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The Effects of Food Safety Standards on Trade and Welfare: The Case of EU Shrimp Imports

Xiaoqian Li
University of Kentucky, xlih@g.uky.edu

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THE EFFECTS OF FOOD SAFETY STANDARDS ON TRADE AND WELFARE: THE
CASE OF EU SHRIMP IMPORTS

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
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By

Xiaoqian Li

Director: Dr. Sayed Saghaian,

Associate Professor of Agricultural Economics

Lexington, Kentucky

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ABSTRACT OF DISSERTATION

THE EFFECTS OF FOOD SAFETY STANDARDS ON TRADE AND WELFARE: THE CASE OF EU SHRIMP IMPORTS

This research explores the link between a gravity model and welfare frameworks and then applies the quantitative model system to analyze how trade and welfare is affected by the Minimum Required Performance Limits (MRPL) in the shrimp importing market of European Union.

The quantitative model system consists of two parts: first, this study uses the "phi-ness" gravity model to investigate the trade effects of MRPL on EU shrimp market. The "phi-ness" gravity model partitions the standard variables to avoid biased estimation caused by the correlation between time and country fixed effects and policy variables. The Poisson Pseudo Maximum Likelihood (PPML) method is incorporated into the estimation in order to control for the zero valued observations.

Second, based on the theoretic foundation of the gravity model, this research sets up the specific nested Constant Elasticity of Substitution (CES) model of consumers' utility and further explores the linkage between these two models. The nested CES model incorporates the effects of MRPL on consumers' confidence in domestic food as well as foreign food imported from developed and developing countries.

The empirical results confirm a consistent fact with previous empirical studies: stricter MRPL has significant and negative effects on trade integration between EU and trading partners with lower level of food safety standards. The welfare analysis shows that the zero tolerance policy of MRPL standard would dramatically enhance consumers' demand for domestic shrimps and foreign shrimps imported from developed countries but reduce the quantity of shrimp supplied from developing countries. It is also indicated that the increased level of MRPL lead to an increase in welfare of domestic consumers, suppliers in developing countries, and in total international trade, as well as a decrease in the welfare of domestic suppliers and foreign suppliers from developed countries.

The empirical results also indicate that the combination of GM and Welfare Approach can also be applied to research on other standards or other industries.

Xiaoqian Li

December 3rd, 2014

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<div style="text-align:right">

_____Dr. Sayed Saghaian_____
Director of Dissertation

_____Dr. Michael Reed_____
Director of Graduate Studies

_____December 3rd, 2014_____

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CHAPTER ONE: INTRODUCTION AND BACKGROUND

1.1 Problem Statement

Food safety regulation issues are becoming increasingly important in the arena of international seafood trade. In order to protect their domestic consumers from potential health hazard, such as the residue of misused pesticide and antibiotics in seafood, most nations have standards to ensure the higher food safety. Since no country has jurisdiction over production outside of its borders, a country can regulate the products produced or entering its borders. Consumers therefore consume not only food from abroad, but also the different services of other countries' food safety regimes (Mitchell, 2003). As the desired level of hazard detection differs, the desired level and form of food safety regulation may vary among countries. In this case, suppliers might confront the difficulty to comply with multiple safety regimes in domestic and aboard. In reality, the differences among food safety standards are even more remarkable between developed countries and developing countries, as the latter often lack necessary machinery or techniques to reach the same level as the former (Baylis, Nogueira and Pace, 2011).

The effects of regulations are ambiguous and complex to determine. On one side, regulations are often necessary to improve the market benefits of increased consumer confidence in safer products and the public health benefits of safer food. But on the other side, strict regulations can affect international trade by increasing the costs of imports or prohibiting them entirely. The imposition of domestic standards may raise the cost of foreign supplies relative to domestic production. Requirements of compliance with importers' standards may effectively prohibit imports from countries that lack adequate

regulatory infrastructure, even if some foreign firms can meet importers' standards. In addition, when the government adopts stricter safety regulations than necessary and the possibility of hazard or threat to food safety is small, the strict regulations could cause welfare losses for both trading partners due to trade reduction (Mitchell, 2003). Such costs from reduced trade must be balanced against the benefit of safer goods. It is the balance of such costs and benefits among countries that makes the measures of regulation so controversial in international trade.

This research focuses on EU shrimp market and measures the impact of a stricter standard, Minimum Required Performance Limits (MRPLs), to control the residues of chloramphenicol on EU shrimp market. The EU has explicitly specified the level requirement of MRPL on chloramphenicol. Products that contain chloramphenicol beyond the level set by MRPL are rejected. The standard strictness depends on the level of MRPL set by EU --the lower the level, the stricter the standard. In this case, this research treats the strictness of food safety standard as the level change of MRPL. One purpose of this article is to quantify how the level change of MRPL influences the EU shrimp trade between two disaggregated country groups and the welfare changes of EU consumers and both domestic and foreign suppliers.

After taking into account the differential origins and corresponding different levels of food safety standards, EU shrimp trading partners are classified into two categories: developing countries and developed countries. It is hypothesized that the imposition of the strict regulation has negative effects on the aggregated EU trade flows. It is also hypothesized that the regulatory effects on trade flow differ by country categories. This

research tests these two hypotheses by using a gravity model estimated by the ratio of bilateral trade over domestic trade, and Poisson Pseudo-Maximum-Likelihood (PPML) method to deal with heterogeneity and zero observation problems.

This research adopts a combination of gravity equation and welfare approach to estimate the regulatory effects on welfare changes. By integrating the coefficient measuring the standard effects on trade via the gravity equation, this research determines the relative variations of both prices and quantities in the nested CES model used for welfare analysis, and evaluates the welfare changes of consumers and suppliers. This combined model allows policy makers/researchers to measure the impact of the stricter standard on domestic producers' and consumers' surplus, and the welfare of foreign exporters in developed and developing countries.

This research makes an important contribution to the literature on the effects of regulation on trade by linking the theoretical foundation of the monopolistic competition gravity model (GM) by Anderson and Van Wincoop (2003) with the nested CES model of consumer and supplier behavior. Many recent empirical assessments measure the effects of regulation on trade via gravity estimation (i.e. Wilson and Otsuki 2004; Disdier, Fontagné, and Mimouni 2008; Anders and Caswell 2009). Other papers develop a welfare approach without gravity estimations (i.e. Yue and Beghin 2009). The combination of gravity and welfare methodologies has been overlooked by those studies. Only a few studies explicitly remedy this absence, such as Disdier and Marette (2010).

However, existing papers just combine the GM estimation function with a quadratic function for demand and supply without considering the foundation of connection. The

combination of the GM and welfare approach is unpersuasive in the absence of a linkage between the GM's economic foundation and demand and supply functions. This dissertation verifies the specific form of the utility function in order to use the GM for welfare analysis and explores the theoretical linkages between the CES utility functions and the GM. Since the derivation of the GM is based on the CES model, the improved CES model is more appropriate for the combined method used in an empirical work.

The second contribution of this dissertation is to differentiate welfare changes from food safety standards based on the economic status of exporters. Conceptual studies show that stricter standards have different effects on trade from developed and developing countries. These differences may in turn indicate different changes to suppliers or consumers in countries with different economic status. However, this discrimination is overlooked by many empirical researches. This dissertation accounts for the heterogeneity among imported shrimp products from different exporters and provides a new way to quantify the welfare changes among countries with differing economic status.

The third contribution of this dissertation is to estimate the welfare variations caused by a stricter standard for shrimp products in the EU. The approach used in this research differs from the previous seafood studies that focus only on the ex post evaluation of trade effects, or on the evaluation of welfare effects via econometric analysis. In this research, a methodology is provided that not only evaluates the existing policy, but also anticipates the effects of policy changes with an ex ante analysis linked to the changing level of chloramphenicol residues in seafood. This welfare study helps anticipate demand and

supply changes of markets and achieves quantified analyses directly usable by the public decision makers.

1.2 Background of Shrimp Market and Food Safety Standards

1.2.1 World Shrimp Market

World shrimp production, as show in Fig. 1-1, has expanded steadily over the past decades. The capture of shrimp increased from 1.6 million metric tons to 3.3 million metric tons in 2003 and has stabilized around its 2003 level (Josupeit, 2004). Yet production of shrimp through aquaculture has kept on growing faster since 2003.

World Shrimp Production from 1980 to 2010
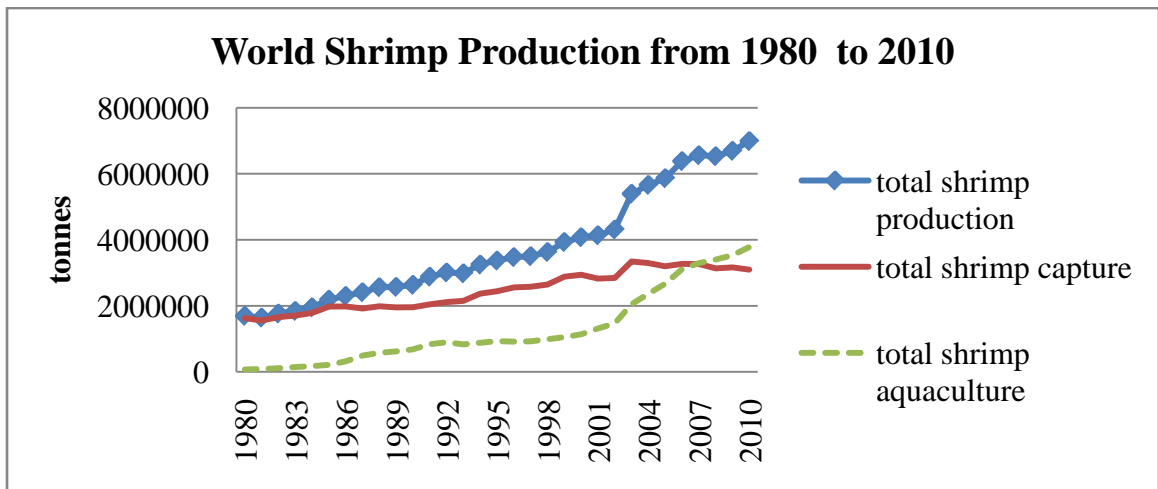
Figure 1-1. World Shrimp Production Trend

Trade in shrimp also has expanded significantly since the early 1980s in response to the increase of aquaculture shrimp production (Keithly and Poudel, 2008). As shown in Figure1-2, world exports of fresh and frozen shrimp expanded from 897 million pounds

in 1980 to 4.1 billion pounds in 2003. The nominal world shrimp price has fallen significantly during the mid-1980s and after 2000.
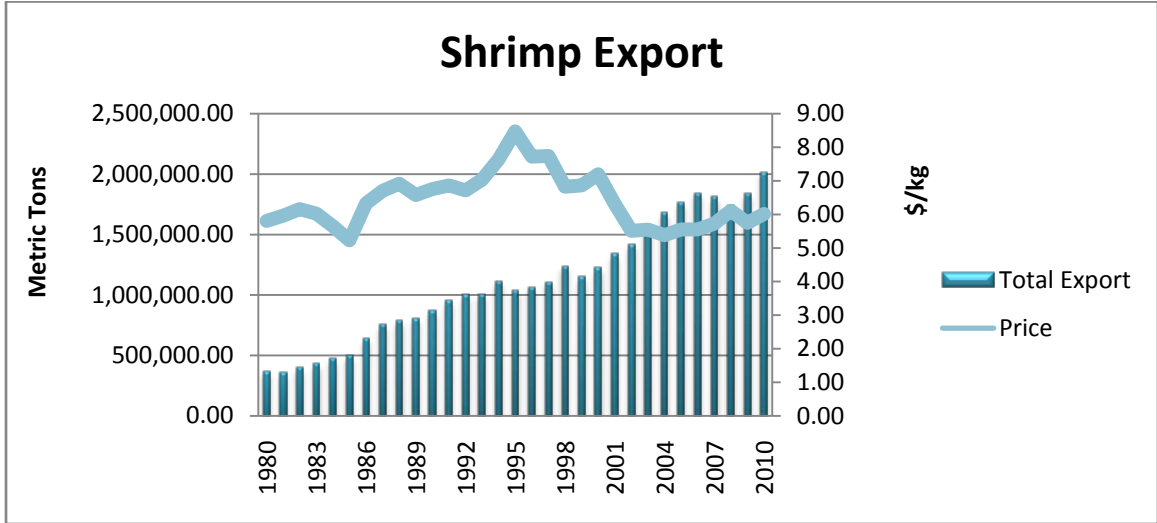
Shrimp Export

Figure 1-2. World Export Quantities and Nominal Price of Shrimp

A marked shift materialized during this period with a growing functional distinction between shrimp-consuming developed countries and shrimp-producing developing countries. Three regions - Asia, Central America and South America – account for about 80% of world shrimp production (Poudel and Walter, 2008). EU, Japan and the U.S. are the main shrimp importing countries, which together consume 60% of world production and absorb 80% of these worldwide exports (Debaere, 2010). As Debaere (2010) states, the causes of the dominant role of developing countries in fish aquaculture are well understood. Shrimp farming requires waterfront property that in many developed countries has higher value in other uses. In addition, water pollution and the destruction of mangrove areas are sometimes linked to shrimp culture. All these factors explain, in

general, that shrimp farms are moved to the coasts of Asia and Latin America where waterfront property is more affordable, labor is cheaper and environmental laws are less stringent.

The boom of shrimp trade has also brought health concerns to consumers. Shrimp farming is risky. First, the crop is largely determined by weather and ecological conditions. Second, shrimp culture is also quite vulnerable to diseases that can severely reduce crops (Debaere, 2010). In this case, developing countries, which are the major exporters, use a range of pesticides and antibiotics (such as chloramphenicol) to prevent and treat bacterial infection (Marette and Beghin, 2010). These chemicals are highly toxic to human health.

The major importers enforce stricter sanitary criteria on detecting antibiotics and chemicals in order to protect their domestic consumers. Studies have shown that the very low levels of antibiotics are safe for human health. In order to determine the point at which a hazardous substance presents a health risk, experts developed the concept of the maximum residue limit (MRL), which is the amount of residue considered to have no significant risk for human health. In the case of chloramphenicol, the level of MRL varies widely among countries. In Japan, the MPL for chloramphenicol is defined as 50 ppb. In the United States, this level is defined as 5 ppb. The EU enforced a much stricter standard than other countries and defined the level at 0.3 ppb based on MRPL (Global Aquaculture Alliance, 2011).

1.2.2 EU Shrimp Market

Shrimp imports into Europe have continued to grow during last ten years. The predominant form is frozen as listed in Table 1-1 and Table 1-2.

Table 1-1. Frozen Shrimps Imported into EU-28 from 2000 to 2010

Year	Commodity	Netweight (kg)	Value ($)	Unit Value ($/kg)
2000	Frozen Shrimp	286356510	1890986129	6.60
2001	Frozen Shrimp	327093638	1871817532	5.72
2002	Frozen Shrimp	342081104	1706788162	4.99
2003	Frozen Shrimp	406897414	2307749883	5.67
2004	Frozen Shrimp	399807299	2278066270	5.70
2005	Frozen Shrimp	430273945	2459801418	5.72
2006	Frozen Shrimp	487027455	2953573545	6.06
2007	Frozen Shrimp	492456664	2941823536	5.97
2008	Frozen Shrimp	466173640	3086425813	6.62
2009	Frozen Shrimp	468998653	2727229869	5.82
2010	Frozen Shrimp	476193317	3082202769	6.47

The value and volume of imports of frozen shrimp into the EU were highest between 2006 and 2008. From 2006 to 2010 the volume of frozen shrimp increased by 13.5 percent, while import volumes of live shrimp and prawns kept almost stable.

Table 1-2. Non-frozen Shrimps Imported into EU-28 from 2000 to 2010

Year	Commodity	Netweight (kg)	Value ($)	Unit Value ($/kg)
2000	Non-frozen Shrimp	3090984	15015138	4.86
2001	Non-frozen Shrimp	3064257	18116873	5.91
2002	Non-frozen Shrimp	4164280	22635821	5.44
2003	Non-frozen Shrimp	5427797	31786939	5.86
2004	Non-frozen Shrimp	3945479	24008235	6.08
2005	Non-frozen Shrimp	3323470	20138248	6.06
2006	Non-frozen Shrimp	3048174	24026508	7.88
2007	Non-frozen Shrimp	3062874	21591045	7.05
2008	Non-frozen Shrimp	5114530	51962594	10.16
2009	Non-frozen Shrimp	2037760	17179007	8.43
2010	Non-frozen Shrimp	1470574	15118771	10.28

Compared with the U.S. and Japan, the EU imports shrimp of a much lower unit value. This can be explained by the fact that the EU imports a lot of coldwater shrimp, generally smaller and lower priced than tropical shrimp (Poudel and Walter, 2008).

The EU mainly imports shrimp products from Asia, South America and other locations such as Southeast Africa and Greenland in Europe. Figure 1-3 presents the top ten exporters of shrimp into the EU-28 in terms of value from 2000 to 2010. Countries in South America lead shrimp exports before 2005 and Asian countries dominated the market thereafter.

Top Ten Shrimp Exporters to EU-28
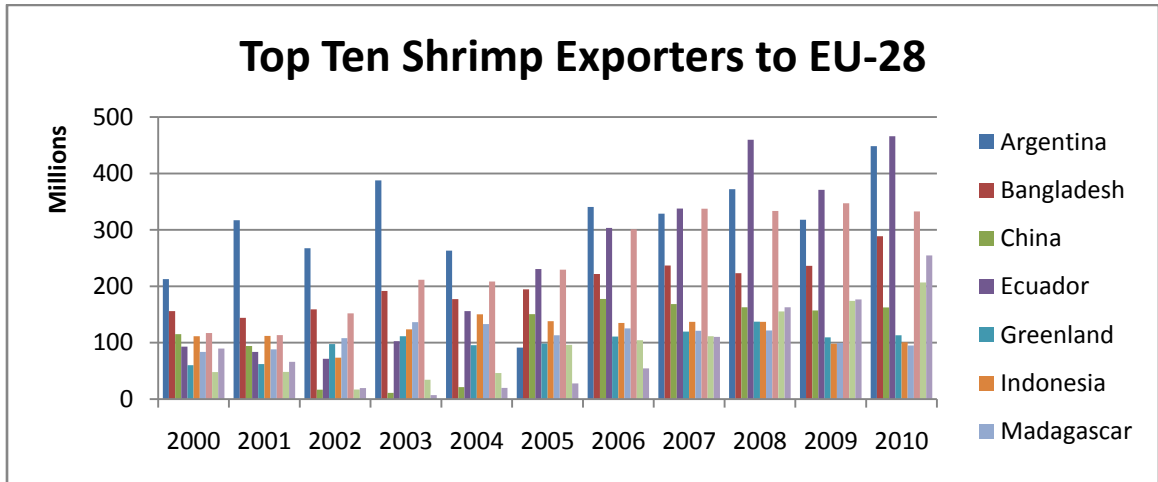
Figure 1-3. Top Ten Exporters of Shrimp to EU-28

Europe is a very heterogeneous market with significant differences from country to country. Consumers in northern Europe tend to prefer cold-water shrimp while those in southern Europe like warm-water shrimp. The two main warm water shrimp species imported into the EU are Giant tiger prawn and White leg shrimp (CBI, 2010). Figure 1-4 shows the share of the top importing countries in the EU. In terms of value, Spain is the major importer of shrimp and prawns, accounting for more than 30 percent of all imports on average, followed by the France (19%), Italy (12%), Belgium (12%), and United Kingdom (10%).

