Three Essays on Market and Non-Market Factors Affecting International Seafood Trade

by

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Abstract

This dissertation is comprised of three separate essays investigating market and non-market factors affecting international seafood trade. The first essay analyzes the impact of food safety standards and management systems established by public and private actors in nations of the industrial North on shrimp producers, middlemen traders, processors, and exporters in Vietnam. The shrimp farming industry in Vietnam is organized in the form of buyer-driven global value chains (GVCs). GVCs dynamically develop and transform through time and place to generate multiple governing patterns between successive actors participating in the chains. Food safety institutions, socio-cultural factors as well as environmental resource conditions both create opportunities and constrain economic organization and governance of the chains for responding to international shrimp market requirements.

The second essay applies different alternative specifications accounting for zero trade flows to reevaluate the hypothesis that food safety standards act as barriers to seafood imports aggregated at two digit levels. Results show that the view of standards as barriers to trade is robust to the OLS as well as alternative zero-accounting gravity models including the Heckman maximum likelihood and Poisson family regressions. Formal statistical tests do not allow specifying which zero accounting model is the best choice. However, based on the magnitude of estimated coefficients, I contend that the Heckman maximum likelihood estimation provides the most reliable parameter estimates.

The third essay examines the impact of strengthening chloramphenicol analytical standards (lowering required analytical limits) on crustacean imports in the EU15, Japan, and the North America. Results of the gravity econometric model estimation using the Heckman selection procedure show that enhancing detection standards of chloramphenicol residues in seafood in developed countries is shown statistically to have negative effects on their bilateral crustacean imports. Aggregated six digit levels, some crustacean products such as frozen shrimps and prawns, and frozen rock lobsters received more negative impacts than other crustacean products. Scale of export is sensitive to the imposition of stricter chloramphenicol analytical standards. Nations which are top crustacean exporters are disciplined more than other exporting countries. Top crustacean exporters in Asia, including China, India, Indonesia, Malaysia, Thailand, and Vietnam experience different impacts, suggesting that the impact of food safety standards on international trade is complex. Developing countries with higher income levels and stronger industry organization are better able to cope with stringent market requirements, strengthen their competitive advantage, and receive lesser negative impacts when food safety standards become stricter.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

FAO	Food and Agriculture Organization
RIA1	Research Institute for Aquaculture No.1, Vietnam
GVC	Global Value Chain
VIFEP	Vietnamese Institute for Fisheries Economics and Planning
MARD	Ministry of Agriculture and Rural Development, Vietnam
GSO	General Statistical Office of Vietnam
EU	European Union
WTO	World Trade Organization
NGO	Non-governmental Organization
WHO	World Health Organization
MRL	Maximum Residue Limit
OLS	Ordinary Least Squares
MLE	Heckman Maximum Likelihood Estimation
NAFTA	North America Free Trade Agreement
PPML	Poisson Pseudo Maximum Likelihood
NB	Negative Binomial Model
ZIP	Zero Inflated Poisson Model
ZINB	Zero Inflated Negative Binomial Model

INTRODUCTION

Background

International trade in seafood was valued at $85.9 billion in 2004 and is dominated by export flows from the South to the industrial North (FAO 2008). Continued access to Northern markets increasingly is being affected by non-tariff measures that have both governmental and non-governmental (private) origins. Governments of the North have focused attention on food safety and consumer health impact associated with seafood consumption while non-governmental organizations (NGOs) have pressed for environmental and social accountability in global seafood production and trade. Both governmental and non-governmental standards affect the ability of seafood producers and processors to be involved in valuable export markets. Meeting new and continually changing standards requires a level of technical sophistication and financial capacity that is far from universal among seafood producers and processors of the South. These standards also can be seen to marginalize small-scale producers and processors who have limited financial capital and technical abilities, resulting in concentration of seafood production and trade into relatively few hands.

The relative importance of non-tariff measures to trade has been growing because of tariff reductions resulting from WTO negotiations (Deardoff and Stern 1998; Maskus and Wilson 2001). The 1994 Agreements on the Application of Sanitary and Phytosanitary (SPS) Measures and Technical Barriers to Trade (TBT) of the World Trade Organization (WTO) provide countries guidelines to regulate food safety, health risk and other market standards of internationally traded products. The SPS Agreement permits governments to provide stricter standards than international norms, provided that the standard regulations are based on adequate risk assessment (Wilson 2003).

A substantial literature exists where economists examine the effects of non-tariff measures on agri-food exports of developing countries (World Bank 2005; Otsuki, Wilson and Sewadeh 2001). Seafood trade plays an important role especially in developing countries (e.g., an important source of foreign currency earning and employment opportunities for rural people) and seafood trade regimes are rapidly tightening. However few studies examine the impacts non-tariff measures on seafood trade (Debaere 2005; Anders and Caswell 2009; Nguyen and Wilson 2009; Disdier and Marette 2010). Most of the existing literature on quantifying non-tariff measures on agri-food trade examines the effects of standards at the country level and supports the view that standards represent non-tariff barriers to exporting countries. In addition there are also arguments that standards can act as catalysts to international trade, helping exporting countries gain better competitive advantage and position in global markets (Henson and Jaffee 2008). Given heterogeneity of standards, Henson and Jaffee (2008) argue that closer investigation is needed to provide better understanding of how standards imposed by the North affect trade from exporting countries, especially nations of the South.

