gravity model of this paper, the cereal trade is measured by trade value which is expressed in US dollars. However, shipping activities is usually measured by tonnage. Therefore the fluctuation of cereal price shall also be taken into consideration. Then the volume of traded cereal can be detected. As a result, solely value of cereal trade cannot express the demand for sea transport precisely. Furthermore, the ton miles are usually used as the measure of demand. It is because the seaborne demand is affected by the distance over which the cargo is shipped. If the volume of cereal trade, together with the ton miles of the routes the cereal are carried over, can be used in this gravity model, the result may be more reliable. However, the volumes of the cereal trade are unobtainable. And it is so difficult to identify how many cereals on earth are transported over each route. Consequently, there is no alternative but using the value of cereal trade as the dependent variable in this gravity model, substituting the ton miles of the cereal transport.

5.2.3 Ship size

Dry bulk carriers are rather versatile vessels which can be used to carry different types of cargoes. Cereal grain, as an agricultural commodity, is seasonal traded. Both volume and routes of cereal trade are irregular so that cereal grain transport by sea depends heavily on general-purpose vessels.

Therefore, the demand for grain transport service will be satisfied by other section of the dry bulk market. Meanwhile, the seaborne demand of other dry bulks will consume the seaborne supply of grain trade section. As the amount of other dry bulks trade will influence the supply of transport service for grain, solely predicting the grain trade is not enough for arranging the supply of dry bulk transport service. Other dry bulks shall be considered.

5.2.4 Unavailable data

Grains are agricultural commodities which grow depending on atmospheric conditions. For example, wheat grows best where is humid and the daytime temperature is about 30 degree with long days. For corn, the best temperature range is 20 to 30 degree. The moisture and temperature of a country will decide the grains yield which will further affect the grains export or import of this country. Therefore, if possible, the rainfalls and temperature shall be incorporated in the group of depending variables of the cereal trade gravity model. And the correlation of the model variables may be improved. Nevertheless, it is very difficult to acquire the statistics of the natural condition data. The rainfalls and temperature differ in different seasons and vary from north to south, from west to east, especially for the countries with vast land. So these natural conditions were not quantitatively analyzed in this paper.

Apart from the unavailable natural condition data, the economic data such as GDP, GDPPC of some major exporters (e.g. Argentina) or importers (e.g. Iran, Egypt, and Algeria) cannot be obtained either. All the data of GDP, GDPPC, population, population growth rate and exchange rate are collected from OECD statistical database. So the data of most countries not belonging to OECD are not in this database. These economic data can be found in some unofficial websites, but they may be unreliable. In order to keep the reliability and consistency of the data, there is no choice but deleting these countries from the country list. If the official data of these countries are available, the result of the model testing may be better.

6. CONCLUSIONS AND FUTURE RESEARCH

6.1 Conclusions

The gravity model has been extensively used in trading research. This paper also develops gravity models as predictive method. The GDP, population, population growth rate, exchange rate and area of cereal exporters and importers as independent variables are incorporated in this model. Besides, the distance between exporters and importers is a crucial independent variable which represents the transport cost. And the cereal grain trade value between two countries is the dependent variable. After deciding the dependent and independent variables and collecting all related data, the statistical analysis software SPSS was used to analyze these data. The result of this model is not perfect with the “R Square” equalling to 0.439 nevertheless it does work. The level of “R Square” is comparatively good, so the gravity model of cereal grain trade fits the collected data. According to the results of SPSS, the cereal grain gravity model has been expressed by a gravity equation. Distance, which coefficient equals to -1.798, lays the most significant impact on cereal trade. The longer between the two countries, the less cereal they trade. The variables with second and third important influence are GDP of exporters (1.548) and population of exporters (-0.809) respectively. It means that economic level and population are important factors affecting the cereal trades. The richer countries will export more cereals and the countries with a large population will export fewer grains. And the remaining variables have minor influence on cereal trades with absolute values of coefficients equalling to from 0.002 to 0.761.

This gravity model will provide managerial implications for shipowners. By the prediction of cereal trade, the dry bulk seaborne demand can be estimated. So the shipowners can arrange supply of sea transport service according to the result derived from this gravity model of cereal trade. However, data availability is crucial for this predictive technique so that limitations exist with this model. If the data of dependent variables are unavailable and unobtainable, this forecaster can provide some qualitative suggestions only. And other parts of the dry bulk market shall be thought over.

It shall be noted that no forecasting tool can guarantee the accuracy of its predictions. Any sudden occurrence will enhance the uncertainty to this model. As a result, this gravity model of cereal trade just can be used to make a reference for the changes of dry bulk seaborne demand, not the judgment standard of demand variations.

6.2 Future research

This study has provided a method of forecasting dry bulk seaborne demand derived from international cereal grain trade. However, it is just a beginning. First of all, this gravity model of cereal grain trade is not a perfect one and still can be improved. Some other factors which have impacts on the grain trade may be taken into this model in the future. Nevertheless, because of limited time and accesses to data sources, the model cannot be improved at this moment.

Besides, in the dry bulk shipping market, the transport services by sea are not merely demanded by grain trade. Iron ore and coal are the other two major dry bulks in the market and even take a larger percentage of seaborne transport than grain. In order to predict the whole seaborne demand in dry bulk shipping market, the demand for sea transport capacity derived from other major dry bulks shall be taken into consideration. So the demands caused by iron ore and coal trades can be studied respectively in future research. Then the overall demand for dry bulk transport capacity can be estimated by integrally considering the international trades of the three major dry bulks.

Apart from the demand aspect, the supply aspect of the dry bulk market shall also be studied. The second-hand ship market will not affect the whole seaborne supply, so the newbuilding market and the scrap/demolish market shall be chosen as the main study objective. Future research may start from the factors which may affect the shipowners' supply decisions. For example, the freight rate market, the steel price, ship financing methods, and so on.

In the end, the changing modes of seaborne demand and supply in dry bulk shipping market will be identified. The participants in the maritime transport market can plan their operations according to the results of these studies in order to maximize their profits and stabilize the market.

Further research is needed. The model is readily extended from value to volume of trade. While GDP and GDPPC are used in this study, the Purchasing Power Parity (PPP) may be a better indicator.

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