Determinants of China's seafood trade patterns

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Abstract

China is the world’s largest seafood exporter, with rapidly increasing exports primarily based on an increasing aquaculture production. Hence, analyzing patterns for China’s seafood trade are of great importance. In this study, gravity models were estimated for various product forms to investigate the impact of economic factors such as GDP, income, distances, per capita seafood consumption, regional trade agreements (RTA), and continental locations on seafood trade. The results of the model indicate that there is substantial variation in trade patterns across product categories. Furthermore, the forms of live and fresh seafood are a separate group for which trade is significantly affected by distance, income, and status of “developed country,” while GDP and continental dummies play an essential role in the trade of products in other forms.

Keywords: seafood trade, augmented gravity model, China, various product forms, trade polices

1. Introduction

Seafood is one of the most traded food products, accounting for about 9% of global agricultural food exports. In 2015, the global trade of seafood reached 36.9 million tonnes with a value of $133.3 billion (FAO, 2016), and it is estimated that 78% of seafood products are exposed to international trade competition (Tveteras et al., 2012). China is the world’s largest producer and exporter of seafood. In 2015, Chinese exports accounted for 15% of global seafood exports with a value of $19.9 million, which was shipped to over 160 countries. The seafood exports are also important for China, as seafood products ranked first by value among all food products (China fishery statistical yearbook, 2016). China’s seafood exports are heterogeneous, composed of multiple species and product forms, varying from unprocessed products such as frozen whole fish to value-added processed products such as fish fillets and prepared fish, crustaceans, and molluscs. The trade patterns have changed in recent decades, as growth rates differ across product forms. In particular, the export value of processed products remained stable, while that of frozen whole fish was expanding at the very high annual growth rate of 19.5%. As a consequence, the share of processed products decreased from 73.9% to 53.6%.

This paper investigates the development in Chinese trade patterns of seafood by estimating gravity models for various product forms. The gravity model is the workhorse in the international trade literature when investigating trade patterns. There are numerous examples of applications of this model to analyze trade patterns for other food products (Sarker and Jayasinghe, 2007; Emlinger et al., 2008; Karemera et al., 2009; Cardamone, 2011; Haq et al., 2012). However, despite the importance of trade in the seafood market, there are few applications to seafood. The few exceptions primarily investigate two types of questions regarding seafood trade: 1) Determinants of trade on some specific species such as shrimp (He et al. 2013) and catfish, basa, and tra fish (Rabbani et al. 2011), or 2) the impact of food safety standards and non-tariff measures on trade flows (Anders et al. 2006; Nguyen and Wilson, 2009; Liu et al., 2011; Tran et al., 2013; Shepotylo, 2016). The gravity model also allows the investigation of the impact of factors such as transportation costs, size of economy and wealth level on China's seafood exports. This is potentially important as there is an indication of a preference for high-value and high-quality seafood in developed countries (Swartz et al., 2010; Asche et al., 2015), while people in poor countries have tend to import more affordable low-value seafood (Beveridge et al., 2013).

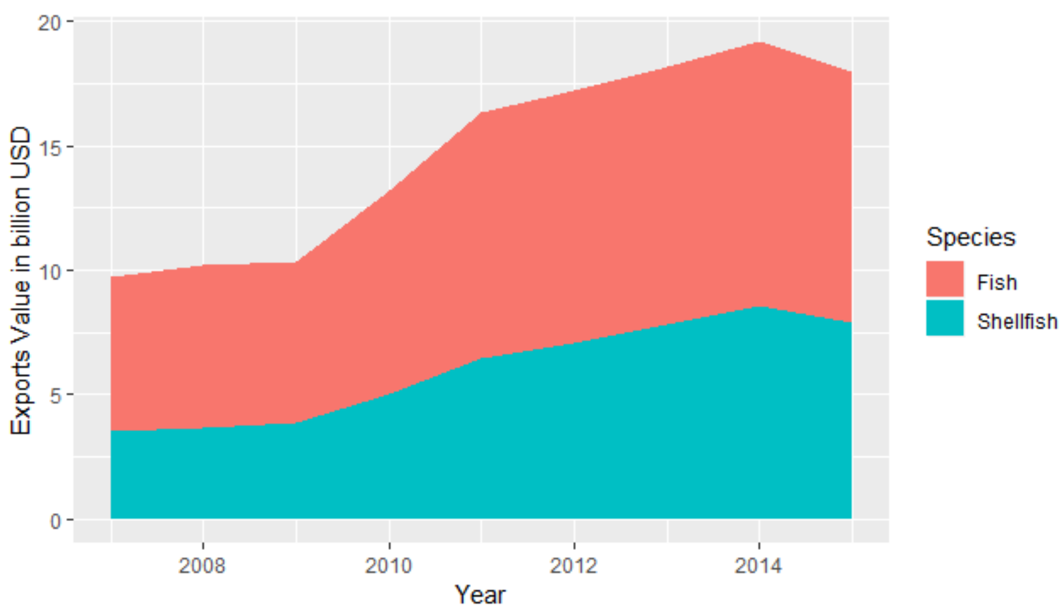
The rest of this paper is organized as follows. Section 2 introduces the data used and presents descriptive statistics of trade flows. Section 3 gives a brief literature review of China's seafood industry and discusses model specifications. Section 4 reports the empirical results. Section 5 draws some conclusions.

2. Industry and data

The export value of Chinese seafood has doubled during the last decade (Figure 1), largely associated with a fast growth in production. China's seafood production increased from 56.1 million tonnes in 2007 to 79.4 million tonnes in 2015. Around 90% of the expansion of production is contributed by aquaculture (Figure 2), while capture production has remained almost constant during this period.

Figure 1

Exports value of fish and shellfish (billion US$), 2007-2015.