Imports of Shrimps per Countries Share in EU
(Share of total average import value from 2000 to 2010)

Germany 6%
Other 1%
Denmark 7%
United Kingdom 10%
Spain 33%
Belgium 12%
Italy 12%
France 19%
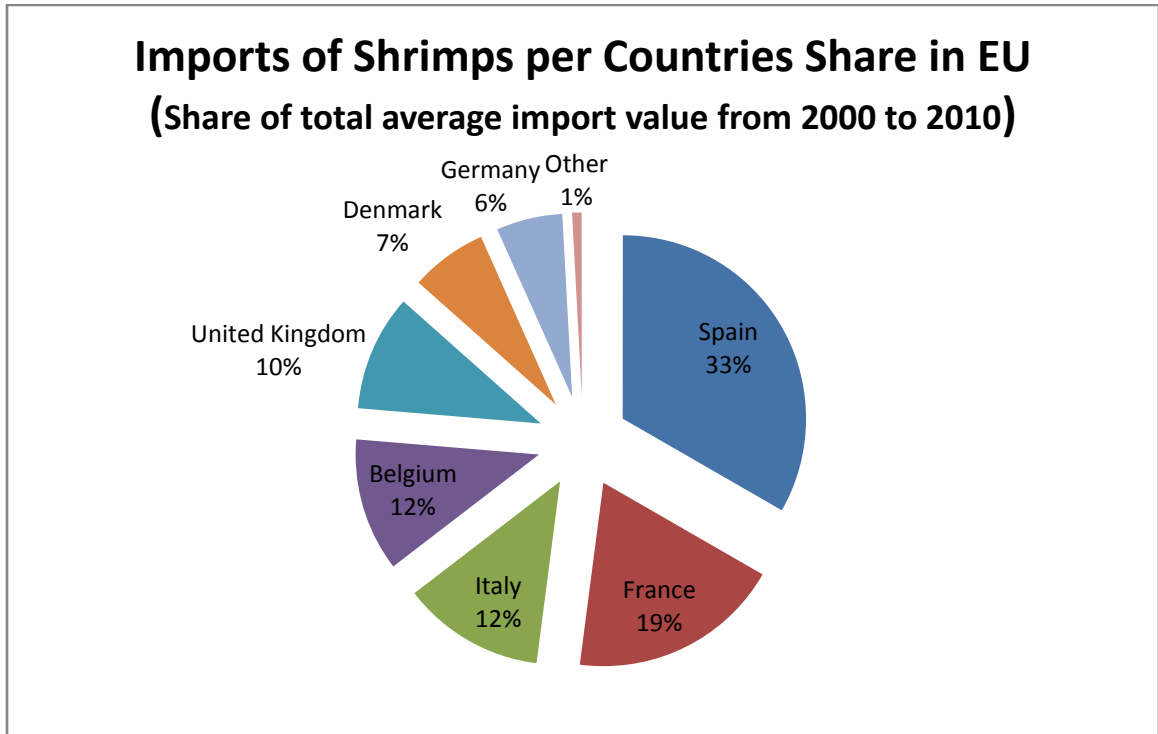
Figure 1-4. Imports of Shrimps per Countries Share in EU

1.2.3 EU Food Safety Regulation

The EU has established a list of non-member countries that grant approval numbers to fish companies certifying that the companies adhere to the food safety rules and, therefore, are allowed to export to the European Union. Countries on the list are confronted with public standards and private standards in the EU. Public food safety standards for imports of fishery products from non-EU member countries have been driven by the EU rules and regulations, which are mandatory. Exporters who do not comply with public regulations could not enter the border of EU member states. The private standards required by retailers, such as European System Related to Good Agricultural Practice (EUREPGAP), British Retail Consortium (BRC) and Safe Quality

Food (SQF), now are applied by supermarkets and importers all over the world to coordinate supply chain activities and control for food safety (Henson, 2008).

For the fish sector, retailers have few private guidelines for food safety and quality. Instead national public regulations are used as a guide for safe and high-quality food. The reason is that the retail market share of fish is still much lower than that of other products. The wholesale markets are still leading shrimp selling (Willems, Roth and Roekel, 2005). In this case, this research only concentrates on the effects of public regulations in the EU.

When the products arrive at the point of entry in the EU, national agencies control the products on public food safety regulation aspects. Regarding the shrimp products, the national inspection service samples and checks the entries and rejects those lots that do not comply with the standards. The major food safety problems encountered for shrimp products are microbiological contaminants, residues of antibiotics, metal contaminants, and parasites. Prohibited use of antibiotics has caused major problems in recent years (Willems, Roth and Roekel, 2005).

In the EU as well as in other markets, chloramphenicol and nitrofuran are banned antibiotics in seafood productions. The EU has refused many contaminated consignments in order to protect their consumers. In 2001, after detecting high levels of chloramphenicol residues, the EU tightened testing for chemical residues and banned any shipment containing the antibiotic in all shrimp imported from Indonesia, China and Vietnam (Ababouch, Gandini, and Ryder, 2005). In January 2002, the EU imposed a 30-month ban on shrimp imports from China because of illegal antibiotic use. They started to import Chinese shrimp again in July 2004, only after the Chinese government

guaranteed that it would test 100% of shrimp exports. In 2007, EU imposed a ban on Thai shrimp contaminated with chloramphenicol and decertified all seafood producers from Pakistan (Disdier and Marette, 2010).

In order to protect consumers and ensure the food imported from other countries safe to eat, the EU applies the MRPL for several substances prohibited or not authorized in food-producing animals, which is the "*minimum content of an analyte in a sample, which at least has to be detected and confirmed*" (European Commission, 2003). MRPL was first used in the official documentation of Commission Decision 2002/657/EC. It was originally used to develop an analytical method that can reliably and repeatedly confirm the present level of banned substances at concentrations in the food of animal origin. In the Commission Decision 2002/657/EC, the MRPL concept did not include any provision for a specific level of action. Nowhere is it stated that the lowest concentration of a banned substance requiring effective enforcement action is XX µg/kg. The EU sets up the level of substances after 2003. In effect MRPL acts as a "cap" on the worst performing methods to ensure that a minimum standard was applied across EU members' laboratories (Kennedy, 2004). If the presence of banned substances at concentrations is confirmed to be equal to, or below, the MRPL, it would be deemed fit for the purpose of consumption.

For the special case of chloramphenicol, the EU experienced a changed policy on MRPL requirements. Due to the outbreak of chloramphenicol in shrimp imported from Asian in 2001, the EU enforced a zero tolerance policy to all shrimp products entering EU countries. Laboratories found it infeasible to uphold a zero tolerance policy (Hanekamp*et al,* 2003). Therefore, the EU shifted from zero tolerance and regulated chloramphenicol at

the MRPL level of 0.3 ppb when the European Commission published a decision on 11 January 2005 (Commission Decision, 2005). Moreover, the EU destroyed the affected imports to prevent contamination within its food chain. Only as the EU was revising its zero-tolerance policy, did it consider the possibility of re-exporting or returning the shrimp with low levels of contamination (Debaere, 2010).

The intention of MRPL requirements in the EU is to protect consumers. But the stricter sanitary criteria raise the cost to both domestic and foreign suppliers and reduce the amount of shrimp supply to consumers, which may result in net consumer losses. In addition, governments spend more time and money on sampling and detection of imported shrimps. Thus, the overall effects of stricter standards on trade and welfare change are worthwhile to quantify for policy makers in the EU.

1.3 Illustrations of MRPL on EU Shrimp Market

The effects of standards on consumers and suppliers are complicated to determine. This section provides the theoretical foundation of stricter standard effects and discusses the possible changes to market equilibrium, and the shifting and rotating of demand and supply curves caused by the stricter standard enforcement.

Whether domestic and foreign consumers can benefit from stricter standards is hard to determine. With regulation it is possible that consumers could gain greater utility from consuming high-quality products and thus would be more willing to pay a higher price (Huang, Kan and Fu, 2000). However, the extent of food safety is hard to observe. If the public is not aware of a food safety concern prior to implementing regulation or is

unaware of the increased magnitude in safety, the regulation might not result in an increase in demand for safer products (Korinek, Melatos and Rau. 2008). In addition, the situation is more complex if international trade is introduced. Countries usually ban foods that do not meet the requirements of food safety regulations. Foreign suppliers need to adjust to stricter standards in order to ship products into importers' border. If the foreign producers cannot provide safer food as cheaply as domestic firms, consumers can benefit from the ban by consuming safe food at lower prices. However, if foreign firms could provide food that is cheaper and safe, consumers lose from a ban (Mitchell, 2003).

Compliance with standards can influence producers in several ways. First, in satisfying regulatory requirements, firms invariably incur additional production costs (i.e., labelling, testing, certification, etc.), or marginal costs (i.e., upgrade facilities) (Korinek, Melatos and Rau. 2008). Second, the standards may reduce the proportion of foreign products entering a market because of tougher inspections linked to stricter thresholds, particularly for suppliers in the developing countries that have difficulties complying with the stricter standards of developed countries (Disdier and Marette, 2010). All these effects contribute to the reduction of the quantities supplied by farmers and tend to increase the resulting equilibrium prices.

As stated before, this dissertation defines the strictness as the level change of MRPL. The EU actually relieved the strict standards by increasing MRPL from zero to 0.3 ppb in 2005. In order to explore the effects of strict standards, this research measures the welfare based on two scenarios with different levels of MRPL and then compares the difference between the welfares under these two scenarios. The initial scenario reflects the current

set of MRPL for chloramphenicol, which values at zero from 2002 to 2004 and at 0.3 ppb since 2005. The new scenario considers the effects of sticking MRPL at the zero level in 2005 and thereafter. MRPL regulation is stricter in the new scenario.
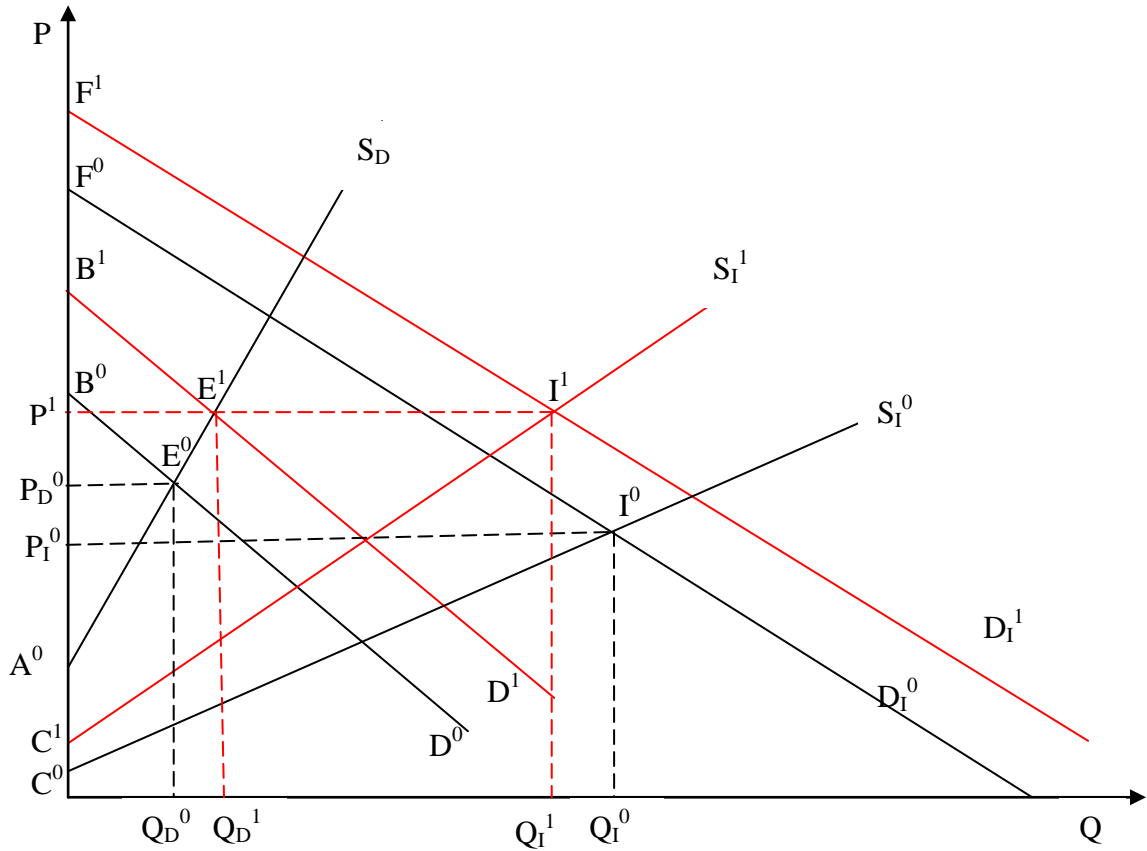
Figure 1-5. The effects of standards on demand and supply curves of the EU

Figure 1-5 shows the possible impacts of stricter regulations on demand and supply of domestic and foreign shrimp products in the EU market. As this research measures the effects of MRPL level changes, index 0 and 1 reflect the situation before and after lowering the MRPL standard. The price P is located on the vertical axis, and the quantity Q is shown along the horizontal axis. D_D and D_I are the demand curve of domestic and

foreign shrimp products in the EU. S_D and S_I respectively represent the domestic and foreign supply of the EU.

For simplicity, it is assumed that all the information on improved food safety has been passed on to consumers after implementing the MRPL requirement. All foreign suppliers are required to comply with the EU's food safety standards before they export shrimp to the EU countries. It is assumed that domestic suppliers already incorporate the MRPL standard and the domestic supply curve is not affected by enforcement of the MRPL standard. This was the case with the new 2002 policy that impacted mainly Asian exporters, since chloramphenicol was already banned in the EU since 1994 (Disdier and Marette, 2010).

The domestic products and foreign products are assumed to be not perfect substitutes. As the EU already banned the substance of chloramphenicol before 2000, domestic products always follow the requirement of zero tolerance policy; while foreign products comply with MRPL setting at 0.3 after 2005. In this case, for the initial situation, the price of domestic product P_D^0 is assumed to be a little higher than the price of foreign product P_I^0 as domestic products actually comply with the higher level of standard. The heterogeneity of domestic and foreign products reflects the different level of standard. After reducing the MRPL level, both domestic and foreign products meet the zero level of MRPL. The products are deemed to be identical and both domestic and foreign suppliers confront the same price P^1.

For the initial situation 0, Q_D^0 and Q_I^0 are domestic output and foreign output in figure 1-5 respectively. The welfare corresponds to the area $P_D^0 A^0 E^0$ for domestic producers and

$P_I^0 I^0 C^0$ for foreign suppliers. The surplus of domestic consumers corresponds to the area $B^0 E^0 P_D^0 + F^0 I^0 P_I^0$. The total domestic welfare is the sum of domestic producers' surplus and consumers' surplus, which is the sum of areaa $B^0 E^0 A^0$ and $F^0 I^0 P_I^0$. The total international welfare is the sum of domestic welfare and foreign suppliers' surplus and is given by $F^0 I^0 C^0 + B^0 E^0 A^0$.

With this initial situation proceeding to a stricter MRPL regulation, the market allocation is modified as represented by the red curves and new equilibrium points of E^1 and I^1 in red. A stringent standard increases consumer confidence in provided shrimp products and stimulates demand for domestic and foreign goods. The domestic demand curve shifts upward from D^0 to D^1, leading to an increased domestic price $P^1 > P_D^0$ and an increased domestic quantity demand $Q_D^1 > Q_D^0$. The upward movement of foreign demand curve also leads to an increase in price and quantity of foreign goods at equilibrium. Moreover, the reduction of the MRPL level increases foreign producer costs and induces the foreign supply curve to shift upward. This movement offsets the effects of increased demand on quantity and pushes the price further to P^1. Whether the foreign quantity at equilibrium after reducing MRPL level increases or not, i.e., $Q_I^1 > Q_I^0$, depends on the extent of the foreign supply curve changes. If the foreign supply curve S_I^1 shifts farther away from the original one, S_I^0, the effects of supply curve would outweigh the effects of the demand curve shift and Q_I^1 would be less than Q_I^0.

When the stricter standard is reinforced, the welfare also changes at the new equilibrium point. The consumers' surplus changes to $B^1 I^1 P^1 + B^1 E^1 P^1$, the domestic supplier surplus increases by $P^1 E^1 E^0 P_D^0$ and the total domestic welfare increases to the $B^1 E^1 A^0 + F^1 I^1 P^1$.

The foreign supplier surplus changes to $P_I^1 I^1 C^1$ and the international welfare is $F^1 I^1 C^1 + B^1 E^1 A^0$.

The effects of MRPL are demonstrated by the comparison between the initial welfare and the new welfare and are hard to determine. If $B^1 I^1 P^1 + B^1 E^1 P^1 > B^0 E^0 P_D^0 + F^0 I^0 P_I^0$, then consumers benefit from reducing MRPL level. If $B^0 E^0 A^0 + F^0 I^0 P_I^0$ is larger than $B^1 E^1 A^0 + F^1 I^1 P^1$, the increase in foreign supply price P_I is small enough for the stricter regulation to be beneficial to the domestic country. Alternatively, $B^0 E^0 A^0 + F^0 I^0 P_I^0$ could be smaller than $B^1 E^1 A^0 + F^1 I^1 P^1$, when the stricter regulation induces a relatively large contraction in foreign supply. In this case, additional regulation would result in domestic welfare losses, since the damage to consumer welfare caused by a reduction in quantity and increase in price offsets the increase in domestic supplier surplus. In addition, foreign suppliers would suffer by stricter standard if $P_I^1 I^1 C^1$ is smaller than $P_I^0 I^0 C^0$.

The analysis above suggests that changes in the foreign supply curve caused by tightening the MRPL are crucial to determine the effects of MRPL. When the stricter MRPL causes a large reduction in foreign supply that overcomes the increase in foreign supply price (i.e., $P^1 * Q_I^1 < P_I^0 * Q_I^0$) and if the difference between $P^1 * Q_I^1$ and $P_I^0 * Q_I^0$ is large enough, both foreign suppliers and the EU would suffer from welfare loss. The expression $P_I * I$ represents the nominal value of shrimp products provided by foreign suppliers. The relationship $P^1 * I^1 < P_I^0 * I^0$ indicates that if the tighten of MRPL dramatically reduces the nominal imported value from foreign suppliers, the domestic welfare of the EU and foreign supplier surplus would reduce. In other words, the significance of MRPL effects on foreign trade flows indicates the welfare changes.

1.4 Dissertation Structure

This dissertation has the following organized structure: in this chapter, the motivation of this dissertation and the background of the world and EU shrimp production and trade are introduced. The theoretical basis of welfare analysis is also illustrated in this chapter. In chapter two, the mainstream of research methodologies and the empirical results about the stricter standard effects are summarized. In chapter three, the model system adopted in this dissertation and the model in the case study of the EU shrimp market are specified. Then the estimation results and changes of trade flows changes and welfare are analyzed in chapter four. At last, the conclusions about the method applied in this research and the evaluation of the MRPL standard in the EU and their implementation are presented.

CHAPTER TWO: LITERATURE REVIEW

2.1 Impact of Stricter Standard

During the last few decades, many researchers have tried to quantify the effects of stricter food safety standards on international trade and welfare changes. Based on different objectives, those researches can be classified into two categories: trade effects and welfare effects.