A substantial body of the international trade literature has reviewed methods for quantifying the impact of non-tariff measures on agri-food trade (e.g., Korinek, Melatos, and Rau 2008; Ferrantino 2006; Fliess and Lejarraga 2005; Beghin and Bureau 2001). The gravity model is the econometric approach used frequently to examine impacts of public standards on trade flows at the country level. Partial and general equilibrium models are also commonly used to measure economic welfare impacts of food safety standards at the country level based on the price gap or trade flows between exporting and importing countries induced or affected by these barriers. These conventional quantifying approaches however fail to capture dynamic impacts of food safety standards on actors involved in agri-food value chains in the same country. Furthermore, quantifying the impact of private standards on agri-food trade represents a particularly difficult challenge because these measures typically do not result in a levy or quarantine at the border of exporting and importing countries.

Dissertation outline

The dissertation consists of three separate essays investigating the impact of non-tariff measures on international seafood trade. The central research questions the dissertation addresses are: how various stakeholders participate in global seafood value chains in developing countries are impacted by seafood safety and environmental standards imposed by governments and NGOs in the North? How food safety standards impact international seafood trade?

Using the global value chain approach, the first essay, “Organization of Global Value Chains (GVC) for Shrimp in Vietnam: Food Safety, Socio-Cultural Factors and Material Resource Conditions” examine the impact of food safety standards and management systems established by governmental and non-governmental actors in the global North on shrimp producers, middle traders, processors, and exporters in Vietnam. The GVC framework requires a systematic examination of governance issues that structure relationships between actors, in this case shrimp farmers, middlemen, processors, exporters, and importers. Governance includes both market and non-market coordination of economic activities, however within the GVC framework, governance analysis emphasizes non-market coordination (Gereffi, Humphrey, and

Sturgeon 2005). Non-market factors include food safety standards as well as socio-cultural values and natural resource conditions.

The significance of this essay is highlighted as follows. First the analysis illuminates the asymmetrical nature of power between actors and how this asymmetry shapes the distribution of development benefits from international shrimp trade. Second, the essay will situate international trade in shrimp within the literature on agri-food chain studies that feature systems characterized by heavy regulation of public and private actors at different times and places. Third, the essay will contribute to understanding organizational aspects and mechanisms of international trade to complement conventional economic studies which focus on trade of final products at the country level as demonstrated in the second and third essays that follow. And fourthly the essay will contribute to understanding the dynamics of export-oriented development in Vietnam as an example of how developing countries respond to stringent world market requirements while maintaining domestic development priorities (e.g., poverty alleviation, ensuring livelihood opportunities for small-scale farmers).

Vietnam is selected for study because it represents an interesting case for exploring impacts of non-tariff barriers to seafood trade. Vietnam is a poor country in transition to a market economy with weak market institutions and low financial, technological, and managerial capacities compared to other seafood exporting countries in the region (Kagawa and Bailey 2006). The country lacks infrastructure to comply with standards but has strong motivation for export-oriented aquaculture development to boost local economic development and foreign exchange earnings to address trade deficits. Export-oriented aquaculture is dominated by small scale production, vulnerable to changing market requirements.

The second essay, “Food Safety Standards and Developed Country Seafood Imports: Fitting the Gravity Equation with Zero-Accounting Models” applies alternative specifications to the gravity econometric model to evaluate the impact of food safety standards on bilateral seafood imports aggregated at two digit level. The impact of food safety standards on international trade is commonly evaluated using the gravity econometric model. The model is traditionally estimated by the ordinary least squares (OLS) method in the form of the log normal transformation (Burger, van Oort, and Linders 2009). The log normal OLS specification of the gravity model can bias estimated results since zero trade observations have to be omitted and the homoscedasticity assumption might be violated because of Jensen’s inequality (Santos Silva and Tenreyro 2006). The essay assesses the performance of different alternative models including the Heckman selection estimation and Poisson family regressions (Poisson Pseudo Maximum Likelihood, Negative Binomial, Zero Inflated Possion, and Zero Inflated Negative Binomial Models).

The third essay, “Standard Harmonization as Chasing Zero (Tolerance Limits): The Impact of Veterinary (Cloramphenicol Analytical) Standards on Crustacean Imports in the EU, Japan, and the North America” examines how enhancing chloramphenicol standards (lowering detection limits) in developed countries affect their bilateral crustacean imports. Research questions that the essay addresses are: (i) Are different crustaceans products in trade affected differently? (ii) What is the impact of standards on crustacean exporters with regard to scale of export? (iii) What are the differential impacts of food safety standards on different exporting countries based on development/income status? The essay is stimulated by a study of Disdier and Marette (2010) and the fact that with enhancements in analytical technologies, since 2001 developed countries are able to detect chloramphenicol residues in seafood at very low levels (FAO 2004).