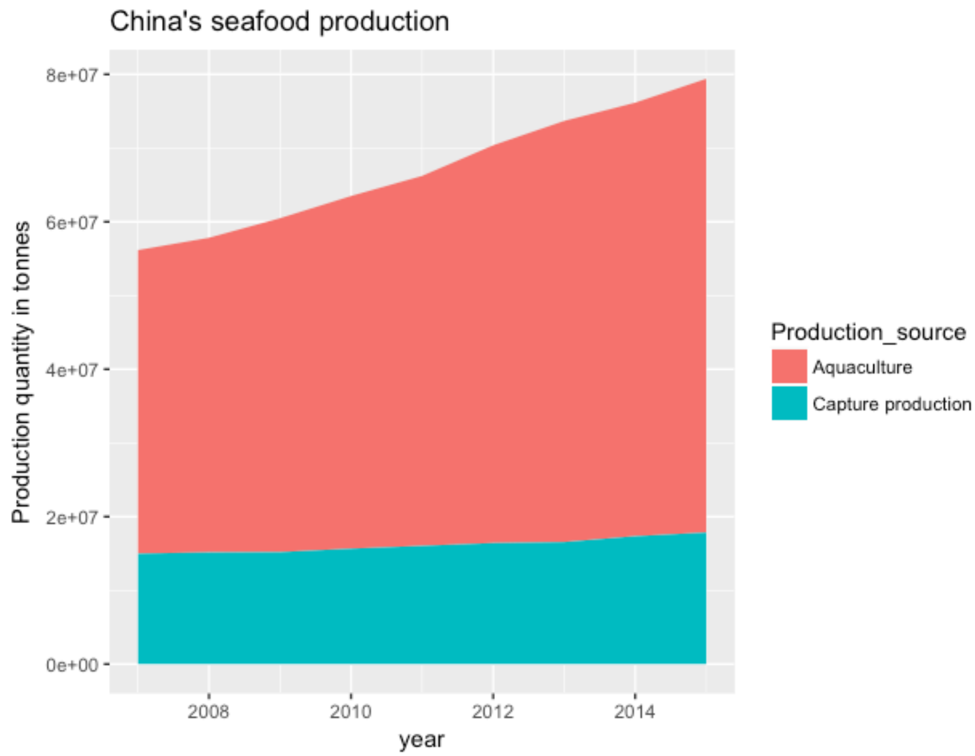


Source: FAOSTAT Database.

Note: The export value is deflated by the U.S. CPI.

Figure 2

China's seafood production by production source in quantity (tonnes), 2007-2015.



Source: FAOSTAT Database.

Data for China's seafood exports for period 2007-2015 is obtained from the UN COMTRADE database. This database provides information on the destination country, quantity, and value (in US$ at current prices) for each commodity classified according to the Harmonized System (HS) 2007 nomenclature at six digits in each year[1]. We deflate export values by the U.S. CPI, which comes from the World Bank. Seafood products in this study are collected at the two-digit HS level from section 03 (Fish and crustaceans, molluscs and other aquatic invertebrates) and four-digit HS code section 1604 (Prepared or preserved fish; caviar and caviar substitutes prepared from fish eggs) and 1605 (Crustaceans, molluscs and other aquatic invertebrates, prepared or preserved).[2] The

[1] HS codes have been revised in 2012. UN COMTRADE database converts data that is recorded in HS 2012 to HS 2007.

[2] Ornamental fish and by-products including livers, roes, caviar, caviar substitutes, and

sample used in this study covers 13,676 observations and 198 trading partners. Figure 1 presents export values of respectively fish and shellfish in period 2007-2015. The figure clearly shows a strong increasing trend in exports for both categories. Export values of fish reached 10.76 billion USD in 2015, compared to 5.70 billion USD in 2007. Export values of shellfish rose to 8.58 billion USD in 2015, which is more than double of the amount in 2007.

Fishery products are classified into five main product forms: live, fresh, frozen, prepared, and dried, salted, smoked; crustaceans are classified into three product forms: prepared, frozen, and fresh[3]. Similarly, molluscs are classified into three product forms: prepared, conserved, and live, fresh or chilled. Frozen, dried, salted or in brine, and smoked molluscs are grouped and defined as conserved molluscs. The composition of two processing categories, prepared and dried, smoked, salted, are somewhat more complex than others. Firstly, there are various methods of preparation and preservation of seafood such as breading, battering, canning, etc., leading to a wide range of product values. The dried, salted, smoked fish category is also a mixture of both high-value (e.g., smoked salmon) and low-value products (e.g., salted anchovies). Current dataset employed by our study does not allow us to differentiate them at a very detailed level, while the results will still fairly shed light on how factors affect trade across product forms.

Figure 3

Exports value of fish by product form (billion USD), 2007-2015.

fish meal are excluded in this study.

[3] The category of fresh crustaceans includes live, fresh, dried, smoked, and salted crustaceans.

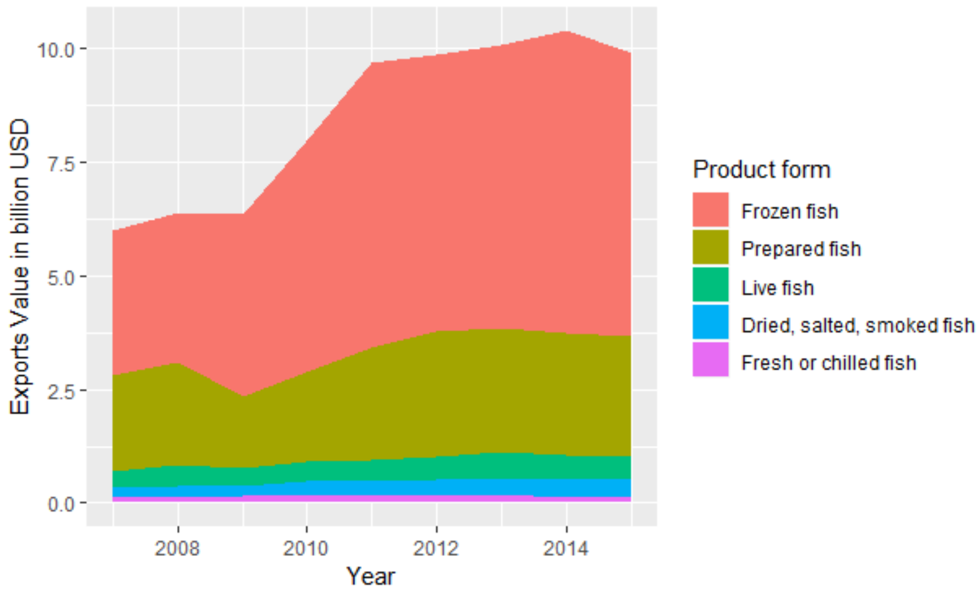


Figure 4

Exports value of shellfish by product form (billion USD), 2007-2015.