2.1.1 Effects on Trade Flows

During the last decades, various private standards are increasingly dominating the improvement of food safety and quality controls. In the basic commodity markets, public standards continue to be the principle mode of the governments. Across the high value agricultural and food products markets, private standards are increasingly the dominant driver (Henson, 2008). However, the mainstreams of empirical researches still focus on the effects of public standards on international trade. In principle, researchers may analyze the impacts of private standards in a similar way as public standards, and indeed it has been suggested that the distinction between these two regimes in the trade setting can be over-emphasized (Henson 2008; Henson and Humphrey 2010). However, isolating the trade effects of a particular private standard or the impacts on particular country product exports is made more difficult due to the lack of data and the firm specific nature of these standards.

Research on the effects of public food safety standards on trade has often focused on two contrasting views: whether food safety standards are "catalysts" or "barriers". Henson

and Steven (2008) and Jaffee and Jabbar (2005) highlighted the potential benefits provided by stricter emerging standards. Tighter standards not only provide certain countries with a competitive advantage and increased shares from stringent standards, but they also provide incentives for developing-country producers to adjust their export industry; these adjustments could benefit poor country consumers through strengthened food and health standards. Caswell and Bach (2007) pointed out the possible spillover effects on consumers, but they show that such spillover effects are weak in their case study of Brazil.

The view of "standards as barriers" holds that many developing countries do not have effective food safety control systems in place, so the stricter safety standards imposed by major developed- country importers impede trade flows through the creation of prohibitive costs of compliance (Grant and Anders 2010; Anders and Caswell 2009; Caswell and Bach 2007). A fairly extensive literature provides empirical evidence for the negative effect of stricter standards on trade. For example, Anders and Caswell (2009) found that as a group, developing countries suffered significant trade reduction under HACCP enforcement in the U.S. However, based on a country-specific picture, larger or more established seafood exporters (even those in developing countries) increased their trade flows while smaller exporters suffered reductions. Nguyen and Wilson (2009) analyzed the product-specific impacts of strict standards by investigating the EU, the US, and Japanese markets and found that the trade impact of food safety standards is negative and significant, but differentiated across seafood products. Shrimps appear to be the most sensitive to changing food safety policies, while fish is the least sensitive.

2.1.2 Effects on Welfare Changes

Regarding the shrimp market, Hudson, et al (2003) examined the effects of a potential ban on shrimp imports by the United States from countries non-complying with the Turtle Excluder Device system. They estimated a linear expenditure system to obtain the own-price elasticity of demand for shrimp imports. They find that such a ban would generate a welfare loss for U.S consumers. The magnitude of the effect depended on whether lost imports from banned countries were reallocated to other countries. However, the research of Disdier and Marette (2010) shows a different story. By focusing on the crustaceans trading markets in the U.S., EU, Canada and Japan, they found that although the stricter standards showed a negative impact on crustacean imports to these four countries, a stricter standard led to an increase in both domestic and international welfare because of a significant reduction in chloramphenicol damage.

Most research assumes that all analyzed countries are small and do not account for potential changes in world price caused by stricter standards. Calvin and Krissoff (1998) suggested that standard enforcement in big countries could result in changes of world prices. In this case, the corresponding tariff equivalent (TE) calculation (one methodology used for measuring trade effects) and welfare analysis could potentially overestimate. Debaere (2010) focused on the shrimp market and showed that the EU's trade policy (especially strict standards on antibiotic residues compared to the ones applied by the U.S.) significantly impacted the world shrimp market and shifted exports away from Europe towards the U.S. in the late 1990s and early 2000s with the added consequence of depressing U.S. prices for shrimp. However, to the best of our knowledge,

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no study has incorporated large country effects on the world market into the calculation of welfare changes.

2.2 Research Methodologies

Generally speaking, existing econometric methods of empirical research can be divided into two groups: ex ante or ex post econometrics. Ex post analyses typically focus on the past measures and trade flows. The econometric models estimating the relationship between standards and trade normally adopt ex post analysis based on historical trade data. In contrast, ex ante analyses concentrate on future potentials and are generally employed to predict the likely impact of a regulatory change before it is introduced. This usually involves simulating a partial or general equilibrium model to determine how individual consumers and producers would respond to price changes arising from a change to the regulatory environment.

2.2.1 Ex Post Method

The gravity equation is widely used as an ex post method to quantify the trade impacts of standards and other non-tariff measurements (NTM). The gravity model explains bilateral trade flows with the distance between trade partners, their size and some resistance factors (including a quantitative measure of standards). The coefficient of the regressor representing standards or NTM quantifies the effects of the standards or NTM on bilateral trade flows. This method shows great power in explaining factors influencing bilateral trade. Researchers using a gravity model analysis have adopted a number of different approaches, reflecting the lack of agreement on the best way to measure standards.

Some studies incorporate frequency and coverage measures of standards to estimate trade impacts, that is, whether standards are trade-restricting or trade-promoting. Frequency measures count the number of regulatory measures within a given product classification and coverage measures are usually expressed as a percentage of the total imports in that product category or tariff line (Rau and Schueter 2009). For example, a binary choice variable is used and is assigned the value of one if a country-pair, product, and year specific trade flow is subject to a regulatory measure, and zero otherwise. For example, Anders and Caswell (2009) corporated the dummy variable of identifying the 1997 Hazard Analysis and Critical Control Point regulation (HACCP) into gravity equation and evaluated the trade impact of HACCP on U.S. seafood imports.

In order to calculate the effects of NTM, Fontagné, von Kirchbach, and Mimouni (2005) used NTM notification data from the United Nations Conference on Trade and Development (UNCTAD) Trade Analysis and Information System (TRAINS) to calculate the import coverage index which is the ratio of notifying country imports to total world imports.

The main drawback of frequency and coverage measures is the assumption that the greater the number of restrictions and the broader their application, the larger the likely restrictive impact on trade. In fact, standards are complex and impact different products in different ways. There is little agreement in the literature on how to weight the importance of different standards in calculating an aggregate measure of their impact on trade (Korinek, Melatos and Rau. 2008). The combined gravity models with frequency and coverage measures usually cover a wide range of products and standards, as well as

technical regulations, under the broad category of NTMs. Most studies estimating the trade impact of multiple regulatory measures in econometric models rely on frequency and coverage ratios.

Many studies have employed the gravity model to directly measure the stringency of regulations and standards. The stringency of regulations and standards can be measured directly if the standard or NTM contains the elements such that they can be ranked on a quantitative scale, for instance regulations and standards defining tolerance maximum levels for residue and contaminants. These studies tend to focus on specific cases of standards for particular products and countries. For example, Otsuki, Wilson and Sewadeh, (2001) estimate the impact of a maximum residue level for Aflatoxin on trade of cereals and fruits, nuts and vegetables from Africa to the EU. The drawback of the direct method measuring the stringency is the difficulties in directly assessing the stringency measures. Not all of standards or regulations provide such quantitative elements that can be used directly as stringency measures.

Some academics contribute to indirectly measure the stringency of regulations and standards by calculating the Tariff Equivalent (TE). The TE provides an ad-valorem equivalent of standards that are directly comparable with tariffs. In order to obtain the TE, academics estimate the quantity impact of regulations and standards on trade via gravity model and then transform the quantity effect, via elasticity, into a price effect, which is referred to TE. Disdier, Fontagné and Mimouni (2008) used a gravity model to estimate TE in this way.

2.2.2 Ex Ante Method

The welfare approach estimates the welfare change from standards based on the traditional simulation model by explicitly depicting the shifting of demand and supply. The costs and benefits for producers and consumers are introduced in the model equations, and the simulation exercise subsequently models the producer and consumer behaviors in response to changing requirements. Model parameters and assumptions are important, but how regulations and standards are depicted in the model also determines the simulation results. On the demand side, regulations and standards are reflected by consumers' willingness to pay for certain product characteristics which are provided by regulatory measures. On the supply side, simulation models usually depict regulations and standards as additional costs that producers incur when complying. Welfare changes are normally estimated by partial equilibrium models.

Among the papers implementing welfare changes analysis, two research papers have made important contributions. Liu and Yue (2009) incorporated the heterogeneity of consumers' preferences between domestic and imported goods into the estimation of welfare changes caused by strict standards. Rau and van Tongeren (2010) considered the heterogeneity of firms, and weighed the variable and fixed compliance costs of standards differently across firms. They specifically modeled the compliance costs in an oligopolistic partial equilibrium model, and applied it to the EU food safety standards for Polish meat firms.

Recently, many academics have adopted simulation models to calculate the TE of Technical Barriers to Trade (TBT) or NTB, caused by stringent standards. The TE

approach is also called the price-wedge approach, which aims to measure the effects of standards or NTB on the domestic price of imported good by comparing the domestic price with the reference price. The typical price wedge method usually assumes that all researched countries face an exogenous world price for imports. The TE of standard is calculated by excluding all other factors unrelated to the standard from the domestic price, including the world price, tariffs, taxes, transportation costs and other factors influencing the import price. Compared with the gravity approach, the advantage of simulation model is to directly capture the price changes. In order to obtain appropriate estimates of the price effect, influences on the domestic price unrelated to standards or NTMs need to be included (Calvin and Krissoff, 1998).

2.2.3 Combination of Ex Ante and Ex Post Method

Some researchers have tried to combine the ex ante and ex post methods to study the welfare impact of standards. Studies by Yue, Beghin and Jensen (2006) and Calvin and Krissoff (1998) on US apple exports to Japan demonstrated how estimates of TE could be combined with demand and supply analysis to obtain estimates of welfare effects of standards. Yue, Beghin and Jensen (2006) incorporated the heterogeneity of preferences into the basic constant elasticity of substitution (CES) model by assuming imperfect substitution between domestic and imported goods. Liu and Yue (2009) further took the heterogeneity of products into consideration in their study to estimate the welfare effect of the Japanese cut flower market by exploring the quality change of goods in the model.

Meanwhile, Disdier and Marette (2010) first explored the link between the gravity model and welfare frameworks for measuring the impact of nontariff measures. Their research

provides the theoretical foundation for estimating endogenous parameters needed for welfare analysis.

Their research only focuses on the shifting of demand and supply curves caused by the enforcement of stricter standards. Liu and Yue (2011) considered the potential effects of standards on the substitution elasticities of demand and supply by applying the variable elasticity of substitution (VES) model to study the welfare change happening between the U.S. and Japan apple trades. Since there is no agreement on the best way to measure welfare effects of standards, as Korinek, Melatos and Rau (2008) suggest, one should consider the attributes of products and consumers, whether homogenous or heterogeneous, and the complexity of standards to determine which model to adopt in welfare analysis.

None of the above combined methods provide a methodology to quantify the relationships among standards, trade and welfare as they do not explicitly draw out the theoretical connection between ex ante and ex post methods.

CHAPTER THREE: THE EMPIRICAL MODEL

This dissertation combines ex ante and ex post econometrics to estimate the effects of the MRPL enforcement on the EU shrimp imports. First, this dissertation sets up the framework and derives the estimation forms of the Gravity Model (GM) and the nested Constant Elasticity of Substitution (CES) model. The ex ante GM model adopts the ratio of domestic and bilateral trade barriers to avoid including time-varying country/industry fixed effects in the estimation. The ex post CES model is a partial equilibrium model, concerned with the effects of MRPL on consumer and suppler behavior. Second, this dissertation explores the links between the GM and CES frameworks for measuring the impact of the MRPL standard. The trade effects of MRPL are captured by the GM, while the welfare effects are estimated by combining the GM and nested CES approaches.

3.1 The Gravity Model

As stated before, the EU adopted the zero-tolerance of chloramphenicol of imported shrimp products in 2002 and stipulated that the rejected shipments must be destroyed, rather than returned to the country of origin. This policy ignored the impact on importers and exporters in terms of disruption in trade and loss of income. In this case, the imports to the EU severely deducted during the short time period between 2002 and 2005. However, in the long time run, the MRPL effect is hard to predict because the EU also imports shrimps from developed countries, which in general enforce stricter food safety standards than developing countries. And developing countries also improve their products to comply with the strict requirement of MRPL in the EU. The hypothesis tested here are:

Hypothesis 1: MRPL has a significant and negative impact on the trade integration of the EU shrimp market in general, regardless of the economic status of exporting countries.

Hypothesis 2: MRPL has differential impacts on the EU shrimp trade integration based on the exporting countries' level of economic development.

This dissertation adopts the transformed way of gravity model to test the above two hypotheses. Trade integration is the transformed variable that captures the domestic barriers over bilateral trade barrier. The concept of the trade integration will be discussed in detail later. The advantage of transformed way over typical gravity equation lies in that it avoids the biased estimation caused by the perfect correlation between standard variables and country and time fixed effects. This section demonstrates the detailed derivation of the transformed gravity equation in following process. First the typical gravity equation is derived based on its economic foundations with CES utility function. Then the transformed model used for estimating MRPL effects on trade is derived by transforming the dependent variables in a typical gravity equation.

3.1.1 Economic Foundations of GM

The aggregated trade effects of stricter food safety standards can be estimated by using a gravity equation, which is analogous to Newton's law of universal gravitation. Larger places attract people, ideas, and commodities more than smaller places. And places closer together have a greater attraction. This equation provides a measure of expected bilateral trade given the size of both partners and the bilateral transaction costs. In economics, gravity models have achieved empirical success in explaining inter-regional and international flows (Cheng and Wall, 2005).

During the last two decades, a remarkable number of studies have derived the GM of trade from very different theories of international trade. Anderson (1979) derived the gravity model by applying CES import demand preferences and assuming that goods differ by origins. Subsequent extensions of the model preserved CES preferences and added other assumptions. With CES preferences, Bergstrand (1989) applied a monopolistic competition model and derived a similar basic GM. Deardorff (1998) adopted a Hecksher-Ohlin structure and also obtained a similar GM.

The basic GM follows similar patterns of including measures of the economic sizes of trading partners and measures of trading costs. However, based on the different theories in deriving the GM, the specifications of independent variables are not identical in empirical applications. The theoretical foundation of the GM helps to explain the economic meaning of variables and specification of data chosen for empirical estimation. The theoretical foundation in the approach used in this dissertation is the standard trade monopolistic competition model, derived by Anderson and Wincoop (2003), which employs CES demand functions.

Following Anderson and Wincoop (2003), two assumptions are needed to derive the basic gravity model. The first one is that all goods are differentiated by place of origin. The second one is homothetic preference of consumers, approximated by a CES utility function. Consider the case of a one good industry. Consumers in country j consume the quantity c_{ij} of goods from the country. Consumers in country j maximize their utility:

$$U = (\textstyle\sum_i \beta_i c_j^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} \tag{3-1}$$

Subject to the budget constraint:

$$\sum_i p_{ij} c_{ij} = y_j \qquad (3\text{-}2)$$

Here σ measures the elasticity of substitution, which is greater than 1. β is a positive parameter. y_j is the nominal income of country j consumers, and p_{ij} is the price in country j. The derivation of Gravity Model is shown in Appendix I.

By imposing market clearing condition and solving the general equilibrium equation, Anderson and Wincoop (2003) derived the following equation of gravity model based on the above derivations:

$$x_{ij} = \frac{y_i y_j}{y^W} \left(\frac{t_{ij}}{\Pi_i \Lambda_j}\right)^{1-\sigma} \qquad (3\text{-}3a)$$

Where

$$\Pi_i = [\sum_j \theta_j (t_{ij}/\Lambda_j)^{1-\sigma}]^{1/(1-\sigma)} \qquad (3\text{-}3b)$$

And

$$\Lambda_j = [\sum_i \beta_i^{\sigma} (p_i t_{ij})^{1-\sigma}]^{1/(1-\sigma)} \qquad (3\text{-}3c)$$

Trade flow x_{ij} depends on the income of suppler y_i and demander y_j and is negatively related to the total world income y^W. Π_i and Λ_j, respectively represent the outward and inward multilateral resistance term. The outward multilateral resistance Π_i essentially represents the fact that exports from country i to country j depend on the trade costs across all possible export markets. The inward multilateral resistance Λ_j captures the dependence of imports into country i from country j on the trade costs across all possible suppliers. In particular, it is apparent that the multilateral resistance term involves trade costs across all bilateral routes. Thus, this model picks up the fact that changes in trade

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cost on one bilateral route can affect trade flows on all other routes because of relative price effects.

In addition, equation (3-3) indicates that large bilateral trade costs t_{ij} reduce bilateral trade flows, whereas large outward multilateral resistance of country i (Π_i) and large inward multilateral resistance of country j (Λ_j) increase bilateral trade flows.

3.1.2 The Mainstream of the GM Estimation

The typical GM is estimated using the logarithm form of equation (3-3). The expression with y variables are proxies of the economic mass of country i and j, which are represented by GDPs in the empirical research. Based on Anderson and Wincoop's derivation (see the budget constraint), one more assumption is imposed in the estimation model. In a single sector economy like equation (3-3), where there is no input-output relationship, the sum of all production must be equal to GDP. Bilateral trading costs t_{ij} indicate trade frictions or barriers between trading partners, for example transaction costs. Distance, dummy variables indicating the relationships between countries and policy variables are commonly used to proxy t_{ij}.

It is clear with equation (3-3) that inward and outward multilateral resistance (Λ_j and Π_i) effectively deflate the value of variables in the basic model. However, these two terms are unobservable price indices. These unobserved price indices are "unobserved heterogeneity" between countries (Baier and Bergstrand, 2007). The unobserved heterogeneity between countries causes the endogeneity problem during estimation. The mainstream technique to consistently estimate the gravity model is to augment the gravity equation with fixed effects by using panel data (Frankel, Stein and Wei 1995; Anders and

Caswell 2009). Adding fixed effects can be as simple as adding time invariant dummy variables as well as importer and exporter country dummies. The unobservable multilateral resistance is accounted for by dummy variables. Considering the time span, the estimation of typical gravity equation (3-3) with country fixed effects can be written as equation (3-4):

$$\ln x_{ijt} = \beta_1 \ln y_{it} + \beta_2 \ln y_{jt} + \beta_3 \ln t_{ijt} + \alpha_0 + \alpha_i + \alpha_j + \alpha_t \qquad (3\text{-}4)$$

This method has one important drawback: researchers must drop any variables that are collinear with the fixed effects. This restriction means that it is not possible to estimate a fixed effects model that also includes data that only vary by exporter (constant across all importers), by importer (constant across all exporters), or by time (constant across the time). This disadvantage limits the estimation of policy effects because many policies enforced in one country are applied to all trading partners. Another way to deal with this endogeneity problem is to transform the variables -- that is to eliminate the fixed effects by transforming the dependent variables. Because the EU enforced a unified standard of MRPL within THE EU countries, this dissertation transform variables to estimate unbiased policy effects of MRPL.

3.1.3 The Transformation Method

The transformed method is to eliminate the "unobserved heterogeneity" problem caused by multilateral resistance through transforming the dependent variables. Several researches adopted the "phi-ness" to indirectly estimate the policy-related trade costs (Head and Mayer 2004; Chen and Novy 2011, 2012). The typical gravity model only concentrates on bilateral trade flows, while the "phi-ness" considers the ratio of intra-

country and bilateral trade flows. This indirect approach avoids the drawback of fixed effects gravity analysis and has the obvious advantage of extending the analysis to more countries and years, and more finely disaggregated data (Chen and Novy 2011). This research takes the advantage of "phi-ness" and improves this approach by incorporating the method of treating zero observations that appear in the dependent variable.

The microeconomics foundations of the Gravity equation (3-3) indicate that larger bilateral trading costs t_{ij} reduce bilateral trading flows x_{ij}; whereas larger average outward trading barriers Π_i, and larger average inward resistance P_j, increase trade flows. Intuitively, if a country's trade barriers with the rest of the world are high (i.e., if the country's multilateral resistance is high), the country will trade mostly domestically (Chen and Novy, 2011).The domestic trade flows in formal Gravity equation can be transformed as (3-5):

$$x_{ii} = \frac{y_i y_i}{y^W} \left(\frac{t_{ii}}{\Pi_i \Lambda_i}\right)^{1-\sigma} \tag{3-5}$$

Equation (3-3) and (3-5) provide a solution for the multilateral resistance. Equation (3-17) contains outward multilateral resistance of country i (Π_i) and inward multilateral resistance of country j (Λ_j). It is useful to consider the corresponding gravity equation for trade flows in the opposite direction.

$$x_{ji} = \frac{y_j y_i}{y^W} \left(\frac{t_{ji}}{\Pi_j \Lambda_i}\right)^{1-\sigma} \tag{3-6}$$

$$x_{jj} = \frac{y_j y_j}{y^W} \left(\frac{t_{jj}}{\Pi_j \Lambda_j}\right)^{1-\sigma} \tag{3-7}$$

After multiplying equation (3-3) by (3-6), one can get

$$x_{ij}x_{ji} = \frac{y_i y_j y_j y_i}{y^W y^W}\left(\frac{1}{\Pi_j \Lambda_i \Pi_i \Lambda_j}\right)^{1-\sigma}(t_{ij}t_{ji})^{1-\sigma} = x_{ii}x_{jj}(\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}})^{1-\sigma} \tag{3-8}$$

This yield

$$\Phi_{ij} \equiv \frac{x_{ij}x_{ji}}{x_{ii}x_{jj}} = (\frac{t_{ii}t_{jj}}{t_{ji}t_{ij}})^{(\sigma-1)} \tag{3-9}$$

Φ_{ij} is called the "phi-ness" index in previous empirical research which is interpreted as a microeconomic founded measure of "*bilateral industry-specific trade integrations*" by Chen and Novy (2011). The more two countries trade with each other (i.e., the higher $x_{ij}x_{ji}$), the higher is the measure of relative trade integrations. Conversely, if the two countries trade more domestically (i.e., the higher $x_{ii}x_{jj}$), the lower is the relative trade integrations. If hold x_{ji} and x_{ii} being equal, higher trade integration means that there are higher imports from i to j than domestic trade within country j.

In addition, the Φ_{ij} combines the ratio of bilateral to domestic trade with the industry-specific elasticity of substitution σ. If σ is high, consumers are very sensitive to trade cost changes and a small increase in bilateral trade cost would lead to high reduction to the ratio of bilateral over domestic trade.

Equation (3-9) infers that the "phi-ness" index is only related with trade costs indicators. The t_{ij} and t_{ji} represent the bilateral trading costs between i and j while t_{ii} and t_{jj} measure domestic trading costs of i and j. The "phi-ness" index can be viewed as an indicator of trade integration that measures the domestic trade barriers relative to bilateral trade

barriers. Trade integration and bilateral trade flows are expected to increase with lower

bilateral trade costs and decrease with lower domestic trade costs.

The trade cost symmetry is not imposed in this research, so t_{ij} and t_{ji} may not be equal.

Because this paper is dedicated to explain the effects of policies, which are dramatically

different among countries, different policies may lead to differentiate trade costs.

However, as Anderson and van Wincoop (2003, footnote 11) point out, there are many

combinations of t_{ij} and t_{ji} that can lead to the same trade flows (x_{ij} and x_{ji}). Given this

theoretical foundation, it is hard to identify the asymmetry of t_{ij} and t_{ji} from the trade

data. This research adopts the same method of using the average trade costs as Chen and

Novy (2011) did in their study. The average trade costs are treated as the geometric mean

of trade cost factors, i.e. $(t_{ij}t_{ji})^{1/2}$.

Then equation (3-9) can be written as:

$$\Phi_{ij} = \frac{x_{ij} x_{ij}}{x_{ii} x_{jj}} = \left(\frac{t_{ii} t_{jj}}{\left[(t_{ji} t_{ij})^{\frac{1}{2}} \right]^2} \right)^{(\sigma-1)} \tag{3-10}$$

After transforming and taking logarithm, the equation (3-10) is

$$\ln\Phi_{ij} = \ln\frac{x_{ij} x_{ji}}{x_{ii} x_{jj}} = (1-\sigma) \cdot \ln\left(\frac{t_{ii} t_{jj}}{\left[(t_{ji} t_{ij})^{\frac{1}{2}} \right]^2} \right) = (1-\sigma) \cdot 2 \cdot \ln(t_{ij} t_{ji})^{\frac{1}{2}} + (\sigma-1) \cdot \ln t_{ii} +$$

$$(\sigma - 1) \cdot \ln t_{jj} \tag{3-11}$$

Neither the averaged bilateral trade cost $(t_{ij}t_{ji})^{1/2}$ nor the domestic trade cost t_{ii} and t_{jj} in

equation (3-11) can be directly estimated. As other academics do, I also use proxy

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variables to reflect the effects of trade cost, including basic gravity variables, policy variable and financial variables (Shepherd, 2013). In the basic GM, the variables influencing bilateral trade cost include distance between export and import economic centers ($DIST_{ij}$), and dummy variables that indicate whether countries share a common land board ($BORD_{ij}$), share a common official language ($LANG_{ij}$), and were once colonized by the same power ($COLY_{ij}$). These variables are used as a part of variable to control the bilateral trade cost. Moreover, I adopt the domestic distance to proxy the domestic trade costs, i.e.

$$lnt_{ii} = \mu_i lnD_{ii} + \xi_i \tag{3-12a}$$

And
$$lnt_{jj} = \mu_j lnD_{jj} + \xi_j \tag{3-12b}$$

the parameter μ_i and μ_j respectively present the elasticity of domestic trade cost t_{ii} and t_{jj} to the changes of domestic distance D_{ii} and D_{jj}. And ξ measures the error term of estimation.

The effects of MRPL on trade flows in this research can be measured by adding the variable $MRPL_t$ to represent the level of MRPL, which is the policy variable of bilateral trade costs. This research defines MRPL in part per billion (ppb) for Chloramphenicol. As discussed in the section 1.2.3, the MRPL level of Chloramphenicol was not specified when the MRPL regulation was originally published in 2002 and THE EU adopted the "zero-tolerance" policy on detecting the residues of Chloramphenicol. In 2005, THE EU shifted from "zero-tolerance" policy to 0.3 ppb level of MRPL for Chloramphenicol. In this research, MRPL values at 0 between 2002 and 2004, and changes to 0.3 ppb

thereafter. European Commission enforced a unified MRPL requirement for all shrimp products imported by member countries, thus the value of MRPL is the same for all importers j and exporters i and varies with time t.

This study adds two more adjustment factors to the gravity model: the exchange rate and tariff, which are also parts of bilateral trade costs. Based on Bergstrand's derivation (1985 and 1989), three important price indices cannot be neglected in the derivation of the gravity equation: transportation costs, tariffs and the exchange rates. Moreover, Soloaga and Winters (2001) and Zarzoz and Lehmann (2002) point out that exchange rate movements become relevant when the time dimension is considered in the analysis. The real exchange rate, $EXCH_{ijt}$, is added to the model specification since a time dimension is incorporated in the analysis. Transportation costs are controlled by distance ($DIST_{ij}$) and tariff is controlled by tariff measure (TAR_{ijt}). Because the intra trade between the EU countries is also included in analysis, a dummy variable EU_{it} is added to identify whether the exporter is the EU member. The proxy of averaged bilateral trade cost can be written as:

$$\ln(t_{ij}t_{ji})^{\frac{1}{2}} = \mu_1 BORD_{ij} + \mu_2 LANG_{ij} + \mu_3 COLY_{ij} + \mu_4 \ln DIST_{ij} + \mu_5 \ln EXCH_{ijt} + \mu_6 MRPL_t$$
$$+ \mu_7 EU_{it} + \mu_8 TAR_{ijt}$$

(3-13)

The parameters of μ measure the elasticity of each factor that affects bilateral trade cost. After substituting (3-12) and (3-13) into (3-11), the basic gravity equation can be written as equation (3-14).

$$\ln\Phi_{ijt} = \ln\left(\frac{x_{ij}x_{ij}}{x_{ii}x_{jj}}\right)_t = \alpha \cdot \ln(t_{ij}t_{ji})_t^{1/2} + \lambda \cdot (\ln t_{ii} + \ln t_{jj})_t$$

$$= \alpha_0 + \alpha_1 BORD_{ij} + \alpha_2 LANG_{ij} + \alpha_3 COLY_{ij} + \alpha_4 \ln DIST_{ij} + \alpha_5 \ln EXCH_{ijt}$$

$$+ \alpha_6 MRPL_t + \alpha_7 TAR_{ijt} + \alpha_8 EU_{it} + \lambda_i \ln D_{ii}^{\frac{1}{2}} + \lambda_j \ln D_{jj}^{\frac{1}{2}} + \varepsilon_{ijt}$$

$$(3\text{-}14)$$

x_{jj} and x_{ii} are respectively the dollar value of domestic demand of shrimp in the EU and country i at time t. x_{ij} and x_{ji} are bilateral trade value at time t. The disturbance term, ε_{jt}, is assumed to be normally distributed with zero mean and constant variance for all time periods. The description of variables and expected signs of explanatory variables are listed in Table 3-1.

Dealing with zero trade observations is a common issue in gravity models. Westerlund and Wilhelm (2009) point out that OLS estimates of the log-linear model may be both biased and inefficient in the presence of heteroskedasticity when zero value observations are omitted. Santos Silva and Tenreyro (2009) point out that the PPML estimator is generally well behaved even when the dependent variable has a large proportion of zeros. EU is one of the biggest importers of shrimp in the world while not a leading exporter. The data of bilateral trade flow contain large amounts of zero observations.

This research introduces PPML method into the log form of "phi-ness" to deal with this problem. PPML with "phi-ness" GM is specified as

$$\Phi_{ijt} = \exp(\alpha_0 + \alpha_1 BORD_{ij} + \alpha_2 LANG_{ij} + \alpha_3 COLY_{ij} + \alpha_4 \ln DIST_{ij} + \alpha_5 \ln EXCH_{ijt} +$$

$$\alpha_6 MRPL_t + \alpha_7 TAR_{ijt} + \alpha_8 EU_{it} + \lambda_i \ln D_{ii}^{\frac{1}{2}} + \lambda_j \ln D_{jj}^{\frac{1}{2}} + \varepsilon_{ijt}) \qquad (3\text{-}15)$$

Table 3-1. Variable Descriptions and Expected Signs

Variables	Variable Description	Expected Sign
Φ_{ijt}	Trade integration measuring the ratio of bilateral trade over domestic trade at time t	
$DIST_{ij}$	Geographical distance between country i and THE EU members j. in miles	-
D_{ii}	Geographical distance of country i. in milies	+
D_{jj}	Geographical distance of the EU member j. in milies	+
$lnEXCH_{ijt}$	Exchange rate between the EU and domestic currency of country j. It is an index with the first year being 100	-
$MRPL_t$	Variable to identify MRPL enforcement in EU., which equals to 0 before 2002, 0.3 between 2002 and 2004, and 1 thereafter	To be determined
$LANG_{ij}$	Dummy variables to identify common official language, which equals 1 if country i shares the common official language with EU member j, and 0 otherwise	+
$COLY_{ij}$	Dummy variables to indicate colony by the same power, which equals 1 if country I was once colonized by the same power with EU member j, and 0 otherwise	+
$BORD_{ij}$	Dummy variables to indicate common land board, which equals 1 if country i shares the common land board with EU member j, and 0 otherwise	+
EU_{it}	Dummy variable to identify EU members, which equals 1 if exporter i is EU members	+
TAR_{ijt}	Weighted average tariff of imported shrimp products between EU member j and exporter i, in %	-

Equation (3-15) is the benchmark model for this study and it is used to test the hypotheses by running separate panel regressions for the three groups of countries: all

exporting countries, developed countries and developing countries. The regression of all

countries is used to test whether MRPL presents significant and negative effect on the

trade integration of the EU shrimp market. The comparison between regressions of

developed country group and developing country group is applied to determine whether

MRPL requirements have differential effects on EU trade integrations with these two

countries groups. The OLS results are included for comparison purposes in order to show

the advantage of PPML when there are a large amount of zero-valued observations.

3.2 Framework of Nested CES Model

Welfare changes of consumers and suppliers are analyzed based on a demand and supply

system. Current research that combines the GM and welfare analysis usually specifies

demand and supply functions without considering the economic foundation of the linkage

between the two with the GM. This treatment infers that the GM can be combined with

demand and supply systems in any formulation. However, the derivation of the GM

shows that consumer demand functions must be in a particular form. Thus welfare

analysis conceptually is problematic because the combination of the GM and demand

functions in other forms lacks theoretical support. The analytical framework in this

research follows a different approach. The modeling system starts by deriving a gravity

equation-CES model, incorporates possible changes in consumer behavior caused by

MRPL, derives demand and supply functions, and analyzes welfare changes using these

consistent functional forms.

The CES model is the base for analyzing welfare change in this research. This approach

is often used for calculating tariff equivalents in existing research. For example, Yue,

Beghin, and Jensen (2006) improve the basic CES model by explicitly incorporating commodity heterogeneity into consumer preferences and Liu and Yue (2009) introduce the possible product quality changes into a CES model for welfare analysis. This study is different from existing studies in two ways. First, this dissertation incorporates the heterogeneity of goods into consumer preferences by considering the substitution between domestic and imported shrimp in the EU. Second, this study considers the power of the EU as a "large country" in the world shrimp market. As one of the top four shrimp importers in the world, the EU has the power to directly change its domestic price through new policies and indirectly change the import price by controlling import quantities.

3.2.1 Consumers Model

This research accounts for the changes in customer confidence in shrimp products provided by internal and external suppliers through a CES analytical framework. Since the EU is a very heterogeneous market and empirical research suggests differing effects of standards based on economic status, the heterogeneity of imported products from different regions is considered through the inclusion of prices by regions. In order to determine the differential impacts of food safety standards on heterogeneous products, this study adopts a nested utility function in a manner similar to Liu and Yue (2011). The representative consumer maximizes utility at two levels. At the first level, the representative consumer optimizes utility by choosing between domestic and imported goods. At the second level, the consumer decides on where the imported goods originate; from developed countries or developing countries.

The CES model used in welfare analysis has the same assumptions as the one used in deriving the GM. Consumers in EU countries must have homothetic preferences, and domestic and imported products are not perfect substitutes. At the first level of the nested model, the representative consumer maximizes the following CES utility function subject to a budget constraint, where the domestic and imported products are defined as D and I respectively:

$$MAX_{D,I}U^1(D, I) = [\beta_D D^{\rho_1} + (1 - \beta_D)I^{\rho_1}]^{1/\rho_1} \tag{3-16a}$$

$$s.t \quad P_D D + P_F I = M \tag{3-16b}$$

$$\beta_D = \varphi_D + \eta_D \cdot MRPL \tag{3-16c}$$

$$\rho_1 = 1 - \frac{1}{\sigma_1} \tag{3-16d}$$

σ_1 measures the elasticity of substitution between domestic and imported goods. β_D and 1- β_D indicate consumer confidence in domestic and imported foods with regard to food safety or quality. This dissertation assumes that β_D is a linear function of MRPL. η_D measures the change in consumer confidence from implementing food safety standards. If the coefficient η_D is significantly different from zero, then it is necessary to account for changes in consumer confidence in domestic and imported goods caused by MRPL standards. M is total expenditures on shrimp products. The variable MRPL is defined in the same way as in the GM. The EU enforced a zero tolerance policy for chloramphenicol in 2002, and shifted away from zero tolerance to set the MRPL limitation at 0.3ppb in

2005. Thus MRPL values at 0 between 2002 and 2004, and changes to 0.3 in 2005 and thereafter.

At the second level of utility maximization, the representative consumer confronts the choice between shrimp products imported from developed countries (I_E) and developing countries (I_I).

$$\text{MAX}_{I_E, I_I} U^2(I_E, I_I) = [\beta_I I_E^{\rho_2} + (1 - \beta_I) I_I^{\rho_2}]^{1/\rho_2} \tag{3-17a}$$

$$\text{s.t} \quad P_E I_E + P_I I_I = M_I \tag{3-17b}$$

$$\beta_I = \varphi_I + \eta_I \cdot \text{MRPL} \tag{3-17c}$$

$$\rho_2 = 1 - \frac{1}{\sigma_2} \tag{3-17d}$$

σ_2 measures the elasticity of substitution between goods imported from developed and developing countries. This research allows the elasticities of substitution in the first and second level optimization to differ; that is σ_1 may not be equal to σ_2. β_I and 1- β_I indicate consumer confidence in imported food with regard to food safety or quality. β_I is also assumed to be a linear function of MRPL. η_I measures the change in consumer confidence due to the implementation of food safety standards. If the coefficient η_I is significantly different from zero, it is necessary to account for changes in consumer confidence at the second level of optimization caused by the MRPL standard. M_I is expenditure on imported shrimp products.

The nested CES framework combined the first and second level maximization of utilities is:

$$\text{MAX}_{D,I_E,I_I} \ U(D, I_E, I_I) = [\beta_D D^{\rho_1} + (1 - \beta_D)\{[\beta_I I_E^{\rho_2} + (1 - \beta_I)I_I^{\rho_2}]^{1/\rho_2}\}^{\rho_1}]^{1/\rho_1} \quad (3\text{-}18\text{a})$$

$$\text{s.t} \ P_E I_E + P_I I_I + P_D D = M \quad (3\text{-}18\text{b})$$

$$P_I I_I + P_E I_E = M_I \quad (3\text{-}18\text{c})$$

From utility maximization, the conditions that the marginal rate of substitution is equal to the relative price of the substitute goods can be written as:

$$\text{MRS}_{D, \ I_E} = \frac{MU_D}{MU_{I_E}} = \frac{P_D}{P_E} = \frac{\beta_D D^{\rho_1 - 1}}{(1 - \beta_D) \cdot I_E^{\rho_2 - 1} \cdot \beta_I \cdot [\beta_I I_E^{\rho_2} + (1 - \beta_I)I_I^{\rho_2}]^{\left(\frac{\rho_1}{\rho_2} - 1\right)}}$$

$$= \frac{\beta_D I_E^{1/\sigma_2}}{(1 - \beta_D)D^{1/\sigma_1}} \cdot \beta_I^{-1} \cdot \left[\beta_I I_E^{(1 - \frac{1}{\sigma_2})} + (1 - \beta_I)I_I^{(1 - \frac{1}{\sigma_2})}\right]^{\frac{\sigma_2 - \sigma_1}{\sigma_1(1 - \sigma_2)}} \quad (3\text{-}19\text{a})$$

$$\text{MRS}_{I_E, \ I_I} = \frac{MU_{I_E}}{MU_{I_I}} = \frac{P_E}{P_I} = \frac{\beta_I}{(1 - \beta_I)} \cdot \left(\frac{I_I}{I_E}\right)^{1 - \rho_2} = \frac{\beta_I}{(1 - \beta_I)} \cdot \left(\frac{I_I}{I_E}\right)^{\frac{1}{\sigma_2}} \quad (3\text{-}19\text{b})$$

After rearranging equation (3-19a) and (3-19b) and taking the natural logarithms, the equations used for estimating parameters are:

$$\ln\left(\frac{M_I}{P_I \cdot I_I} - 1\right) = \sigma_2 \cdot \ln\frac{\beta_I}{1 - \beta_I} + (\sigma_2 - 1) \cdot \ln\left(\frac{P_I}{P_E}\right)$$

$$= (\sigma_2 - 1) \cdot \ln\left(\frac{P_I}{P_E}\right) + \sigma_2 \cdot \ln\left(\frac{\varphi_I + \eta_I \cdot MRPL}{1 - \varphi_I - \eta_I \cdot MRPL}\right)$$

$$(3\text{-}20\text{a})$$

$$\ln \frac{P_D \cdot D}{P_E \cdot I_E} = (\sigma_1 - 1) \ln \left(\frac{P_E}{P_D}\right) + \sigma_1 \cdot \ln \left(\frac{\varphi_D + \eta_D \cdot MRPL}{1 - \varphi_D - \eta_D \cdot MRPL}\right) - \frac{(\sigma_1 - 1)\sigma_2}{(\sigma_2 - 1)} \ln\left(\varphi_I + \eta_I \cdot MRPL\right) +$$

$$\frac{\sigma_2 - \sigma_1}{\sigma_2 - 1} \ln[1 + \left(\frac{1}{\varphi_I + \eta_I \cdot MRPL} - 1\right)^{\sigma_2} \cdot \left(\frac{P_E}{P_I}\right)^{\sigma_2 - 1}]$$

$$(3\text{-}20b)$$

Annual data on the exogenous variables D, I_E, I_I, P_I, P_E, P_D, and M_I can be retrieved from databases and the parameters σ_1, σ_2, φ_I, φ_E, η_I, and η_E can be estimated using non-linear three stage least square (N3SLS).