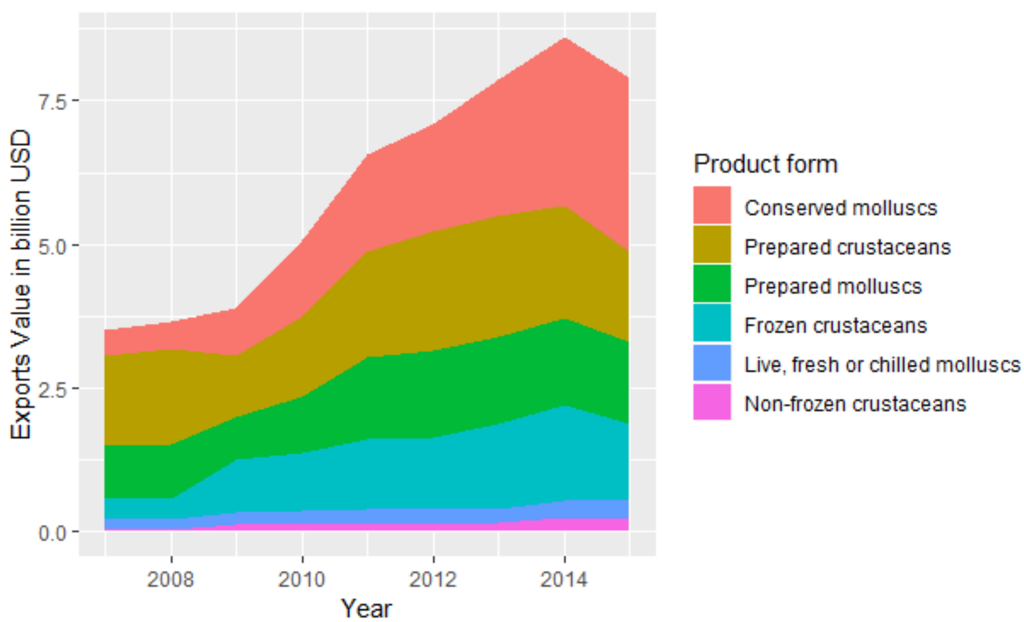


Figure 3 and 4 present export values of fish and shellfish by product form respectively. Figure 3 indicates that the frozen is the most important product form, accounting for over 60 percent of the fish exports. The export of frozen fish has more than doubled from 2007 to 2015, making a significant contribution to the total growth of fish exports. For shellfish, the export of conserved molluscs has increased rapidly from 0.4 billion USD in 2007 to 3.3 billion USD in 2015. It has surpassed prepared crustaceans and become the most important shellfish product form. Furthermore, the export of frozen crustaceans has more than tripled in the past decade. The increases in those two products have led to a decline in the export shares of all shellfish products in other forms except for fresh crustaceans.

Figure 3 shows that export value of prepared fish has remained stable since 2012 and accounted for 26.8 percent of total exports of fish in 2015. Similarly, export values of prepared crustaceans and molluscs make up 38.0 percent of total shellfish exports in 2015 (Figure 4), but has also remained stable. The importance of prepared products is most likely due to the comparative advantage in abundant labor endowment at a low-cost level. Based on a national sample survey of fishermen's household income and expenditures, Chinese fishermen's average per capita net income was 15,594.8 CNY (around 2,500 USD) in 2015. Although this number has more than doubled since 2007, compared with the average annual income of fishermen in Norway in 2012 which is EURO 50,163 (around 66,215 USD) (Nielsen et al., 2017), labor cost in China is still quite low.

Japan, the United States, and the European Union (EU) are three largest export destinations for China's seafood. However, it is worthwhile to note that the export shares to these three main markets have declined significantly in period 2007-2015. Exports to Japan have declined the most with 12.06 percentage point, followed by EU (5.42 percentage point) and U.S. (3.34 percentage point). Hence, other markets are increasing in importance, in line with the general development in the seafood trade (Asche et al, 2015).

Table 1 shows the share of total export values in top three largest destinations by product form in 2007 and 2015. For all product forms, the largest three markets imported more than half of total exports in 2007, while export shares to the main markets have declined particularly in frozen fish, conserved molluscs, and frozen crustaceans. The regional patterns of some products such as frozen fish, prepared fish, dried, salted, smoked fish, and prepared crustaceans are fairly stable. The EU, Japan, and the U.S. remain to be the largest markets for frozen fish and prepared crustaceans, while Japan and the U.S are two important markets for prepared fish. Korea, the U.S., and the EU are the main partners for dried, salted, smoked fish exports. However, the regional patterns have changed, and new partners have emerged for other categories including conserved molluscs, prepared molluscs, and frozen crustaceans. Thailand has taken over Japan and become the largest importer of conserved molluscs with a share of 20.01%. The imported conserved molluscs including squid, cuttlefish, scallop, etc. are used both for local consumption and as raw materials for re-processing (Infofish, 2013). Low labor cost in Thailand contributes to the development of processing industry and allows low-value products to be processed into high-value products for re-export. Hong Kong and Unspecified Asian countries have taken over the U.S. and Korea for prepared molluscs and taken over Korea and the EU for frozen crustaceans, then become main trading partners.

The export values of live and fresh seafood (Figure 3 and Figure 4) have shown an increasing trend. It is associated with the expansion of preferences for high-quality seafood with freshness being a significant factor (Roheim et al., 2007). Over 90% of live and fresh fish are exported to Hong Kong, Korea, Japan, and Unspecified Asian countries, which are wealthy and located in close geographic proximity with China. A similar trade pattern could also be applied to live, fresh or chilled molluscs and fresh crustaceans. For other major destination of China's seafood such as the United States, air transport is employed as the only suitable mode of transportation for live and fresh seafood, making China less competitive compared with Latin American countries due to high transportation costs (Asche, 2008).

Table 1

Share of total export value in largest destinations by product form (%).