The associated Marshallian Demand functions are

$$D(P_D, P_E, P_I, M_I) = M_I \left(\frac{\beta_D}{1-\beta_D}\right)^{\sigma_1} \left(\frac{1}{P_D}\right)^{\sigma_1} [\beta_I^{\sigma_2} P_E^{1-\sigma_2} + (1 - \beta_I)^{\sigma_2} P_I^{1-\sigma_2}]^{\frac{1-\sigma_1}{\sigma_2-1}} \quad (3\text{-}21a)$$

$$I_E(P_E, P_I, M_I) = M_I \left(\frac{\beta_I}{P_E}\right)^{\sigma_2} [\beta_I^{\sigma_2} P_E^{1-\sigma_2} + (1 - \beta_I)^{\sigma_2} P_I^{1-\sigma_2}]^{-1} \quad (3\text{-}21b)$$

$$I_I(P_E, P_I, M_I) = M_I \left(\frac{1-\beta_I}{P_I}\right)^{\sigma_2} [\beta_I^{\sigma_2} P_E^{1-\sigma_2} + (1 - \beta_I)^{\sigma_2} P_I^{1-\sigma_2}]^{-1} \quad (3\text{-}21c)$$

The indirect utility functions of the first and second level maximization are V^1 and V^2.

$$V^1(P_D, P_E, P_I, M_I) = M\{\beta_D^{\sigma_1} P_D^{1-\sigma_1} + \left(1 - \beta_D\right)^{\sigma_1} [\beta_I^{\sigma_2} P_E^{1-\sigma_2} + \left(1 - \beta_I\right)^{\sigma_2} P_I^{1-\sigma_2}]^{\frac{\sigma_1-1}{\sigma_2-1}}\}^{\frac{1}{\sigma_1-1}}$$

$$(3\text{-}22a)$$

$$V^2(P_E, P_I, M_I) = M_I[\beta_I^{\sigma_2} P_I^{1-\sigma_2} + \left(1 - \beta_I\right)^{\sigma_2} P_E^{1-\sigma_2}]^{\frac{1}{\sigma_2-1}} \quad (3\text{-}22b)$$

The expenditure functions of the first level and second level optimization are

$$E^1(P_E, P_I, u^1) = u^1 \left(\beta_I^{\sigma_2} P_E^{1-\sigma_2} + (1 - \beta_I)^{\sigma_2} P_I^{1-\sigma_2} \right)^{\frac{1}{1-\sigma_2}} \qquad (3\text{-}23\text{a})$$

$$E^2(P_D, P_E, P_I, u^2) = u^2 \{ \beta_D^{\sigma_1} P_D^{1-\sigma_1} + (1 - \beta_D)^{\sigma_1} [\beta_I^{\sigma_2} P_E^{1-\sigma_2} + (1 - \beta_I)^{\sigma_2} P_I^{1-\sigma_2}]^{\frac{\sigma_1-1}{\sigma_2-1}} \}^{\frac{1}{\sigma_1-1}}$$

$$(3\text{-}23\text{b})$$

3.2.2 Supply Model

An equilibrium displacement model is used for the model's supply side. Let S_D, S_{I_E} and S_{I_I} be the domestic supply, foreign supply of shrimp from developed countries, and foreign supply of shrimp from developing countries, respectively. The supply is an increasing function with price P and parameter γ. The supplier functions follow the relations shown in (3-24):

$$S_D(P_D, \gamma_D) = \gamma_D P_D \qquad (3\text{-}24\text{a})$$

$$S_{I_E}(P_E, \gamma_E) = \gamma_E P_E \qquad (3\text{-}24\text{b})$$

$$S_{I_I}(P_I, \gamma_I) = \gamma_I P_I \qquad (3\text{-}24\text{c})$$

where subscript D, E, and I respectively indicate domestic supply, foreign supply from developed countries, and foreign supply from developing countries. All of the γs are positive. Decrease in parameter γ would reflect the upward shift of supply function if the MRPL requirement increases the compliance cost for suppliers and induce the increase of production costs. The original γ parameters can be estimated with data of domestic and foreign supply quantity and price. The (3-24) system is estimated simultaneously by using seemingly unrelated regression (SUR) in SAS.

It is assumed that domestic suppliers already incorporate the MRPL standard and the domestic supply curve is not affected by lowering MRPL. This was the case with the new 2002 policy that impacted mainly Asian exporters, since chloramphenicol was already banned in EU since 1994 (Disdier and Marette, 2010). Thus γ_D will not change with MRPL level. If EU shifts MRPL policy to zero, foreign suppliers, no matter in developed countries or developing countries, may incur more compliance cost and the foreign supply curve may rotate upward. Thus the parameter γ_I and γ_E may reduce after the reduction of MRPL. The changes of γ_I and γ_E could be captured by the estimation of MRPL in the "phi-ness" GM, which will be discussed in detail later.

3.2.3 Calculation of Welfare Change

As stated in section 1.3, in order to explore the effect of strict standard, this research measures the welfare based on two scenarios with different levels of MRPL and then compare the difference between welfares under these two scenarios. The initial scenario reflects the current set of MRPL for chloramphenicol, which values at zero from 2002 to 2004 and at 0.3 ppb since 2005. The new scenario considers the effects of sticking MRPL at zero in 2005 and thereafter. MRPL regulation is stricter in the new scenario.

The first step of calculating welfare changes is to determine the price and quantities at the new equilibrium. Equation (21) and (24) provides the parameters and the demand and supply functions at the initial scenario. The products supplied by domestic suppliers and foreign supplier from developed countries and developing countries are heterogeneous as the prices differ among P_D, P_E and P_I. At the new equilibrium, the domestic and foreign

shrimp products are identical and share the same price P. The new price is determined by the total demand and total supply of domestic and foreign products.

At the new equilibrium, there is $P_D = P_E = P_I = P$ and the total demand of shrimp products in the EU can be written as:

$$TD = D^1 + I_E^{\,1} + I_I^{\,1}$$

$$= M_I \left(\frac{\beta_D^{\,1}}{1 - \beta_D^{\,1}} \right)^{\sigma_1} (\frac{1}{P})^{\sigma_1} [(\beta_I^{\,1})^{\sigma_2} P^{1-\sigma_2} + (1 - \beta_I^{\,1})^{\sigma_2} P^{1-\sigma_2}]^{\frac{1-\sigma_1}{\sigma_2-1}}$$

$$+ M_I \left(\frac{\beta_I^{\,1}}{P} \right)^{\sigma_2} [(\beta_I^{\,1})^{\sigma_2} P^{1-\sigma_2} + (1 - \beta_I^{\,1})^{\sigma_2} P^{1-\sigma_2}]^{-1}$$

$$+ M_I \left(\frac{1 - \beta_I^{\,1}}{P} \right)^{\sigma_2} [(\beta_I^{\,1})^{\sigma_2} P^{1-\sigma_2} + (1 - \beta_I^{\,1})^{\sigma_2} P^{1-\sigma_2}]^{-1}$$

$$= M_I \left(\frac{\beta_D^{\,1}}{1 - \beta_D^{\,1}} \right)^{\sigma_1} \frac{[(\beta_I^{\,1})^{\sigma_2} + (1 - \beta_I^{\,1})^{\sigma_2}]^{\frac{1-\sigma_1}{\sigma_2-1}}}{P} + \frac{M_I}{P}$$

$$(3\text{-}25)$$

The total supply function can be written as:

$$TS = S_D^{\,1} + S_{I_E}^{\,1} + S_{I_I}^{\,1} = \gamma_D P + \gamma_E^{\,1} P + \gamma_I^{\,1} P \qquad (3\text{-}26)$$

The superscript 1 reflects the new equilibrium when MRPL sticks at level zero from 2002. γ_D is assumed to be the same in the initial and new scenario. The changes of γ_E and γ_I can be captured by the estimation of MRPL effects on trade integrations in "phi-ness" GM with PPML. The direct relationship between γ_I, γ_E and the parameters of estimating MRPL effects on trade integrations will be discussed in detail in the next section.

The market clear condition at equilibrium can be written as:

$$TS = TD \qquad (3\text{-}27)$$

The equation of (3-25), (3-26) and (3-27) constitute the calibrated model system to determine the universal price and the supply quantities at the new equilibrium.

This dissertation considers the changes to consumers' surplus caused by the reduction of MRPL. For consumer welfare analysis, the Equivalent Variation (EV) measure is used.

$$EV = V^1\left(\widetilde{P}^1, M_I\right) - V^0 \qquad (3\text{-}28)$$

where $\tilde{P} = (P_D, P_E, P_I)$ and superscript 1 and 0 indicate new and initial prices in equation (3-28) and thereafter. The change of consumers' surplus is defined as the changes of consumers' utility. The new price P and quantity $D^1 \; I_E^{\;1} \; I_I^{\;1}$ are determined by the domestic market equilibrium, which considers the effects of lowering the MRPL at zero tolerance policy on imports and domestic market.

The calculation of the supplier's welfare change (ΔSW) is shown with equation (3-29). If γ does not change with MRPL, the welfare changes of suppliers are calculated as (3-29a), otherwise the welfare changes are calculated as (3-29b).

$$\Delta SW = \int_{P_0}^{P_1} S \cdot P \, dP \qquad (3\text{-}29a)$$

$$\Delta SW = \int_0^{P_1} S_1 \cdot P \, dP - \int_0^{P_0} S_0 \cdot P \, dP \qquad (3\text{-}29b)$$

The total EU welfare change caused by reduction of MRPL is the sum of consumer's utility change and domestic suppliers' welfare changes. The welfare changes for foreign suppliers can also be obtained with equations of (3-29).

3.3 Combination of GM and Nested CES

The "phi-ness" GM and nested CES model adopted in this research play different roles in estimating the effects of MRPL enforcement on the EU shrimp market. The former model is used to estimate the effects on the trade flows while the latter is used to quantify welfare changes caused by MRPL. In this application, these two models are developed based on the same foundation. The basic GM equation is derived with a CES utility function and competitive assumptions. The "phi-ness" method for estimating the GM is setup by transforming the bilateral trade flows of the basic GM into intra-country and extra-country trade flows. The nested CES model begins with the basic CES model and introduces two levels of utility maximization into a representative consumer's utility function. The demand and supply functions are then developed based on a nested CES function.

Because the two models are derived with the same foundations there are inherent links between the "phi-ness" GM and the nested CES model. These two models can be viewed as two different branches originating from the same basic theory. In general, the links can be inferred from the variable concepts, the elasticity of substitution and the measurement of standard effects.

3.3.1 Links of Variables Concepts

The links of variables concepts lie in the relationship between trade flow variables used in the "phi-ness" GM and nested CES model. As stated earlier, the "phi-ness" GM considers bilateral trade flows between EU importers j and exporters i (x_{ij} and x_{ji}) and trade flows intra j (x_{jj}) and intra i (x_{ii}). The nested CES model considers domestic supply of EU members D, total foreign supplies from developed countries I_E, and total foreign supplies from developing countries I_I.

In equation (3-3) of the basic GM, x_{ij} represents the domestic supply of EU members when i=j; while when i≠j, x_{ij} is the value of shrimp products exported to EU from either developed countries or developing countries depending on importing origins. In equation (3-16), (3-17) and (3-18), the domestic supply D equals x_{jj} in the GM. At the first level of optimizing consumer utility, I_E and I_I are the aggregated value of shrimp imported from developed and developing countries. In other words, I_E and I_I in equation (3-17) and (3-18) are the summed values of x_{ij} that weigh the bilateral trade flow by the consumers' preferences across different exporters in each country groups of respectively developed countries and developing countries. In this case, the nested CES model, equation (3-18) can be viewed as the weighted aggregate form of the basic CES model, equation (3-1).

In general, both the "phi-ness" GM and nested CES model adopt the domestic supply variable for the EU, and foreign supply from developed countries and developing countries. However, these two models use these variables at different levels of aggregation. The "phi-ness" GM adopts the disaggregation of trade flows while the nested CES uses an aggregated trade flow. This difference originates from their differing

purposes. The "phi-ness" GM concerns international trade, which emphasizes differentiation between trading partners. Disaggregated data provides more detailed information about the variable effects among exporters and importers. The nested CES concentrates on the welfare changes for EU countries and emphasizes the changes to suppliers and consumers in aggregation, so aggregated data are more suitable for CES model.

3.3.2 Links of Elasticities of Substitution

As stated above, "phi-ness" GM and nested CES model originate from the same basic model. In addition to the same variables used in estimation, these two models share the same value of substitution elasticities: σ or ρ in nested CES model. The value of σ plays an important role in estimating the "true" elasticity of trade cost variables with respect to trade cost. Based on the derivation of equation (3-11), (3-12) and (3-13), the estimated coefficient of equation (3-14) are the product of the elasticities of substitution (1-σ) and the "true" elasticities μ with respect to variables that proxy trade cost, i. e. $\alpha=2(1-\sigma)\cdot\mu$ and $\lambda=(\sigma-1)\cdot\mu$. If the σ is high and the "true" elasticity μ is low, one small change in variable would not change the trade cost so much but dramatically change the trade integration.

Only once the elasticities of substitution σ are observed can the elasticities of proxy variables with respect to trade costs be retrieved as $\mu = \alpha/2(1-\sigma)$ and $\mu = \lambda/(\sigma-1)$. As the research groups or industries differ, the value of elasticities of substitution could also be different (Chen and Novy's 2011; Liu and Yue 2011). σ can be estimated by nested CES model, as shown in estimating equation (3-20a) and (3-20b).

Estimation results for equations of (3-20) provide two values of elasticities of substitution: σ_1 and σ_2. At the first level of maximization of CES model, σ_1 measures the substitution between domestic supply and overall foreign supply and can be combined with the "phi-ness" GM that quantifies the standard effects on overall imports. When the regression covers all exporting countries, σ_1 is applied to equation (3-15). σ_2 measures the substitution between imports from developing countries and developed countries. This elasticity of substitution in allows the standard effects to vary by economic status of exporters. Thus σ_2 is applied to equation (3-15) of the GM when the regression is running with the data of developed country group and developing country group. In order to keep the estimation and analysis consistent, the same country groups of developed countries and developing countries are used in the "phi-ness" GM and nested CES models.

3.3.3 Links of Measuring Standard Effects

The link in measuring MRPL effects between the GM and nested CES models is reflected by the essence of trade flows and welfare changes. MRPL affects disaggregated trade flows by changing trading costs and affects aggregate welfare by changing consumer and supplier behavior. Trade flows are comprised of import price and quantities, which are P_I, P_E, I_I and I_E in nested CES model. The changes of MRPL level influences consumer and supplier behavior and further alters demand and domestic and foreign supply. Market equilibrium is affected because of the supply and demand shifts, so welfare and international trade flow change too.

The reduction of MRPL could affect foreign supply by changing the value of γ_I or γ_E and these changes can be captured by the estimation of MRPL effects on trade integrations of

developing countries and developed countries in the GM model. For the purpose of easy understanding, let's first focus on the supply curve of developing countries. If γ_I dramatically reduces and induces import-quantity shrink distinctly after the reduction of MRPL, the imported value of developing countries decrease at equilibrium as the contraction of import-quantity is larger than the increase in price (i.e. $P*I_I^1 < P_I^0*I_I^0$). Since the domestic supply is not affected by MRPL, the domestic trade flow increases with increased new price, and then the trade integration would be significantly reduced by the MRPL reduction. And the welfare of foreign suppliers from developing countries deceases significantly. The welfare of domestic consumers may also decrease when the new price is too high.

Alternatively, if γ_I stays unchanged, the trade integration would not be affected by MRPL regulation. At the initial scenario, the trade integration can be calculated as:

$$\Phi_0 = \left(\frac{x_{ji}*P_I*I_I}{x_{ji}\,P_D*D} \right) = \left(\frac{P_I*P_I*\gamma_I}{P_D*P_D*\gamma_D} \cdot \frac{x_{ji}}{x_{ji}} \right) = \left(\frac{P_I^2*\gamma_I}{P_D^2*\gamma_D} \cdot \frac{x_{ji}}{x_{ji}} \right) \tag{3-30}$$

At the new equilibrium it then only depends on γ_I and γ_D.

$$\Phi_1 = \left(\frac{P*I_I}{P*D} \cdot \frac{x_{ji}}{x_{ji}} \right) = \left(\frac{P^2*\gamma_I}{P^2*\gamma_D} \cdot \frac{x_{ji}}{x_{ji}} \right) = \left(\frac{\gamma_I}{\gamma_D} \cdot \frac{x_{ji}}{x_{ji}} \right) \tag{3-31}$$

Since this research concentrates on EU countries (j in the equations) and assumes that domestic trade flows and imports of import country i are not changed, the changes from Φ_0 to Φ_1 depend on the difference between the initial price P_I and P_D. In reality this difference is remote. Most of empirical research normally treats P_I and P_D at the same value. In this case the change of trade integration is negligible.

If γ_I does not dramatically reduce, then the increase of P_I overcomes the changes of quantity $(P*I_I^1 \geq P_I^0*I_I^0)$. So the effects of MRPL on trade integration may not be significant. In this case, the significance of MRPL effects on trade flows could indicate the movement of supply curve of the developing countries.

The above analysis indicates that when MRPL demonstrates significant effects on trade integrations, γ of foreign supplier curve would dramatically change; while if MRPL demonstrates insignificant effects on trade integrations, γ may stay unchanged or change slightly, which could not be quantified with econometric estimation. This indication applies to each exporters group of developed and developing countries.