Product form	Largest markets	2007	Total share	Largest markets	2015	Total share
Fish						
Frozen fish	EU	31.14	71.45	EU	18.56	52.09
	United States	22.13		United States	18.37	
	Japan	18.18		Japan	15.16	
Prepared fish	Japan	42.87	72.89	Japan	31.23	58.07
	United States	22.04		United States	20.37	
	Russian Federation	7.98		Hong Kong	6.47	
Live fish	Korea, Rep.	43.11	97.20	Hong Kong	43.78	96.18
	Japan	32.47		Korea, Rep.	26.67	
	Hong Kong	21.61		Japan	25.74	
Dried, salted, smoked fish	United States	22.46	63.61	Korea, Rep.	19.44	51.34
	EU	21.67		United States	17.60	
	Korea, Rep.	19.48		EU	14.30	
Fresh fish	Hong Kong	39.10	95.45	Hong Kong	63.19	91.67
	Japan	30.60		Unspecified Asia	24.31	
	Korea, Rep.	25.74		Korea, Rep.	4.17	
Shellfish						
Conserved molluscs	Japan	26.77	66.57	Thailand	20.01	43.53
	United States	22.57		United States	12.00	
	Korea, Rep.	17.23		Hong Kong	11.52	
Prepared crustaceans	United States	23.54	57.29	United States	29.96	51.73
	Japan	20.66		Japan	10.94	

	EU	13.10		EU	10.83	
Prepared mollucs	Japan	54.23	75.69	Japan	31.13	58.12
	United States	11.78		Unspecified Asia	14.48	
	Korea, Rep.	9.69		Hong Kong	12.51	
Frozen crustaceans	Japan	30.39	78.38	Hong Kong	22.12	51.04
	Korea, Rep.	25.35		Japan	15.23	
	EU	22.64		Unspecified Asia	13.69	
Live, fresh or chilled molluscs	Japan	47.18	93.03	Korea, Rep.	64.65	91.63
	Korea, Rep.	41.57		Japan	17.32	
	Hong Kong	4.28		Hong Kong	9.66	
Fresh crustaceans	Hong Kong	43.67	78.70	Hong Kong	31.95	79.29
	Japan	18.09		Unspecified Asia	25.96	
	Korea, Rep.	16.94		Korea, Rep.	21.39	

Figure 5

Distribution of fish exports over destination markets, 2007-2015.

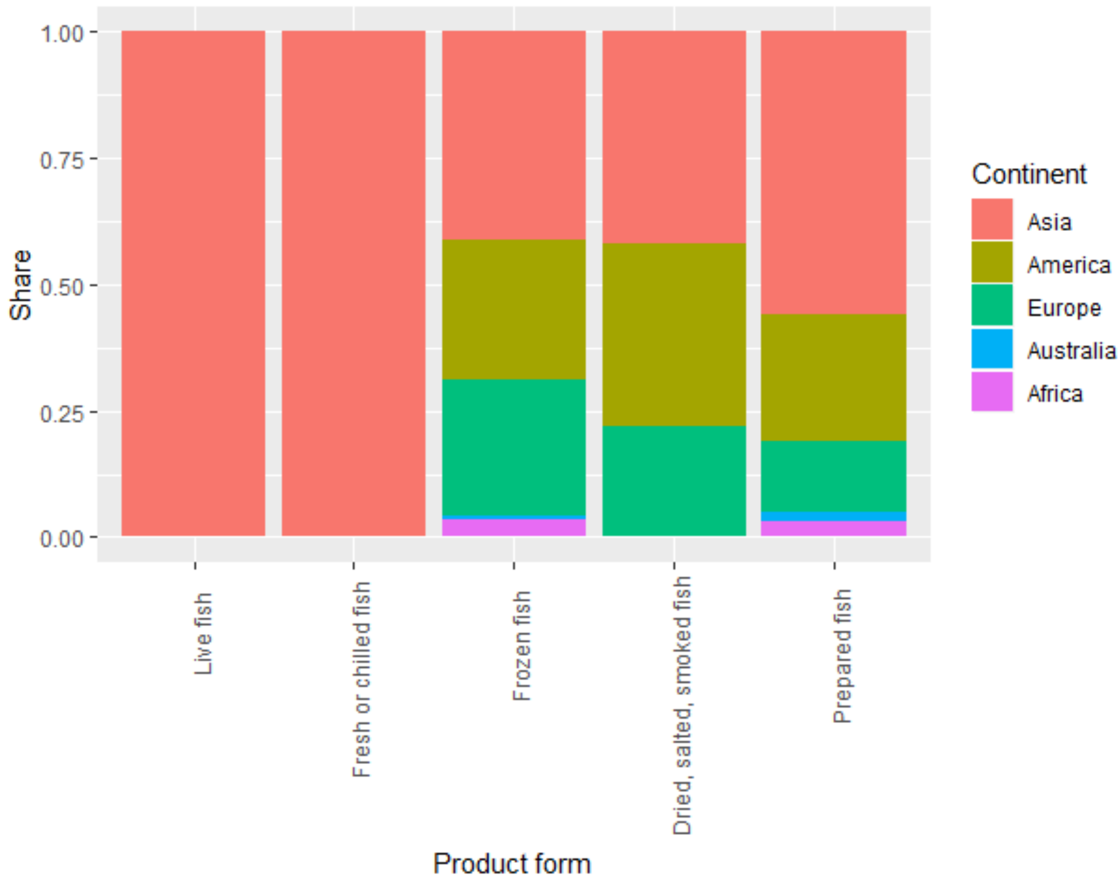


Figure 6

Distribution of shellfish exports over destination markets, 2007-2015.