Based on the research of Disdier and Marette (2010), if the MRPL has no significant impact on trade, no further welfare analysis of the MRPL will be necessary. This research follows the same pattern. If α_6 in equation (3-15) is estimated to be statistically significant, it will be used for the welfare analysis linked to MRPL.

By taking the derivative from (3-15), the relative variation of exports in value linked to MRPL can be defined as $dx/x = \alpha_6 \cdot dMRPL$ (everything else being constant). The relative variation of exports linked to the MRPL can be rewritten as:

$$d[\ln\left(\frac{x_{ij} x_{ji}}{x_{ii} x_{jj}}\right)] = \alpha_6 dMRPL \qquad (3\text{-}32)$$

Since the domestic trade flow and imports of import country i are assumed to be unchanged, equation (3-42) can be derived as:

$$d\left[\ln\left(\frac{x_{ij}\,x_{ji}}{x_{ii}\,x_{jj}}\right)\right] = d\left[\ln\left(\frac{x_{ij}}{x_{jj}}\right)\right]] = \alpha_6 dMRPL \tag{3-33}$$

As stated in section 3.1.3, separate panel regressions are run with the benchmark of the GM model with PPML for the three groups of countries: all exporter countries, developed countries, and developing countries. The value of trade is defined by x =P·Q, where P and Q are the price and the quantity. For developed country group and developing country group, equation (3-33) can be written as equation (3-34a) and (3-34b) after substituting in the new and initial price and quantities at equilibrium:

$$d\left[\ln\left(\frac{x_{ij}^E}{x_{jj}}\right)\right] = d\left[\ln\left(\frac{P_{ij}^E Q_{ij}^E}{P_{jj} Q_{jj}}\right)\right] = \frac{P - P_E^0}{P_E^0} + \frac{I_E - I_E^0}{I_E^0} - \frac{P - P_D^0}{P_D^0} - \frac{D - D^0}{D^0} = \alpha_6^{\ E}\Delta MRPL$$

$$\tag{3-34a}$$

$$d\left[\ln\left(\frac{x_{ij}^I}{x_{jj}}\right)\right] = d\left[\ln\left(\frac{P_{ij}^I Q_{ij}^I}{P_{jj} Q_{jj}}\right)\right] = \frac{P - P_I^0}{P_I^0} + \frac{I_I - I_I^0}{I_I^0} - \frac{P - P_D^0}{P_D^0} - \frac{D - D^0}{D^0} = \alpha_6^{\ I}\Delta MRPL$$

$$\tag{3-34b}$$

The superscript 0 indicates the initial price and quantity while parameters of price and quantities without index 0 indicate the corresponding values at the new equilibrium after removing the changes of MRPL. As stated in former section, the new price P are universal between domestic and foreign products as the products are identical after enforcing MRPL at zero level. $\alpha_6^{\ E}$ and $\alpha_6^{\ I}$ are respectively the coefficients measuring MRPL effects on trade with all exporters, developed countries and developing countries. When the impact of the MRPL is statistically significant, the gravity analysis can be

integrated into the welfare analysis via equation (3-34) that isolates the effect of the MRPL variation from other effects.

The estimation of α_6^A for group of all exporters is not considered in the welfare analysis that measures the differentiate changes of supplies based on exporters' economic status. Since this α_6 concentrates on the MRPL effects on the aggregated imported products and does not consider the heterogeneity among products, it could not provide the information of differentiate effects of MRPL based on different country group.

Equation (3-25), (3-26), (3-27) and (3-34) constitute the calibrated model to calculate the new coefficient γ and the new price and supply quantities at the new equilibrium. Only if α_6 demonstrates statistical significance, the corresponding equation of (3-34) is incorporated into the calibration. The calibration includes the following two scenarios depending on the significance of α_6.

1. If any one of α_6^E and α_6^I or both show statistical significance, the analysis of changes to γ_E or γ_I should be combined with the estimation of corresponding α_6 of the GM.

2. If neither α_6^E nor α_6^I demonstrates statistical significance, γ_E and γ_I are deemed to stay unchanged at the new equilibrium. In this case, the welfare analysis based on the heterogeneous products from different origins is unachievable. If α_6^A presents significance, then the welfare analysis should be based on all exporters in aggregation. This happens when both γ_E and γ_I changes slightly and the estimation of MRPL in the GM could not capture these changes, but the changes of total foreign supplies that add the two together are significant. Otherwise, if α_6^A is insignificant, the welfare analysis is then deemed to be unnecessary.

The significance of the MRPL effect can also be indirectly reflected by parameters in the consumer CES utility function. If the MRPL has significant effects on trade integrations of all exporters, then consumers change the consumption between domestic and total foreign shrimp products. Thus, consumer confidence in domestic and foreign suppliers may be dramatically affected by MRPL and the parameter η_D may have a statistical significant effect. Moreover, if any α_6 for the developed country or developing country group is statistically significant, then the trade with corresponding country group is significantly affected by the MRPL standard. This result infers that consumer confidence in shrimp products imported from developed countries and developing countries may be severely influenced by MRPL. Thus the parameter η_I may demonstrate statistical significance.

3.4 Data Description

3.4.1 Data Description of "phi-ness" GM

This research uses annual data between 2002 and 2010 across 12 EU countries to estimate the model. The 12 EU countries included are Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherland, Portugal, Spain, Sweden, and United Kingdom. The sample is not balanced due to limitations on trade data. The time series begins in 2002 because that is when the MRPL was first enforced. Since the legitimate information about MRPL is lacking before 2002, only countries with data that is available since 2001 are considered in this research. After selection, 72 exporting countries are used in the analysis. Developed and developing countries are categorized according to the list of High-income OECD members provided by the World Bank. 24 developed

countries and 48 developing countries are used in the analysis. The majority of developed countries are EU countries. Other developed countries include Australia, Canada, Greenland, Japan, South Korean, and the United States. In this case, the EU and non EU developed countries are combined together in the analysis.

The estimation needs the domestic trade of countries i and j, x_{ii} and x_{jj}, as well as their bilateral exports, x_{ij} and x_{ji}, at time t to compute the "phi-ness" index for the GM. The Harmonized System Code (HS) category 030613 and 030623, for the frozen and non-frozen shrimps and prawns are the focus of this analysis. These two categories exclude all the more-processed shrimp and prawn products, which have been processed and put into air-tight containers or prepared with other fish or meat. These last products are categorized under the HS category 160520. All data on value, quantity and unit price used in analysis are separately provided for frozen and non-frozen categories. Since the data of all shrimp products are used for the analysis, this research uses the aggregated data by adding frozen and non frozen shrimp together.

The data of domestic trade flows were not found directly in the existing database. Only data on the domestic supply of all crustaceans is available through FAOSTAT (2014); data on domestic shrimp supply is not available. As in previous literature (Chen and 2011, Liu and Yue 2011), the domestic trade of country j (i) is calculated by the value of gross shrimp output minus the value of total shrimp exports of j (i) to the rest of the world. There are no available data on the value of shrimp output. The values of shrimp outputs are calculated by multiplying the quantity of total shrimp production with the

aggregated Cost, Insurance and Freight (CIF) shrimp price. Data on total production

(measured in tonne) is obtained from the Global Production database.

Table 3-2. Data Summary of "phi-ness" Gravity Model with All Exporters

Country Group	Variable	Observation	Mean	Variance	Min	Max
All	x_{ij} (thousand $)	4062	8075742	20700000	5	341000000
Exporters	x_{ji} (thousand $)	1846	6715581	15400000	1	140000000
	x_{ii} (thousand $)	4062	435.95	1201.57	0	11454.08
	x_{jj} (thousand $)	4062	35.37	36.72	0.70	150.26
	cif ($/kg)	4062	5.58	7.39	0.022	164.70
	Production (tonne)	4062	58625.90	223760.10	0	2582651.00
	Total Export (tonne)	4062	17020.90	35749.65	0	252949.00
	DomesticTrade (tonne)	4062	44790.81	204036	0	2414490
	Φ_{ij}	4041	293063.40	2723519	0	79400000
	$DIST_{ij}$ (kilometers)	4062	5655.70	4054.63	160.93	17625.29
	D_{ii} (kilometers)	4062	399.44	377.13	8.45	1853.80
	D_{jj} (kilometers)	4062	261.37	142.32	66.78	462.52
	MRPL	4062	0.18	0.15	0	0.30
	Tariff	2802	0.17	0.15	0	0.30
	Exchange Rate index	4062	1.40	1.00	0.62	8.51
	EU	4062	0.31	0.46	0	1.00
	zero observations	2195				

Table 3-3. Data Summary of "phi-ness" Gravity Model with Developed Countries

Country Group	Variable	Observation	Mean	Variance	Min	Max
Developed countries	x_{ij} (thousand $)	1702	5610238	11600000	5	108000000
	x_{ji} (thousand $)	1275	8738960	17000000	1	140000000
	x_{ii} (thousand $)	1702	107.47	230.73	0	1324.84
	x_{jj} (thousand $)	1702	32.02	35.42	0.70	150.26
	cif ($/kg)	1702	5.91	2.44	1.15	12.85
	Production (tonne)	1702	22725.76	40335.87	0	188216
	Total Export (tonne)	1702	15361.33	23593.29	0	132921
	Domestic Trade (tonne)	1702	17195.93	30895.79	0	144446
	Φ_{ij}	1683	666127.50	4076545	0	79400000
	$DIST_{ij}$ (kilometers)	1702	2925.47	3754.69	160.93	17625.29
	D_{ii} (kilometers)	1702	394.69	458.55	66.78	1853.80
	D_{jj} (kilometers)	1702	246.29	137.23	66.78	462.52
	MRPL	1702	0.18	0.15	0	0.30
	Tariff	1702	0.028	0.053	0	0.14
	Exchange Rate index	1702	1.01	0.14	0.65	2.18
	EU	1702	0.72	0.45	0	1
	zero observations	408				

Table 3-4. Data Summary of "phi-ness" Gravity Model with Developing Countries

Country Group	Variable	Observation	Mean	Variance	Min	Max
Developing Countries	x_{ij} (thousand $)	2360	9853830	25100000	17	341000000
	x_{ji} (thousand $)	571	2197527	9471805	3	102000000
	x_{ii} (thousand $)	2360	672.85	1520.87	0	11454.08
	x_{jj} (thousand $)	2360	37.78	37.45	0.70	150.26
	cif ($/kg)	2360	5.47	8.48	0.02	164.70
	Production (tonne)	2360	71359.17	258171.40	0	2582651.00
	Total Export (tonne)	2360	17609.53	39160.51	0	252949.00
	Domestic Trade (tonne)	2360	54578.32	236029.00	0	2414490.00
	Φ_{ij}	2358	26792.42	827421.00	0	39300000.00
	$DIST_{ij}$ (kilometers)	2360	7552.46	3023.61	451.42	16870.66
	D_{ii} (kilometers)	2360	402.86	305.29	8.45	1366.11
	D_{jj} (kilometers)	2360	272.24	144.93	66.78	462.52
	MRPL	2360	0.17	0.020	0	0.30
	Tariff	2360	0.090	0.060	0	0.14
	Exchange Rate index	2360	1.56	1.15	0.62	8.51
	EU	2360	0.014	0.12	0	1
	zero observations	1787				

The aggregated CIF is constructed as the sum of unit CIF weighted by the quantities of imported frozen and non-frozen shrimp products. The aggregated CIF is measured in US

dollar per kilogram and is converted into dollar per ton when calculating total production value. Bilateral trade data, x_{ij} and x_{ji}, are taken from UN Comtrade Legacy Annual Database and measured in thousand dollars. Table 3-2, Table 3-3 and Table 3-4 has detailed information on trade flow data used in this study.

Information on Gravity variables, including bilateral distance D_{ij}, unilateral distance D_{ii} and D_{jj}, common land board $BORD_{ij}$, common official language $LANG_{ij}$, and colonized by the same power $COLY_{ij}$ are obtained from the CEPII Gravity Database. Data on distances are measured in kilometers. The weighted average distance between country i and j is used as the bilateral distance, which provides current population figures and geographic coordinates for cities, towns and places of all countries. The unilateral distance is determined by the internal distance of country i or j, which measures the average distance between consumers and producers in a country. Head and Mayer (2002) present more details of the measure of bilateral distance and unilateral distance.

Data on the export value and unit CIF are obtained for the frozen and non-frozen categories from the UN Comtrade Legacy Annual Database. Total export value is the sum of export values of frozen and non-frozen shrimp and is measured in thousand dollars.

Data for exchange rates are obtained from the database of World Development Indicators. The real exchange rate, which is calculated as the local currency units relative to the U.S. dollar based on annual average is converted into an index form in order to avoid the changing scale among countries; this makes exchange rate changes comparable among countries. The base year for the exchange rate is 2000.

Tariff data are obtained from Trade Analysis Information System (TRAINS). The import weighted average tariff rate for shrimp and pawns, which is measured in percentage and is the average tariff rates of frozen and non-frozen shrimp products weighted by the country's own imports from the world in the same or nearest available year, is used. The tariff rate for each shrimp product is itself a simple average rate of included tariff lines.

The data of MRPL is summarized from the Official Journal of the European Communities: Commission Decision 2002/657/EC, Commission Decision 2003/181/EC, Commission Decision 2005/34/EC and the study of Hanekamp and Calabrese (2007).

Before assigning values for EU variable, the effective time of each European country's membership as the exporter is carefully verified, because member countries may not join in EU on the same date.

3.4.2 Data Description of Nested CES Model

In order to keep the consistent linkage with "phi-ness" GM, the same 12 EU countries and the same time span from 2002 to 2010 are adopted in CES analysis. The sample panel is balanced with 108 observations. Table 3-5 provides detailed information on the data used in the nested CES model.

The domestic supply of shrimp products D is estimated as total shrimp production minus exports. The export quantity is the sum of exported frozen and non frozen shrimp products. P_D is estimated as the aggregated CIF and is constructed in the same way as for the "phi-ness" GM. I_E and I_I are estimated by summing the quantity of frozen and non-

frozen shrimp products that are imported from developed countries and developing countries, respectively.

Table 3-5. Data Summary of Nested CES Model

Variable	Observation	Mean	Variance	Min	Max
P_D ($/kg)	108	6.84	1.97	2.077	11.62
Production (tonnes)	108	6833.19	7067.74	83	35267
Total Export (tonnes)	108	20066.92	26342.87	368	132921
Domestic Supply (tonnes)	108	5058.32	5608.37	25	25943
I_E (tonnes)	108	12500	7452.26	1198.33	36400
I_I (tonnes)	108	36300	38300	124.53	155000
P_I ($/kg)	108	6.73	1.67	1.86	9.76
P_E ($/kg)	108	7.21	2.091	2.40	11.62
Total Consumption (tonnes)	108	3568.65	3589.42	87	13102
M	108	336.45	298.042	10.77	1505.53
M_I (million $)	108	301	287	10.60	1280
HICP	108	100.0835	11.1164	75.01	135.7
Effect. Exch. Rate index	108	97.91929	6.654906	78.01	116.35
Fleet	108	153186	124025.9	15812	550340
Wage Index	108	104.6962	7.109592	92.46546	134.3878
Shrimp/Other. Crust. Index	108	1.60	0.72	-0.043	3.57
EU Real GDP index	108	113.38	10.40	84.90	135.60
EU Population (millions)	108	31.40	27.20	39.32	82.50

Data on total production, export quantity and import quantity of frozen and non-frozen shrimp products are obtained from the database of FAO Global Production and are measured in tons. The value of P_E and P_I is estimated as the aggregated CIF price of shrimp products imported from developed countries and developing countries,

respectively. The aggregated CIF price is obtained by dividing the sum of imported value of frozen and non-frozen products by the sum of imported quantity. Each of the aggregated CIF price is measured in dollars per kilogram and transformed into dollar per ton in the analysis. The value of frozen and non-frozen products imported from developed and developing countries are obtained from the UN Comtrade Legacy Annual Database and are measured in thousand dollars.

The income spent on shrimp consumption is used as the imperfect proxy of income budget M. The shrimp consumption is estimated as total production plus total imports minus total exports, and includes both industrial and consumer. The total import value of shrimp products is used to estimate M_I.

In order to estimate equation (3-34) with N3SLS, seven instrumental variables are used in the analysis. They are Harmonized Indices of Consumer Prices (HICPs), Fish Fleeting, Real Effective Exchange Rates, Average Annual Wage index, the Price index of Shrimp to Other Crustacean, Real GDP and Population of importers. Data on HICP, Fish Fleeting Real GDP index with 2000 as the base year and average Population are obtained from EUROSTAT. HICP is the a set of consumer price indices (CPIs) calculated according to a harmonized approach and measures the change over time of the prices of consumer goods and services acquired by households. The fishing fleet reflects the size of fleet and the management of fishing capacity. Fishing Fleet is measured in vessels but it is converted into an index form with a 2000 base in order to avoid the changing scale among countries. The Real Effective Exchange Rate is also obtained from EUROSTAT. The index of real effective exchange rate that uses the deflator of unit labor costs in the total

economy is used in the analysis with 2005 as the base year. Data on wages is obtained in index form from the OECD Labor Average Annual Wages Database with 2000 as the base. The Price Ratio of Shrimp to Other Crustacean is calculated as dividing the aggregated CIF of shrimp by the aggregated CIF of other crustacean. Unit CIF values are obtained from the UN Comtrade database and each aggregated CIF value is calculated as total import value divided by total import quantity. The index of this ratio is calculated with 2002 as the base.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This section presents the analysis of how the enforcement of MRPL affects the trading of shrimp products between EU members and the rest of the world, and the resulting changes in the EU domestic welfare and international welfare. The analysis begins with explaining the results of the Gravity Model (GM) and examines the relationships between trade cost variables and trade integrations. Then, based on the GM results, this research quantifies the change to consumer and supplier behavior and the welfare changes of EU consumers and suppliers as well as foreign suppliers from developed countries and developing countries.

Before starting the analysis, it is better to clarify the relationship between the strictness of food safety standards and the level of MRPL. As stated before, the strictness of the MRPL standard depends on the level of MRPL set by EU --the lower the level, the stricter the standard. In addition, the MRPL regulation was first enforced in 2002 and there is no legitimate information about this standard before 2002. In this case, this dissertation concentrates only on the time span from 2002 to 2010, when the MRPL was in effect. As the EU relieved the strictness of food safety standard by increasing MRPL from zero to 0.3 ppb in 2005, the effects of standard measured in this research are based on analyzing trade and welfare changes caused by MRPL level change. The baseline is 0 before 2005 and 0.3 ppb in 2005 and thereafter and the new scenario is defined as lowering MRPL to zero level from 2002.

4.1 MRPL Effects on Trade

Table 4-1 presents the estimation results for the three groups of countries with two estimation methods. For each table the first column is the typical "phi-ness" gravity model specification (equation (3-14)) using OLS, which excludes zero-valued trade observations. The second column is the PPML estimation (equation (3-15)) which includes zero observations to reduce potential bias. The Table 4-1 presents the estimated coefficients α and λ of trade cost variables, which are the product of elasticities of substitution $(1-\sigma)$ and the "true" elasticities of trade costs; while Table 4-2 presents the "true" elasticities of trade costs after removing the effect of elasticities of substitution. The values of elasticities of substitution are estimated based on the nested CES model, which will be discussed in detail later.

4.1.1 Comparison between OLS and PPML

The difference in results between the OLS and PPML method highlights the effects of a different functional form and the inclusion of zero observations. All three country groups had a large portion of zero-valued observations, so the estimation differed between the two methods in terms of coefficients and significance. The sign of exchange rate changes to negative with the PPML method; a negative sign is consistent with theoretical expectations and previous empirical results.