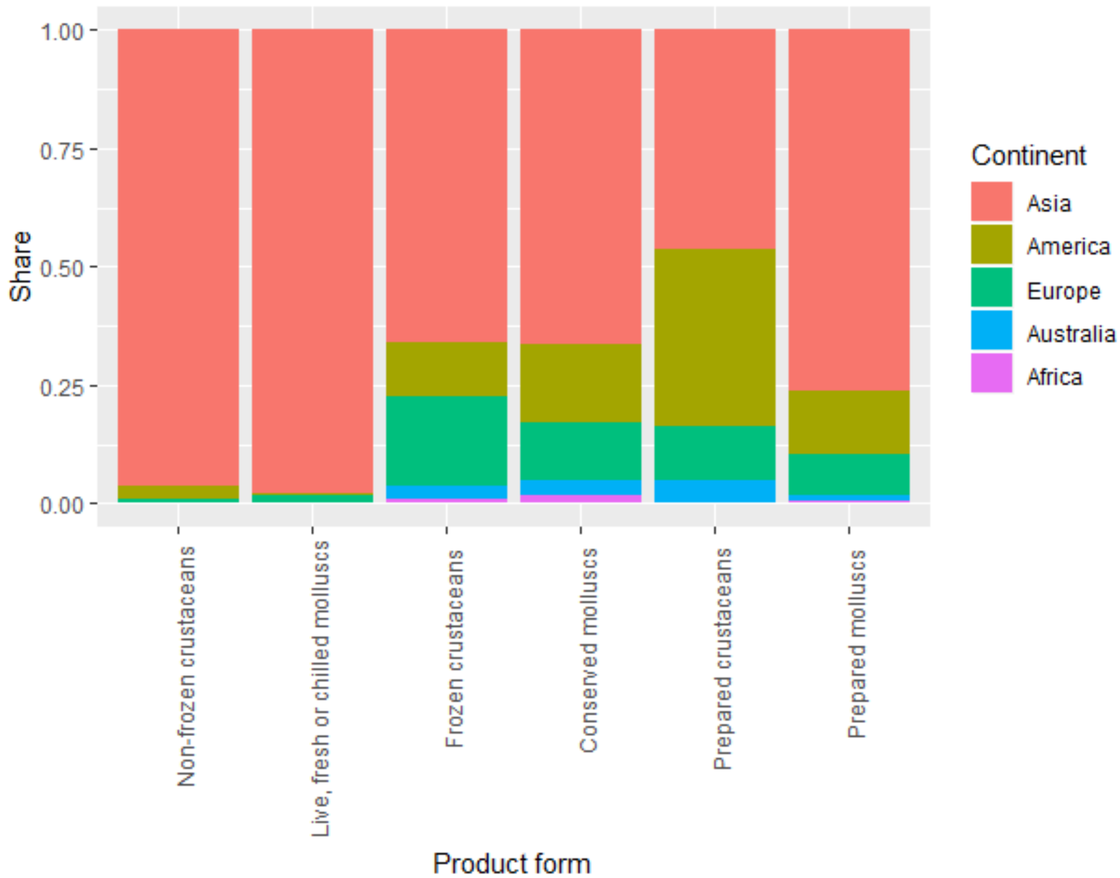


Figure 5 and 6 report distribution of fish and shellfish over destination markets by product form respectively. Overall, Asia is the most significant destination market with an export share of 55.94 percent, while America and Europe rank as the second and third leading destination markets with a share of 23.06 percent and 17.17 percent over the sample period. Exports to Africa and Australia only account for 2.06 percent and 1.79 percent respectively.

Exports of live and fresh products are exceptionally highly concentrated with over 95 percent of those goods exported to Asian countries, indicating the importance of distance for these product categories, possibly together with cultural preference. The U.S. seems to play a more significant role in importing conserved fish products, as well as prepared crustaceans than at the aggregation level. Shares of frozen fish, dried, salted, smoked fish, and frozen crustaceans received by the EU are higher than at the aggregation level.

America and Europe are the largest importers of frozen fish fillets, indicating a demand for convenient and easy-prepared food in countries with high-income levels and high labor-market participation of housewives.

It is worthwhile to note that Africa has the lowest importing price of all other products. Africa is the second largest market of China's frozen whole fish by value, while its importing price is less than half of the price paid by the U.S. over the sample period ($1.38 in Africa vs. $3.02 U.S.A). A similar situation exists for prepared fish where the African import price is $2.15 while it is $5.39 in Europe. This suggests that the quantity shares to Africa are significantly higher than the value shares. Given price is a representative of quality, China primarily exports lower-quality products to African markets.

As for gravity model variables, data of GDP, GDP per capita, and population are obtained from the World Bank. Geographic distances and continents are obtained from CEPII database. Per capita consumption of different countries is computed using FAO production data and the U.S. population statistics. The list of developed countries is shown in appendix 1. The data on RTAs is acquired from WTO RTA database.

3. Methodology

The gravity model, which was first introduced by Tinbergen (1962), has been widely used to analyze trade flows of various products at different aggregation levels across countries and regions. Its basic idea is that bilateral trade between two markets is proportional to their economic sizes and inversely proportional to the distance between them. The bilateral distance between the exporter and the destination market is usually employed as a proxy of transportation costs. The gravity model has been extended by employing additional explanatory variables, including the regional trade agreements

(RTAs) (Frankel and Rose, 2002; Feenstra et al., 2001), per capita GDP (Rose, 2000; Breuss and Egger, 1999), continent dummies (Magerman et al, 2016), etc. Kepaptsoglou et al. (2010) conduct a comprehensive summary with a list of the variables that have been applied to the gravity model. They also find that the gravity model is successful in investigating trade flows due to its empirical robustness. The gravity model has been applied to a wide variety of food products (Sarker and Jayasinghe, 2007; Karemera et al., 2009; Natale et al., 2015; Cardamone, 2011; Emlinger et al., 2008; Haq et al., 2012).