The significance of the colony coefficient is also highlighted under the PPML method for all countries and developed countries. Although the sign for the colony coefficient is negative for developing countries, the effect is insignificant.

Table 4-1. PPML and OLS with "phi-ness" GM Estimation of Effects of MRPL on EU

Shrimp Imports

		All		Developed Countries		Developing Countries	
	Variables	OLS	PPML	OLS	PPML	OLS	PPML
Estimated	$lnDIST_{ij}$	-2.40*	-1.56*	-4.19*	-1.57*	-4.09*	-4.78*
trade cost		(0.14)	(0.20)	(0.20)	(0.20)	(0.81)	(1.15)
coefficients	lnD_{ii}	0.43*	1.55*	0.96*	1.76*	6.82*	1.85*
α and λ		(0.10)	(0.24)	(0.15)	(0.19)	(1.57)	(0.53)
	lnD_{jj}	0.69*	0.19	0.96*	0.45**	0.17	0.37*
		(0.13)	(0.27)	(0.16)	(0.19)	(0.55)	(0.14)
	$lnEXCH_{ijt}$	0.30	-0.89**	1.11	-1.00	0.04	-6.19**
		(0.30)	(0.39)	(0.98)	(1.23)	(0.80)	(3.12)
	$MRPL_t$	0.04	2.10*	0.14	1.98**	0.94	3.26***
		(0.61)	(0.71)	(0.66)	(0.71)	(1.01)	(2.024)
	$LANG_{ij}$	2.73*	2.19*	0.75	2.69*	0.52	2.12
		(0.38)	(0.49)	(0.46)	(0.45)	(0.70)	(1.66)
	$COLY_{ij}$	-0.10	0.79***	0.60	0.68***	0.16	-0.93
		(0.40)	(0.42)	(0.50)	(0.41)	(0.63)	(1.20)
	$BORD_{ij}$	2.24*	0.28	1.66*	0.039	-1.77	1.60
		(0.33)	(0.34)	(0.36)	(0.30)	(1.78)	(3.23)
	EU_{it}	1.05*	1.87*	2.06*	4.87*	-2.31***	-6.37*
		(0.33)	(0.67)	(0.43)	(0.62)	(1.23)	(1.18)

Table 4-1. PPML and OLS with "phi-ness" GM Estimation of Effects of MRPL on EU

Shrimp Imports (Continued)

		All		Developed Countries		Developing Countries	
	Variables	OLS	PPML	OLS	PPML	OLS	PPML
Estimated	TAR$_{ijt}$	-0.0096	-0.029	-0.052**	-0.15*	-0.0004	-0.044*
trade cost		(2.07)	(2.86)	(2.85)	(2.24)	(5.96)	(1.55)
coefficients	Constant	17.53*	11.70*	25.13*	6.28**	12.54	50.97*
α and λ		(1.36)	(2.69)	(1.63)	(2.48)	(1.08)	(10.89)
	Adjusted R^2	0.44	0.41	0.44	0.41	0.55	0.39

Note: *, ** and ** * respectively indicate significance at 1%, 5% and 10% level.

There were fewer zero observations with the developed country data set. The main differences in estimates from the OLS model are the different coefficient magnitudes compared with the PPML model. The sign of lnEXCH changes to negative, which is consistent with expectations. The significance levels for the coefficients on LANG, COLY and BORD change while the coefficient signs remain unchanged (consistent with expectation).

As stated before, the results of the PPML model are expected to be more reliable because they avoid the bias problems from using the log model and excluding zero observations. Considering the fact that developing countries and all countries have much higher ratios of zero-valued observations than developed countries, the conclusion is that the results of OLS may be more biased for these country categories (where there is a larger portion of zero observations). Thus, the PPML results are more reliable in this situation.

4.1.2 MRPL Effects

As stated before, lower MRPLs mean stricter food standards. In this case, a negative coefficient for MRPL indicates that higher standards decrease trade integration, Φ, while a positive coefficient indicates higher standards increase trade integration.

This study hypothesizes that everything else equal, the introduction of stricter MRPL has a significant and negative impact on the trade integration for the EU shrimp market. The PPML model shows that the MRPL variable has a significant and positive coefficient for the all country group. This indicates that lowering the MRPL would decrease the trade between the EU and trading partners. Thus the requirement of MRPL does impede the trade integration. In this case, this result supports the first hypothesis by verifying that the stricter percentage MRPL standard induces a decrease of foreign trade flows over domestic trade of shrimp products.

The results in Table 4-1 fail to reject the second hypothesis that MRPL impacts depend on the status of economic condition in exporting countries. The MRPL variable has a positive coefficient which is statistically significant for all three country groups. This result infers that the lowering MRPL would significantly reduce the trade integration between the EU and exporters in developing countries and developed countries. In other words, EU members increase the portion of bilateral trade with developing and developed countries when compared with the domestic trade after the MRPL level is increased. The estimated results have different magnitudes for the MRPL coefficient for developed and developing countries with coefficients of 1.98 and 3.26, respectively. Developing country exports are more sensitive to MRPL changes than developed country exports.

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Table 4-2. "True" Elasticities of Proxy Variables with Respect to Trade Costs

	Variables	All		Developed Countries		Developing Countries	
		OLS	PPML	OLS	OLS	PPML	OLS
True trade cost μ	$\ln DIST_{ij}$	0.63	0.41	0.62	0.23	0.61	0.71
	$\ln D_{ii}$	0.22	0.81	0.28	0.52	2.02	0.55
	$\ln D_{jj}$	0.36	0.10	0.28	0.133	0.049	-1.10
	$\ln EXCH_{ijt}$	-0.08	0.23	-0.16	0.15	0.0061	0.92
	$MRPL_t$	-0.01	-0.55	-0.02	-0.29	-0.14	-0.85
	$LANG_{ij}$	-0.72	-0.57	-0.11	-0.40	-0.077	-0.31
	$COLY_{ij}$	0.03	-0.21	-0.09	-0.10	-0.023	0.14
	$BORD_{ij}$	-0.59	-0.07	-0.25	-0.01	0.26	-2.37
	EU_{it}	-0.28	-0.49	-0.30	-0.72	0.34	0.94
	TAR_{ijt}	0.25	0.76	0.77	2.28	0.0060	0.66

As stated before, the estimated coefficient of MRPL reflects the influence of two parts: the elasticity of substitution σ and the elasticity of "true" trade cost μ. The estimations of σ_1 and σ_2 are shown in the later section of CES model results. The results in Table 4-2 indicate that for developing countries, a 0.1 ppb increase in MRPL level would decreases the bilateral trading cost by 8.5% (the true trading cost elasticity 0.85*0.1*100%) and increases the trade integration by 33% (0.1*3.26*100%). Most importantly, for the all country group, if the MRPL was originally set as 0.3 ppb in 2002, the average MRPL would increase from 0.18 to 0.12. This level increase would reduce trade cost by about

10.2% (0.12*0.85*100%), and increase Φ by over 25% (0.12*2.1*100%). This magnitude of Φ changes with MRPL is far from negligible and suggests that by shifting from zero tolerance, EU dramatically increased its potential for seafood trade with other countries.

A number of studies have showed empirically that stricter standards act as a barrier to exports from developing countries (Baylis, Nogueira and Pace 2011, Anders and Caswell 2009 and Nguyen and Wilson 2009) and it is conceptually reasoned that exports from developed countries should be less affected. These results support existing empirical research by verifying that the MRPL dramatically reduces EU shrimp imports from developing countries compared with developed countries.

4.1.3 Gravity Trading Costs Variables

Based on the estimated results of the PPML model, most gravity variables have significant explanatory power and have signs that are consistent with expectation. Bilateral distance and domestic distance have significant effects for all three countries groups. The coefficient for colony in the estimation for the developing country group is negative but is not statistically significant. The average domestic distance of the exporter and language have significant impacts on developing and developed countries in the PPML models. Language, colony and common border show no significant explanatory effects for developing countries in the PPML model.

As shown in Table 4-1, the coefficient of bilateral distance and domestic distance of exporter are statistically different from zero for all three country groups. Trade integrations decrease with international distances, $DIST_{ij,}$ and increase with the average

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domestic distances of exporter D_{ii}. As shown in Table 4-2, one percentage point increase in bilateral distance would reduce trade integration for all countries by 1.56%, developed countries by 1.57% and developing countries by 4.78%. The domestic distance represents the trade cost of domestic trade flows, such as transportation costs. Higher domestic trade cost infers that consumers are more likely to import shrimp. A one percentage increase in the exporter's domestic distance would increase the trade integration by 1.55%, 1.76%, and 1.85%, respectively, for all countries, developed countries and developing countries. The domestic distances of the importer D_{ii} has a significant effect on trade integrations for the developed and developing country groups, but not the all country group.

Moreover, for all exporters and developed countries, trade integrations are, respectively, 2.19 and 2.69 percent higher between EU and countries that speak the same language. For countries sharing a colonial relationship with EU members, trade integrations are, respectively, 0.79 and 0.68 percent higher for all-country and developed country categories.

4.1.4 Other Bilateral Costs Variables

Based on the results of PPML model, the estimated coefficients of the exchange rate variable have signs that are consistent with expectation --they are negative and statistically significant for developing countries. The results indicate that a one percentage increase in the exchange rate is associated with a 0.89 percent and 6.19 percentage decrease in trade integration of all-country and developing-country groups, respectively.

The tariff (TAR) coefficient is significant and negative for exports from all three groups of countries, which is consistent with expectation. The elasticities of tariff are about 14.31% (exp (-0.15)-1) for developed countries, and 4.31% (exp (-0.044)-1) for developing countries, meaning that the trade integrations between the EU and those countries reduce by 100% if the annual average tariff rate increase by one unit.

The dummy variable identifying EU exporters has significant effects on trade integration for all three country groups, which is expected due to no tariffs and harmonized standards. The trade integration for EU exporters is 1.87% and 4.87% higher, respectively, than for non EU exporters in all- and developed-country groups; and it is 6.37% lower than non EU exporters in developing countries.

4.2 MRPL Effects on Welfare Change

In this section, the nested CES model is used to investigate the effects of MRPL on the demand and supply for the EU and its trade partners in developing and developed countries. The estimated parameters from applying the nested CES model are discussed first and then welfare changes are estimated for EU consumers and suppliers caused by lowering MRPL using the GM and nested CES.

4.2.1 Parameter Estimation

The parameters discussed in this section are used to setup the initial demand and supply functions that incorporate the MRPL changes in 2005.

4.2.1.1 Consumer's Model

The parameters of consumers' model are estimated based on two equations (3-20a) and (3-20b). Non-linear three stage least squares regression (N3SLS) is used to estimate equations (3-20) since the right-hand side variables - MRPL, $\ln(P_I/P_E)$ and $\ln(P_E/P_D)$ - are endogenously determined. Equation (3-20a) and (3-20b) are estimated simultaneously by using SAS command of proc model and 3SLS. Fixed country effects are also introduced to control for systematic differences across different importing countries.

As Kelejian (1971) and Quandt (1975) indicate, the number of Instrument Variables (IV) chosen must be greater than or equal to the number of estimated parameters in any equation; otherwise some of the parameters cannot be identified. In addition to import country fixed effects, seven linearly independent instruments are included that represent different indicators affecting the demand and supply of shrimp products. The fish and seafood part of Harmonized Indices of Consumer Prices (HICPs) is used to represent the price indicator. The Average Annual Wage Index is used to indicate the income impact. The Real Effective Exchange Rate Index represents the financial impact. The Fish Fleeting Index measures the total average annual number of fishing vessels and infers the effect of fishery support. The Price Ratio of Shrimp to Other Crustaceans reflects the substitution effects between shrimp and other crustaceans. Real GDP and population of importers represent the condition of EU society.

Table 4-3.Estimated Parameters of the Nested CES Model Consumer and Supply

Functions

Model	Parameter	Value	Standard Error
Consumer	σ_1	2.91	2.12
model	σ_2	4.38*	0.57
	φ_I	0.47*	0.012
	φ_D	0.027	0.054
	η_I	0.12**	0.057
	η_D	-0.0067	0.0085
	β_D	0.027	-
	β_I	0.51	-
Supplier	γ_D	530.23*	79.07
model	γ_E	1290.15*	117347
	γ_I	3823.36*	533707

Note: *, ** and ***respectively indicate significance at 1%, 5% and 10% level.

Table 4-3 presents the estimated parameters for the nested CES model. The coefficient η captures the change in consumer confidence for shrimp products from different origins. The results show that η_I is statistically significant and positive, indicating that the increasing the MRPL standard (making it more lax) increases EU consumer confidence in shrimp imported from developed countries compared to developing countries. The parameter of confidence, β_I, increases from 0.47 to 0.51, as shown in Table 4-3, which means that increasing the MRPL has a significant demand-enhancing effect on imported

shrimp products from developed countries. The significant change in the parameter of confidence indicates that it is necessary to account for the changing consumer confidence caused by the MRPL standard, and a nested CES function can be used in the analysis.

In addition, the assumption of heterogeneity for shrimp imported from developed and developing countries, which is used in this dissertation, is verified with the nested CES estimation as the demands of the two products with different origin varies with β_I.

The coefficient η_D is negative and statistically insignificant, which indicates that the implementation of a MRPL standard did not change consumer confidence between domestic and foreign shrimp products. The value of β_D is much lower than β_I, which infers that consumers have more confidence in foreign shrimp than domestic shrimp. The fact that EU consumption of shrimp is mainly from imports explains the estimation of β_D and η_D.

As stated in section 3.4.3, the changes in consumer behavior caused by enforcing the MRPL could indirectly reflect the effect of MRPL on trade. The estimation of η_I and β_I are consistent with the estimation of MRPL effects on trade integrations. The reduction of MRPL level would significantly reduce consumer confidence in shrimp imported from developing countries. The reduction of confidence is reflected by the consumption reduction effects on trade flows with developing countries. The MRPL standard presents statistically significant and negative effects on trade integrations between EU and developing countries. The stricter the standard, the less trade integration is present. In consumers' part, this significant effect is reflected by the indication that MRPL

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dramatically affects consumers' confidence in shrimp imported from developing countries.

The parameter σ measures the elasticity of substitution among variables in the CES utility function. The values of σ_1 that is used to calculate the "true" trade costs of aggregated country group and σ_2 used for developed and developing country groups in Table 4-2. The estimated values of σ_1 and σ_2 are greater than one, which are consistent with the assumptions in the CES model. In addition, the statistical significance of σ_2 indicates that the substitution between shrimp imported from developed and developing countries is significant when the MRPL is in effect. The results also show that σ_2 is larger than σ_1, which means that the substitution between shrimp from developed countries and developing countries is larger than the substitution between domestic shrimp and foreign shrimp.

4.2.1.2 Supplier Model

The values of γ are shown in the last three rows of Table 4-3. As discussed in section 3.3.3, the changes in γ when considering the effects of varying the MRPL can be retrieved from the estimation of MRPL coefficient in the "phi-ness" GM with PPML. The results show that implementation of the MRPL has significant effects on trade integrations of developing country group and developed country group. Thus the linkage function of GM and welfare change, (equation (3-30a) and (3-30b)) is used to capture the changes of γ_I and γ_E. Further, the domestic supply function is assumed unaffected by MRPL changes so γ_D stays unchanged in the welfare analysis.

An unchanged domestic supply function, D, does not mean that domestic supply doesn't change with the new price, P_D^1, and new quantities D^1 at the equilibrium; it means that the domestic curve does not shift with the changed MRPL standard. As the results indicate, consumer confidence in shrimp products imported from developed countries and developing countries changes, so the demand function also changes with a differing MRPL requirement. In this case, P_D^1 and D^1 change too.

4.2.2 Welfare Change Analysis

The baseline for the welfare analysis is the MRPL defined as 0.3 ppb in 2005 and thereafter (time 0). The new scenario considers lowering MRPL to zero again in 2005 (time 1).

4.2.2.1 Changes of Demand and Supply Functions

In order to calculate the new equilibrium, consumers in the EU are assumed to spend the same amount of money on shrimp products. The budget variables, M and MI, remain unchanged in the analysis. Since the EU shifted away from zero tolerance in 2005, the average prices, quantities, and budgets for 2005 are the baseline to calibrate the new parameters assuming that the EU still enforced a zero tolerance policy. The mean values of the key variables and parameters used in the calibration are listed in the first column of Table 4-4.

The first step in calculating welfare changes is to obtain the new equilibrium prices P_D^1, P_E^1 and P_I^1, as well as the quantities D^1, I_E^1 and I_I^1 after implementing the MRPL

requirement at time 1. Equations (3-21), (3-24) and (3-30) are used to determine the new

equilibrium parameters.

Table 4-4. Values of Parameters for Calibrated Model, in 2005

Parameters	Value with MRPL=0.3	Value with MRPL=0	Changes in Value	Change in %
MRPL (ppb)	0.3	0	-0.30	
β_D at 2005	0.027	0.027	0.00	0.00
β_I at 2005	0.51	0.47	-0.04	-7.84
Average D (in tonne)	5880.08	6891.21	1011.13	17.20
Average I_I (in tonne)	34915.49	6369.76	-28545.73	-81.76
Average I_E (in tonne)	13731.37	11709.02	-2022.35	-14.73
Average P_D (in \$/kg)	6.78	13.00	6.22	91.67
Average P_E (in \$/kg)	7.06	13.00	5.93	83.98
Average P_I (in \$/kg)	6.74	13.00	6.26	92.85
γ_D	530.23	530.23	0.00	0.00
γ_E	1290.15	900.93	-389.22	-30.17
γ_I	3823.36	490.11	-3333.25	-87.18
Average MI (in thousand \$)	290430.02	290430.02	0.00	0.00
Average M (in thousand \$)	325225.14	325225.14	0.00	0.00
Total Domestic Trade	39870.78	89562.69	49691.91	124.63
Trade with Developed Country	97002.56	152178.08	55175.53	56.88
Trade with Developing Country	235299.74	82785.56	-152514.18	-64.82

As stated before, the corresponding equation in (3-30) can only be used in the welfare analysis of MRPL if the standard has a significant effect. Equations (3-21), (3-24), the market equilibrium conditions of (3-25), and (3-30) constitute the calibrated model system, which is used to calculate the parameter γ_I, γ_E and the new price and quantities of domestic and foreign supply from developed and developing countries. The new values of these parameters are listed in the second column of Table 4-4. The baseline scenario for comparison is that MRPL set as 0.3 ppb, which is the initial situation of calibration.

The estimations in Table 4-4 indicate that if the EU still followed a zero tolerance policy, consumer confidence in shrimp imported from developed countries would decrease to 0.47. The decreased confidence may lead to less demand for imported shrimp from developed countries. However, the estimation indicates a significant increase in imports from developed countries. Based on demand function of I_E (equation (3-21b)), the decreased β_I leads the demand function of I_E to downwardly rotate; while the dramatic increase in import price with developing countries (an increase of 92.85%), P_I, pushes the demand function of I_E upward. As a large consumer, the EU has huge demand for shrimp. The importing price for developing counties would rise considerably if the EU continued a zero tolerance policy. This would induce an increase in the demand for shrimp from developed countries. In addition, the domestic demand quantity would increase by about 17% and the quantity demanded of shrimp from developing countries would sharply decrease if the MRPL was set at zero.

If the EU still followed a zero tolerance policy, both the value of domestic trade and imports from developed countries would increase (by 124.63% and 56.88%,

respectively). Thus, for suppliers from developed countries, the increase in price would overweigh the decrease in quantity and push up the trade value of domestic demand. For EU domestic suppliers, the rising price and quantity would contribute to the increase in trade integration. Trade with developing countries would suffer a remarkable reduction. Although the price would increase over 92%, the decrease in quantity would exceed the increase in price and causes a 64.84% decrease in trade value. The changes in supply from developing countries also verify the estimation from the GM that stricter MRPL presents significant and negative effects on trade integrations with developing countries.

Table 4-4 shows that the coefficient of the supply function of developing country would decrease by 87% if MRPL was set at zero. The changes infer that the supply function for developing countries rotates downward after the EU raises the MRPL to 0.3 ppb. In addition, with an increased MRPL, the price, P_I, sharply falls from 13 to 6.74 and the price of domestic supply and trade from developed countries also decrease.

4.2.2.2 Changes of Welfare

Table 4-5 presents the ex ante estimations of welfare in the EU for 2005 with two MRPL levels, 0.3 and 0. The table focuses on the impact of the MRPL increase in 2005 and presents the changes in domestic consumer surplus, domestic producer surplus, total EU welfare (the sum of the former two), and foreign producer surplus based on economic status.

The results show that changing the MRPL for the EU from zero to 0.3 improved domestic customer welfare. The relief of MRPL requirement increases the total consumer surplus

by 45,836. This result infers that domestic consumers benefit from the reduction in price linked to less strict standards comes from the increase in MRPL. However, domestic producers gain more surpluses with a zero MRPL than with a 0.3 MRPL. Increasing the MRPL has a large negative effect on domestic producer prices that is not overcome by increased quantity sale. The total EU domestic surplus is higher with the MRPL at 0.3. This indicates that the benefit for domestic consumers outweigh the loss for domestic suppliers from less strict standards. The EU government transfers welfare from producers to consumers by increasing the level of MRPL but total domestic welfare increases.

Table 4-5. Welfare Changes from an Increase in the MRPL for 2005

Welfare		MRPL=0.3	MRPL= 0	Change in Value	Change in %
Consumers	Overall Utility	163,984	118,148	-45,836	-27.95
	Utility of Foreign Shrimp	161,346	114,208	-47,138	-29.22
Domestic Supplier		19,935	44,781	24,846	124.63
Total EU Domestic Welfare		183,919	162,930	-20,990	-11.41
Suppliers in Developed Countries		48,501	76,089	27,588	56.88
Suppliers in Developing Countries		117.650	46,386	-71,264	-60.57
Total Foreign Supplier		166,151	41,393	-124,758	-75.09
Total World Surplus		350,070	204,322	-145,748	-41.63

If the MRPL is set at zero, foreign suppliers in developed countries would benefit from the increased price while those in developing countries would suffer from the

considerable loss in imports, despite the price increase. Total surplus for foreign suppliers would decrease by 75.09% because most imports come from developing countries. The analysis indicates that the increased MRPL transfers surplus from suppliers in developed countries to those in developing countries and dramatically increases the welfare of suppliers in developing countries (and total foreign suppliers).

Total world welfare includes total EU domestic surplus and total foreign surplus. The results show that by increasing MRPL, the EU dramatically improves total international surplus.

In sum, the analysis shows that increasing the MRPL from zero benefits consumers and suppliers in general. By relieving the restrictive MRPL, total domestic welfare in the EU improves by shifting the surplus from domestic suppliers to domestic consumers. Suppliers in developing countries also benefit from the increase level of MRPL, while those in developed countries suffer a welfare loss. Total foreign supplier welfare and total world welfare improves with the MRPL increase. These analyses indicate that EU standards were originally too tough because there was a net welfare increase of total international welfare and total EU domestic welfare when the MRPL went from 0 to 0.3.

CHAPTER FIVE: CONCLUSIONS AND IMPLICATIONS

This research explores the use of gravity model in a welfare analysis for a food safety standard. For this purpose, this research employs the monopolistic competition gravity framework by Anderson and Van Wincoop (2003) and connects it to the nested CES model of consumer and supplier behavior. This research verifies that the consumer utility function used for welfare analysis follows the specific CES form in order to use the GM in welfare analysis and then derives the linkage between the CES and GM. This research partitions the policy variable from its perfect correlate with time and country fixed effects by using the "phi-ness" index with the GM, and zero observations are handled by adopting the PPML method.

This research measures the impact of MRPL standards for the EU shrimp market on trade and welfare. Heterogeneity in shrimp products is handled by considering price differences between shrimp products imported from developed countries and developing countries in the CES model and specifying different MRPL effects on trade with these two groups of exporters. The possible effect of MRPL on consumer behavior is considered by specifying the consumer confidence in products from different origins as a linear function of the EU MRPL standard.

The results demonstrate that while the econometric estimation of the gravity equation shows a negative impact on EU trade, the welfare evaluations also show that a stricter standard would lead to a decrease in domestic welfare as well as international welfare. The analysis with domestic welfare justifies the EU's policy on tightening the food safety standard on importing shrimps by protecting its domestic suppliers. However, EU

consumers would suffer from a welfare loss with stricter standards. This result infers that the zero tolerance policy violates the purpose of food safety standard that stricter standard should benefit consumers by providing food with higher quality, as it reduces consumers' utilities. In addition, the stricter zero tolerance policy is shown to be too tough because there was a net welfare increase of total international welfare and total EU domestic welfare when the MRPL went from 0 to 0.3.

The estimation for international welfare verifies the barriers that tighter food safety standards have on importing shrimps. Stricter standards do not necessarily mean domestic welfare losses but they do lead to international welfare losses. This is why the World Trade Organization is dedicated to eliminating the unnecessary strict standards among member countries in order to balance the welfare changes caused by standard conflicts.

The results also show that with stricter standards, the welfare of suppliers from developing countries is severely reduced while suppliers from developed countries benefit. This analysis of foreign and international welfare supports the assertion of comparative advantage of developed countries over developing countries in international shrimp trade markets. Developing countries should increase their level of food safety by adopting advanced regulations or techniques in order to reduce the loss from trade reduction when they need to comply with stricter regulation requirements of importers.

It was interesting to find that developing countries might benefit from the MRPL as the supplier surplus increased when MRPL increased from 0 to 0.3. Their products were suspect before the enforcement of MRPL in 2002 because of the detection of high hazard to human health. After the EU relieved the required level of MRPL, consumers bought

more shrimp products from developing countries. This research only uses data span from 2002 to 2012 because of the absent legitimate information of MRPL level. Applying methods and using data before 2002 might show more about the effects on developing country.

Some extensions could be integrated into the presented model. If the data is available, the different private standards applied by retail companies could be incorporated into the analysis in order capture the discrimination among standards effects. The analysis could also become dynamic. In addition, this research does not consider detailed factors affecting supplier behavior due to the limitation of data availability of the shrimp industry. Taking into account the changes of variables and fix costs caused by stricter effects may provide more information of ex ante analysis if related information is available in other industries.

The results of this research also indicate that it is especially necessary for governments to examine the combination of gravity and welfare approaches when standards are analyzed. The gravity estimations help policy makers to know whether a standard really impacts trade and provides a basis for anticipating market reactions. Then the integration of market reactions into a welfare measure helps policy makers with information about the changes of domestic demand as well as domestic and foreign supply functions. The estimation of welfare variations helps policy makers assess the impacts of ex ante regulatory measures and changes before adjusting the strictness of safety regulations and standards.

APPENDICES

Appendix I The Derivation of Gravity Model

Consumers in country j maximize their CES utility:

$$U = \left(\sum_i \beta_i c_j^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{AI-1}$$

Subject to the budget constraint:

$$\sum_i p_{ij} c_{ij} = y_j \tag{AI-2}$$

Let p_i denotes to the supply price in country i and t_{ij} is the trade costs factor between i and j. Assuming that for each good shipped from i to j the exporter incurs the export trade cost equal to t_{ij}-1 in a portion of p_i, then $p_{ij} = p_i + p_i(t_{ij} - 1) = p_i t_{ij}$. The nominal export value from i to j is $x_{ij} = p_{ij} c_{ij}$, and the production value of goods in country i is $p_i c_{ij}$. Assuming that the exporters in country i pass on these trade costs to importers in country j, trading costs are $x_{ij} - p_i c_{ij} = (t_{ij-1}) p_i c_{ij}$, The total income of region i is therefore

$$y_i = \sum_j x_{ij} = \sum_j p_{ij} c_{ij} \tag{AI-3}$$

There is one more inherent assumption in equation (AI-3): the retail price that consumers in j spend on goods equals the import price p_{ij}.

Maximizing utility in equation (AI-1) subject to the budget constraint, equation (AI-2), the Lagrangian is:

$$\text{Max } \left(\sum_i \beta_i \, c_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} - \lambda\left(\sum_i p_{ij} c_{ij} - y_j\right) \qquad \text{(AI-4)}$$

The first order condition, the ith equation is

$$\left(\sum_i \beta_i \, c_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \beta_i \, c_{ij}^{\frac{-1}{\sigma}} - \tau \cdot p_{ij} = 0 \qquad \text{(AI-5)}$$

Seting $\Delta = \left(\sum_i \beta_i \, c_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{-1}{\sigma}}$, then

$$\Delta \cdot \beta_i \, c_{ij}^{\frac{-1}{\sigma}} = \tau \cdot p_{ij} \qquad \text{(AI-6)}$$

$$\text{For } \forall m \neq n, \qquad \frac{\text{nth equation}}{\text{mth equation}} = \frac{\beta_n \, c_{nj}^{\frac{-1}{\sigma}}}{\beta_m \, c_{mj}^{\frac{-1}{\sigma}}} = \frac{p_{nj}}{p_{mj}} \qquad \text{(AI-7)}$$

The relationship between consumption of different residents in country j can be expressed as:

$$c_{mj} = c_{nj} \cdot \left(\frac{p_{nj}}{p_{mj}} \cdot \frac{\beta_m}{\beta_n}\right)^{\sigma} \qquad \text{(AI-8)}$$

Substituting c_{mj} into equation (AI-2), the budget constraint can be rewritten as:

$$\text{For } \forall m \neq n,$$

$$y_j = \sum_j p_{ij} c_{ij} = p_{nj} c_{nj} + \sum_{m \neq n}^{i} p_{mj} c_{mj} = p_{nj} c_{nj} + \sum_{m \neq n}^{i} c_{nj} \cdot (p_{nj} \cdot \frac{\beta_m}{\beta_n})^{\sigma} \cdot p_{mj}^{\ 1-\sigma}$$

$$= p_{nj}^{\ \sigma} c_{nj} \beta_n^{\ -\sigma} \cdot \beta_n^{\sigma} p_{nj}^{\ 1-\sigma} + p_{nj}^{\ \sigma} c_{nj} \beta_n^{\ -\sigma} \cdot \sum_{m \neq n}^{i} \beta_m^{\sigma} \cdot p_{mj}^{\ 1-\sigma}$$

$$= p_{nj}^{\ \sigma} c_{nj} \beta_n^{\ -\sigma} (\beta_n^{\sigma} p_{nj}^{\ 1-\sigma} + \sum_{m \neq n}^{i} \beta_m^{\sigma} p_{mj}^{\ 1-\sigma})$$

$$= p_{nj}^{\ \sigma} c_{nj} \beta_n^{\ -\sigma} [\sum_{m=n}^{} \beta_m^{\sigma} p_{mj}^{\ 1-\sigma} + \sum_{m \neq n}^{i} \beta_m^{\sigma} p_{mj}^{\ 1-\sigma}]$$

$$= c_{nj} p_{nj}^{\ \sigma} \beta_n^{\ -\sigma} \Sigma_i \beta_m^{\sigma} (p_{mj})^{1-\sigma} \tag{AI-9}$$

So for $\forall i$, the optimized consumption of country j's output depends on the budget constraint y_j, import price p_{ij}, and the distribution parameter β, as shown in equation (AI-10).

$$c_{ij} = y_j \frac{p_{ij}^{\ -\sigma} \beta_i^{\sigma}}{\Sigma_i \beta_i^{\sigma} (p_{ij})^{1-\sigma}} \tag{AI-10}$$

Substituting equation (AI-10), the nominal value of optimized exports from i to j, x_{ij}, can be rewritten as

$$x_{ij} = p_{ij} c_{ij} = \frac{y_j \beta_i^{\sigma} (p_{ij})^{1-\sigma}}{\Sigma_i \beta_i^{\sigma} (p_{ij})^{1-\sigma}} \tag{AI-11}$$

Substituting the trade cost factor t_{ij} into equation (AI-11) by using $p_{ij} = p_i t_{ij}$, we get

$$x_{ij} = y_j \cdot \frac{\beta_i^\sigma (p_i t_{ij})^{1-\sigma}}{\sum_i \beta_i^\sigma (p_i t_{ij})^{1-\sigma}} \qquad (AI\text{-}12)$$

Seting $\Lambda_j = [\sum_i \beta_i^\sigma (p_i t_{ij})^{1-\sigma}]^{1/(1-\sigma)}$, where Λ_j represents the inward multilateral price resistance of country j, equation (AI-11) can be rewritten as

$$x_{ij} = y_j \cdot \beta_i^\sigma \left(\frac{p_i t_{ij}}{\Lambda_j}\right)^{1-\sigma} \qquad (AI\text{-}13)$$

After imposing the market clearing condition of equation (AI-3) by substituting the expression of x_{ij} in equation (AI-13), the income of country i is shown in the following expression (AI-14):

$$y_i = \sum_j x_{ij} = \sum_j y_j \cdot \beta_i^\sigma \left(\frac{p_i t_{ij}}{\Lambda_j}\right)^{1-\sigma} = \beta_i^\sigma p_i^{1-\sigma} \sum_j y_j \cdot (t_{ij}/\Lambda_j)^{1-\sigma}, \forall\, i \qquad (AI\text{-}14)$$

The scaled prices $\{\beta_i p_i\}$ can be solved as in equation (AI-15).

$$\beta_i^\sigma p_i^{1-\sigma} = \frac{y_i}{\sum_j y_j \cdot \left(t_{ij}/\Lambda_j\right)^{1-\sigma}} \qquad (AI\text{-}15)$$

We define the world nominal income as $y^W = \sum_j y_j$ and the income share as $\theta_j = y_j / y^W$. Then the nominal value of trade can be derived by substituting (AI-15) into (AI-13):

$$x_{ij} = y_j \cdot \beta_i^\sigma (\frac{p_i t_{ij}}{\Lambda_j})^{1-\sigma} = \beta_i^\sigma p_i^{1-\sigma} \cdot y_j (\frac{t_{ij}}{\Lambda_j})^{1-\sigma} = \frac{y_i}{\sum_j [(t_{ij}/\Lambda_j)^{1-\sigma} y_j]} \cdot \left(\frac{t_{ij}}{\Lambda_j}\right)^{1-\sigma} \cdot y_j$$

$$= y_i y_j \cdot \left(\frac{t_{ij}}{\Lambda_j}\right)^{1-\sigma} \cdot \frac{1}{\sum_j [(t_{ij}/\Lambda_j)^{1-\sigma} \cdot y^W \theta_j]}$$

$$= \frac{y_i y_j}{y^W} \cdot \left(\frac{t_{ij}}{\Lambda_j}\right)^{1-\sigma} \cdot \frac{1}{\sum_j [(t_{ij}/\Lambda_j)^{1-\sigma} \cdot \theta_j]}$$

$$\text{(AI-16)}$$

Where $$\Pi_i = [\sum_j \theta_j (t_{ij}/\Lambda_j)^{1-\sigma}]^{1/(1-\sigma)} \qquad \text{(AI-17)}$$

And $$\Lambda_j = [\sum_i \beta_i^\sigma (p_i t_{ij})^{1-\sigma}]^{1/(1-\sigma)} \qquad \text{(AI-18)}$$

Appendix II Functions Used to Calculate the Quantity and Price at New Scenario

At the new scenario, the endogenous parameters including D, I_E, I_I, P, TD, TS, γ_I or/and γ_E. The exogenous parameters of D_0, I_E^0, I_I^0, P_D^0, P_I^0, P_E^0 and γ_D are estimated by equation (3-21) and (3-24). Functions used in the calculation including:

Demand functions:

$$D(P, M_I) = M_I \left(\frac{\beta_D^{\,1}}{1-\beta_D^{\,1}}\right)^{\sigma_1} \frac{1}{P}[(\beta_I^1)^{\sigma_2} + (1 - \beta_I^{\,1})^{\sigma_2}]^{\frac{1-\sigma_1}{\sigma_2-1}} \qquad \text{(AII-1)}$$

$$I_E(P, M_I) = M_I \frac{(\beta_I^{\,1})^{\sigma_2}}{P[(\beta_I^1)^{\sigma_2}+(1-\beta_I^{\,1})^{\sigma_2}]} \qquad \text{(AII-2)}$$

$$I_I(P, M_I) = M_I \frac{(1-\beta_I^{\,1})^{\sigma_2}}{P[(\beta_I^1)^{\sigma_2}+(1-\beta_I^{\,1})^{\sigma_2}]} \qquad \text{(AII-3)}$$

Supply functions:

$$S_D(P, \gamma_D) = \gamma_D P \qquad \text{(AII-4)}$$

$$S_{I_E}(P, \gamma_E) = \gamma_E P \qquad \text{(AII-5)}$$

$$S_{I_I}(P, \gamma_I) = \gamma_I P \qquad \text{(AII-6)}$$

Market Equilibrium:

$$TD = D^1 + I_E^{\,1} + I_I^{\,1} = M_I \left(\frac{\beta_D^{\,1}}{1-\beta_D^{\,1}}\right)^{\sigma_1} \frac{[(\beta_I^{\,1})^{\sigma_2}+(1-\beta_I^{\,1})^{\sigma_2}]^{\frac{1-\sigma_1}{\sigma_2-1}}}{P} + \frac{M_I}{P} \qquad \text{(AII-7)}$$

$$TS = S_D^{\,1} + S_{I_E}^{\,1} + S_{I_I}^{\,1} = \gamma_D P + \gamma_E^{\,1}P + \gamma_I^{\,1}P \qquad \text{(AII-8)}$$

$$TD = TS \qquad \text{(AII-9)}$$

Mathematical linkage of MRPL measurement:

$$\frac{P - P_E^0}{P_E^0} + \frac{I_E - I_E^0}{I_E^0} - \frac{P - P_D^0}{P_D^0} - \frac{D - D^0}{D^0} = \alpha_6{}^E \Delta MRPL \qquad \text{(AII-10)}$$

And/or

$$\frac{P - P_I^0}{P_I^0} + \frac{I_I - I_I^0}{I_I^0} - \frac{P - P_D^0}{P_D^0} - \frac{D - D^0}{D^0} = \alpha_6{}^I \Delta MRPL \qquad \text{(AII-11)}$$

When α_6 presents statistically significance, the corresponding linkage function is

incorporated in welfare analysis.

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VITA

Xiaoqian Li was born in Heze, Shandong, China.

EDUCATION

M.S. in Accounting, University of Kentucky, Lexington, KY, USA.   Aug, 2009

M.S. in Accounting, Harbin Institute of Technology, Harbin, China.   Jul, 2006

B.S. in Accounting, Harbin Institute of Technology, Harbin, China.   Jul, 2004

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     Xiaoqian Li

     December 3rd, 2014