For the studies regarding seafood trade, He et al. (2013) examine the determinants of the U.S. shrimp imports from China, Thailand, Indonesia, and Vietnam using the augmented gravity model. They find that imports of shrimp in the U.S. depend on the tariff, GDP, and exchange rate. Rabbani et al. (2011) employs the augmented gravity model and study the determinants of catfish, basa and tra imports to the U.S. They conclude that per capita GDP, population, and import prices affect import values, while significance and magnitude of effects are varied across the country of origin. Tran et al. (2013) assess the impacts of food safety (chemical) standards on seafood exports to Japan, EU, and the U.S. with the gravity model. Increasing the stringency of regulations is found to have negative impacts on trade flows. They compare different specifications of gravity model but conclude which approach is the best one remains inconclusive. Natale et al. (2015) investigate the determinants of global seafood trade by applying the gravity model to different aggregation levels of commodities. Their results show that seafood exports are driven by high seafood preferences or advantages in low labor cost for further processing. They also attribute seafood expansion to aquaculture production growth and trade for re-processing. Shepotylo (2016) explores the extensive and intensive margins of global seafood exports for the period 1996-2011. He finds that standard gravity-type variables such as shipping costs, GDP, and RTAs have a significant impact on exports with expected signs. He emphasizes the heterogeneous effects of non-tariff measures and the different magnitude of effects across products.[4]

As indicated above, it is increasingly common to augment the gravity model with variables capturing specific features relevant for the specific case one are addressing, and that is also of importance in this paper. Per capita GDP is included in the model as a proxy for the wealth level in the destination market. This is nuanced by also adding an interaction term of developed country and per capita GDP to distinguish the impact of wealth in developed and developing countries. The variable per capita consumption of seafood is used to capture the strength of preference for seafood consumption traditions in the destination market.

RTAs are reciprocal trade agreements between two or more partners, including free trade agreements and customs unions. A binary variable RTA is employed in the gravity model to capture the difference in China’s trade with RTA members and non-members. Some authors claim that RTAs between China and importing countries could promote bilateral agricultural trade by improving resource allocation efficiencies and reducing trade barriers (Yang and Martinez-Zarzozo, 2014; Qiu et al., 2007). However, there is less consensus in previous studies on the significance and magnitude of such effect since RTAs have different characteristics and cover various groups of commodities. A set of continental dummies are used to measure the border effect which is also a proxy of trade costs. The empirical literature on border effects finds that the direction and magnitude of border effects are sensitive to the estimation methods and also change gradually. Anderson and van Wincoop (2003) find the border effect is always negative. In contrast, Magerman et al. (2016) indicate that some open economies like Europe trade more with global markets than with intra-continental countries, while Australia trades more inside

4 Although not quite a gravity mode, Straume (2017) use the gravity variables to explain trade duration.

than with global markets. As we will discussed in detail in section two, trades of live fish, fresh fish, fresh crustaceans, and fresh molluscs are highly concentrated in Asia. Therefore, continental dummies are not included in regressions of those four categories.

The augmented gravity models estimated in this paper has the following specification:

$$\ln(X_{jt}) = \beta_0 + \beta_1 \ln(GDP_{jt}) + \beta_2 \ln(dist_j) + \beta_3 \ln(GDP/capita_{jt}) + \beta_4 DE * \ln(GDP/capita_{jt}) + \beta_5 \ln(cons/capita_{jt}) + \beta_6 RTA_{jt} + \beta_7 Europe + \beta_8 America + \beta_9 Australia + \beta_{10} Africa + \sum_t \gamma_t D_t + \epsilon_{jt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where X_{jt} is the export value of seafood from China to the destination market j in period t. The definition of the variables can be found in Table 2.

Table 2

A description of independent variables included in the gravity model.

Explanatory variables	**Description**
GDP_j	(Real) Gross domestic product (GDP) of the importing country j
$dist_j$	Bilateral distance between China and the importing country j (kilometers) [5]
$GDP/capita_j$	(Real) GDP per capita in the importing country j[6]
DE	Binary variable, equals 1 if country j is a developed country
$cons/capita_j$	Per capita consumption of seafood in the importing

[5] Bilateral distances are calculated with the great circle formula, which uses latitudes and longitudes of the most important cities of two countries in terms of population.

[6] Real GDP and GDP per capita are denominated in constant US$ (2010).

	country j (kg per capita)
RTA_{jt}	Binary variable, equals 1 if country j is a member of China's regional trade agreements
Europe	Binary variable, equals 1 if country j is located in Europe
America	Binary variable, equals 1 if country j is located in North America or South America
Australia	Binary variable, equals 1 if country j is located in Australia
Africa	Binary variable, equals 1 if country j is located in Africa
D_t	Dummy variable of the year

In recent years, the fact that there are zero trade flows in many potential trade relationships has received particular attention. Silva and Tenreyro (2006) emphasize that heteroskedastic residuals and zero trade flows could lead to severely-biased estimates for parameters. There are several methods proposed in to deal with zero observations: 1. Ignoring all zero trade flows (Frankel and Rose, 2002; Anderson and Van Wincoop, 2003); 2. replacing the zero with a small number (Van Bergeijk and Oldersma, 1990; Wang and Winters, 1991; Raballand, 2003); 3. Using the Tobit model (Eaton et al. 1994; Soloaga and Winters, 2001); 4. Using Poisson family regressions (Silva and Tenreyro, 2006; Burger et al., 2009); 5. using the Heckman sample selection model (Wooldridge, 2002; Helpman, Melitz & Rubinstein, 2008). Based on formal statistical tests, Martin and Pham (2008) and Burger et al. (2009) conclude that the choice of the best model specification to treat zero trade flows and heteroskedastic issues is inconclusive. In this study, Poisson Pseudo Maximum Likelihood (PPML) is employed to estimate the gravity model. Year dummies are included in the model to capture all the time-variant effects of China that are omitted from model specifications, such as China's seafood production and economic conditions. Therefore, I specify the empirical model as:

$$X_{jt} = \exp\{\beta_0 + \beta_1\, ln(GDP_{jt}) + \beta_2\, ln(dist_j) + \beta_3\, ln(GDP/capita_{jt}) + \beta_4 DE * ln(GDP/capita_{jt}) + \beta_5\, ln(cons/capita_{jt}) + \beta_6 RTA_{jt} + \beta_7 Europe + \beta_8 America + \beta_9 Australia + \beta_{10} Africa + \sum_t \gamma_t\, D_t + \epsilon_{jt}\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

4. Empirical results

Table 3 and 4 present the results from the gravity models grouped by product form. As one can see, with the exception of frozen fish all regressions have an R^2 higher than 0.4, suggesting a relatively good fit.[7] The relatively low R^2 of frozen fish is most likely attributed to the large number of heterogeneous products within this category. To get a better understanding of the trade pattern for the frozen fish category, separate regressions are conducted according to their processing stages, and results are reported in table 5 bellow. Most of the parameters in tables 3 and 4 are statistically significant and have expected signs. Moreover, the impacts of most variables vary with product form, providing a clear indication that trade patterns are not identical across product forms.

The magnitude of distance parameters ranges from -0.680 to -2.423 for fish and from -0.238 to -3.330 for shellfish. Distance is particularly important for live and fresh fish, fresh molluscs and fresh crustaceans. Hence, high transportation costs of live and fresh products can to a large extent explain their small proportions in total exports and high concentration in East Asia. Lower values on the distance variable are reported for other

[7] Multicollinearity was tested by computing variance inflation factor (VIF). All VIF values are below 5 with the exception of GDP per capita (6.05) and the interaction term (5.04). But it is still within the limit of 10, suggesting this model is not suffering serious multicollinearity issues.

fish products, frozen crustaceans, and prepared molluscs, indicating that distance is less important for these products. Finally, insignificant coefficients for conserved molluscs and prepared crustaceans indicate that exports of those products do not seem to be affected by distance. The sign of coefficients for GDP is positive and statistically significant in all cases, which is in line with the assumption that larger economies trade more. The magnitude of the relationship is relatively smaller for live and fresh products compared with other commodities.

The role of the income level in a country also varies significantly. Most trade flows increase with increased income, but to varying degrees. Interestingly, dried, salted and smoked fish has a negative parameter while the effect is statistically insignificant for frozen fish. The significant negative impact of income on exports of dried, salted, smoked fish could be attributed to the fact that dried fish, which accounts for a significant proportion of exports in this category, are more consumed by poor countries due to its low-value characteristics (Dey et al., 2008). Also here, live and fresh fish and crustaceans are much more sensitive than the other variables, indicating that the main markets for these products are wealthy countries with a short distance from China. These results are in line with the findings of Asche et al. (2015) that people in wealthier countries have a preference for high-quality and high-value seafood.

The coefficients of per capita seafood consumption for all products are positive and statistically significant except for fresh molluscs. The impacts of RTA are ambiguous. They increase exports for live fish, fresh fish, frozen fish, and all shellfish with the exception of live and fresh molluscs, while there are negative effects of RTA on prepared fish. The relative effects of RTA are particularly high for live and fresh fish and fresh crustaceans.

Disregarding live and fresh fish, the continental dummies show that America seems to import more fish, whatever the level of processing, than Asia. The same applies to Europe with the exception of prepared fish. In the case of shellfish (excluding fresh crustaceans and fresh molluscs), the negative coefficients of Europe dummies indicate that exports of all shellfish face a border effect when entering the European market. For frozen crustaceans and conserved molluscs, a border effect also exists to the US. This is not too surprising given the trade tensions for shrimp (Keithley and Poudel, 2008).

As noted above, frozen fish has a low R^2, a feature that may be due to this being a large category containing several important subcategories. The data allows us to break down the frozen category by degree of conservation; that is into whole frozen, frozen fillets and frozen fish meat. The results from the gravity model in equation (2) estimated on these categories are reported in Table 5. As one can see, the R^2 are all improved relatively to the aggregated model, and there is substantial variation between parameters in the different categories. Of particular interest is it that the coefficient of Africa for whole frozen fish is significant and positive, indicating that whole frozen fish are much more important for Africa. It can be explained by Africa importing low-value whole frozen fish as affordable sources of protein. Africa's unit price in this product category is much lower than for the other continents. There is a positive and significant effect of income for frozen fish fillets, while the effect is significantly negative for whole frozen fish and frozen fish meat. The results indicate that frozen fish fillets are considered to be more valuable, thus are preferred by Europe and the United States. Given that frozen whole fish are imported and used for reprocessing by some importers, a lower income level reflects a comparative advantage in cheap labor, which enables those countries to process low-value frozen whole fish into higher-value products such as fillets.

5. Conclusion

This study investigated the determinants of China's seafood exports by estimating augmented gravity models for various product forms. As proposed by Silva and Tenreyro (2006), PPML is applied to solve the issues of zero trade flow and heteroskedastic residuals. Most of the parameters are statistically significant and have expected signs. Moreover, there is significant variation in trade patterns between the product categories. The results indicate that transportation costs and wealth level seem to be much more important for products with higher perishability, while the impacts are insignificant on some other products (e.g. conserved molluscs and prepared crustaceans). Furthermore, most trade flows are driven by increased income but with highly varied degrees. Of particular interest is it that dried and smoked fish has a negative income parameter, suggesting that these products are "inferior", and are primarily being exported to poor countries with limited ability to pay.

In general, the product forms live and fresh seafood are a separate group of which trade is significantly affected by distance and income level. This has significant implications for future marketing strategies as it suggests that wealthy Asian countries will hold the leading role in importing live and fresh seafood. Furthermore, the lower impact of GDP also suggests that demand for high-value seafood is not significantly driven by the size of the economy.

The role of continental locations is different across product categories. Europe and America provide China with more opportunities and larger markets for a number of fish products (e.g. frozen fish fillets and dried, smoked, salted fish), while they also face border effects for some other products. It is worthwhile to point out that low-value whole frozen fish is much more important for Africa than other continents as affordable sources of protein.

In contrast to the strong growth of frozen products exports, China's exports of processed products have remained stable in the past decade, suggesting that its role in re-exporting seafood is becoming less important.[8] It can be attributed to the fact that seafood processing industry is increasingly challenged by increases in labor and environmental costs (USDA, 2017). Therefore, there is a trend that China has limited potentials of processing seafood, although it has potentials of producing seafood as global demand growth. Meanwhile, countries with low labor cost, such as Thailand and Vietnam, has experienced a development of processing industry in the past decade.

[8] China took the lead in re-exporting seafood when freezing technology became good enough to allow seafood to be thawed and refrozen several times without a strong reduction in product quality, largely due to low labor cost and economies of scale (Anderson et al, 2017).

Table 3
Gravity model of China's fishery products exports by product form

	Dependent variable:				
	Trade flow				
	Live	Fresh	Frozen	Dried, salted, smoked	Prepared
	(1)	(2)	(3)	(4)	(5)
log (distance)	-2.423***	-1.379***	-0.680***	-1.193***	-1.238***
	(0.101)	(0.150)	(0.110)	(0.213)	(0.119)
log (GDP)	0.548***	0.466***	1.004***	0.676***	0.999***
	(0.058)	(0.086)	(0.034)	(0.051)	(0.037)
log (GDP per capita)	1.974***	1.737***	0.032	-0.400**	-0.029
	(0.256)	(0.429)	(0.086)	(0.167)	(0.092)
DE*log (GDP per capita)	0.311**	0.354	0.008	0.121***	-0.087***
	(0.134)	(0.220)	(0.017)	(0.035)	(0.018)
log (consumption per capita)	0.438***	0.517***	0.211***	0.411***	0.691***
	(0.061)	(0.094)	(0.051)	(0.087)	(0.057)
RTA	1.119***	2.786***	0.609***	-0.072	-0.992***
	(0.242)	(0.368)	(0.138)	(0.244)	(0.146)
Europe			0.467***	0.752**	-0.124
			(0.157)	(0.330)	(0.156)
America			0.674***	2.377***	1.080***
			(0.194)	(0.383)	(0.203)
Australia			-0.848*	-4.339	0.665**
			(0.462)	(5.612)	(0.327)
Africa			1.201***	-1.928	0.761***
			(0.244)	(1.473)	(0.258)
Constant	-6.478*	-13.654**	-8.895***	5.471**	-3.128*
	(3.752)	(5.705)	(1.652)	(2.592)	(1.739)
Observations	4,089	8,669	39,546	11,343	10,512

R^2	0.78	0.59	0.38	0.45	0.56
Year dummies	Yes	Yes	Yes	Yes	Yes
Note:					$^{*}p^{**}p^{***}p<0.01$

Table 4
Gravity model of China's shellfish exports by product form

	Dependent variable:					
	Trade flow					
	Fresh crustaceans	Live and fresh molluscs	Frozen crustaceans	Conserved molluscs	Prepared crustaceans	Prepared molluscs
log (distance)	-1.282***	-3.330***	-0.238*	-0.169	-0.056	-0.776***
	(0.080)	(0.182)	(0.126)	(0.110)	(0.121)	(0.163)
log (GDP)	0.378***	0.695***	0.908***	0.810***	0.814***	1.014***
	(0.043)	(0.095)	(0.050)	(0.039)	(0.037)	(0.064)
log (GDP per capita)	1.166***	1.504***	0.638***	0.214**	0.489***	0.705***
	(0.167)	(0.353)	(0.106)	(0.090)	(0.098)	(0.141)
DE*log (GDP per capita)	0.126***	0.120	-0.061***	0.047**	0.012	-0.072**
	(0.036)	(0.084)	(0.023)	(0.022)	(0.021)	(0.030)
log (consumption per capita)	0.397***	0.117	0.636***	0.474***	0.414***	0.612***
	(0.054)	(0.147)	(0.055)	(0.054)	(0.054)	(0.080)
RTA	2.353***	0.190	1.296***	1.220***	1.059***	0.482**
	(0.177)	(0.389)	(0.169)	(0.137)	(0.139)	(0.222)
Europe			-0.550***	-1.131***	-1.227***	-1.151***
			(0.194)	(0.183)	(0.192)	(0.241)
America			-0.904***	-0.462**	0.241	-0.399
			(0.246)	(0.204)	(0.208)	(0.296)
Australia			-0.174	-0.331	0.039	-0.454
			(0.315)	(0.267)	(0.252)	(0.439)
Africa			-0.167	0.118	-1.526**	0.080
			(0.512)	(0.334)	(0.709)	(0.611)
Constant	-2.809	3.693	-17.094***	-10.898***	-12.586***	-13.372***
	(2.643)	(5.914)	(2.378)	(1.808)	(1.777)	(3.130)

Observations	5,428	6,416	6,570	9,198	5,256	1,314
R^2	0.68	0.78	0.50	0.54	0.61	0.85
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Note:						*p**p***p<0.01

Table 5
Gravity model of China's frozen fish exports by product form

	Dependent variable:		
	Trade flow		
	Frozen fillets	Frozen whole	Frozen meat
log (distance)	-1.163***	-0.868***	-0.223
	(0.166)	(0.102)	(0.240)
log (GDP)	1.084***	0.790***	0.872***
	(0.037)	(0.031)	(0.074)
log (GDP per capita)	0.345***	-0.136**	-0.470**
	(0.130)	(0.063)	(0.185)
DE*log (GDP per capita)	-0.014	-0.040**	0.139***
	(0.021)	(0.018)	(0.047)
log (consumption per capita)	-0.190***	0.777***	0.578***
	(0.061)	(0.051)	(0.112)
RTA	-0.794***	0.885***	0.052
	(0.215)	(0.122)	(0.277)
Europe	1.114***	-0.935***	-1.367***
	(0.196)	(0.197)	(0.361)
America	1.318***	0.077	-1.189***
	(0.267)	(0.195)	(0.436)
Australia	-0.610	-0.278	-1.531*
	(0.542)	(0.393)	(0.783)
Africa	-0.545	1.805***	-2.215**
	(0.701)	(0.178)	(1.068)
Constant	-6.595***	-2.757**	-6.319*
	(2.227)	(1.295)	(3.499)
Observations	2,785	33,512	3,249
R^2	0.72	0.40	0.59
Year dummies	Yes	Yes	Yes
Note:			*p**p***p<0.01

Appendix 1

List of developed countries

Country	ISO3	Country	ISO3
Australia	AUS	Lithuania	LTU
Austria	AUT	Luxembourg	LUX
Belgium	BEL	Macau	MAC
Canada	CAN	Malta	MLT
Cyprus	CYP	Netherlands	NLD
Czech Republic	CZE	New Zealand	NZL
Denmark	DNK	Norway	NOR
Estonia	EST	Portugal	PRT
Finland	FIN	Puerto Rico	PRI
France	FRA	San Marino	SMR
Germany	DEU	Singapore	SGP
Greece	GRC	Slovakia	SVK
Hong Kong	HKG	Slovenia	SVN
Iceland	ISL	South Korea	KOR
Ireland	IRL	Spain	ESP
Israel	ISR	Sweden	SWE
Italy	ITA	Switzerland	CHE
Japan	JPN	United Kingdom	GBR
Latvia	LVA	United States	USA

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