Cloramphenicol is banned in many developed and developing countries because it has carcinogenic potential in humans. Since an acceptable daily intake (ADI) has not been allocated, no maximum residue limit (MRL) is established for cloramphenicol in the EU15, Japan, and North America. Cloramphenicol analytical standards are established based only on analytical technology improvements and have no cause and effect relationship with health risk. Using the Heckman selection procedure for the micro-founded gravity model, the paper explores the impacts of chloramphenicol analytical standards on crustacean imports in the EU15, Japan, and North America. Unlike Disdier and Marette (2010) the third essay explores the complex impacts of chloramphenicol standards on different crustacean products aggregated at 6 digit level, scale of exports, and top crustacean exporters in Asia.

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CHAPTER 1: ORGANIZATION OF GLOBAL VALUE CHAINS (GVC) FOR SHRIMP IN VIETNAM: FOOD SAFETY, SOCIO-CULTURAL FACTORS AND MATERIAL RESOURCE CONDITIONS

Introduction

Shrimp is the largest seafood product (value terms) traded globally, accounting for 17% of the total world fisheries export value ($85.9 billion) in 2006 (FAO 2008). Before the 1980s, most shrimp production entering international trade came from capture fisheries (Hall 2004). Cultured production has gradually gained a substantial and increasing share as a result of export oriented development policies pursued by developing countries in the global South (e.g., Brazil, China, Columbia, Ecuador, Honduras, India, Indonesia, Mexico, Thailand, and Vietnam). The contribution of farmed shrimp to world shrimp production skyrocketed from about 6% in 1970 (FAO 2004) to about 30% in 1998 (Rosenberry 1998) and to 43% in 2006 (FAO 2008). International shrimp trade is characterized by shrimp flows from the South to the industrialized North (e.g., the USA, EU, and Japan) and money flows from the North to the developing South (Skadany and Harris 1995). Expansion of the global shrimp industry horizontally and vertically connects a diverse array of local, national and international actors to each other and to world markets through dynamic institutions and economic networks (Lebel et al. 2008).

Like many other parts of Southeast Asian nations, shrimp farming has long been a traditional activity and is well established in Northern and Southern Vietnam in the form of extensive polyculture farming systems operated by small-scale farmers, fulfilling their family subsistence needs and selling surplus to local markets. Interviews with officials of the former Ministry of Fisheries of Vietnam revealed that during the period of 1975 to 1986 there was no incentive for promoting shrimp culture development in Vietnam since the country mainly traded with the Union of Soviet Socialist Republics (USSR) and landlocked eastern European countries with low demand for shrimp. The economic reform launched by the Vietnamese Communist Party (VCP) in 1986 gradually helped the country develop a market economy and establish diplomatic and trading relationships with all countries in the world. This "open door policy" connected the country with developed markets with high demand for shrimp, especially Japan, the U.S., and the European Union (EU), creating favorable conditions for a modern shrimp industry development in Vietnam.

The first phase of the modern shrimp industry development in Vietnam started in the late 1980s and lasted to the late 1990s, characterized by gradual hatchery production capability improvements, grow-out culture technology enhancements, and processing capability building. Nhuong et al. (2006) report that in 1990 Vietnam had 500 shrimp hatcheries and 93,000 ha of land area for shrimp culture, producing 38,000 metric tons. By the end of the first development phase in 2000, the number of shrimp hatcheries, cultured area and grow-out production in Vietnam climbed to 2,900 establishments, 235,000 ha, and 103,000 metric tons (Nhuong et al. 2006). The second phase of shrimp industry development in Vietnam was marked with the promulgation of Resolution 09/NQ-CP of the Government in June 2000, allowing farmers to convert low productive rice fields, uncultivated areas, and salt pans into aquaculture ponds. Shrimp farm area skyrocketed from 235,000 ha in 2000 to 478,000 ha in 2001, 530,000 ha in 2003, and to 630,000 ha in 2008 (Ministry of Fisheries (MoF) annual reports 2000-2003; Ministry of Agriculture and Rural Development (MARD) annual report 2009). Vietnamese

Association of Exporters & Producers (VASEP) reports that shrimp export value in Vietnam reached $662 million in 2000 and has become a billion dollar annual export industry since 2003 (VASEP 2008). According to Vietnamese Institute for Fisheries Economics and Planning (VIFEP), Vietnam used 650,000 ha to produce 383,000 tons of shrimp in total (0.59 metric ton per ha on average) and obtain an export revenue of $1.5 billion in 2009 (VIFEP 2009).

Development of the export oriented global shrimp industry during the last three decades has important developmental, social and environmental implications, and attracts the attention of both development and academic communities worldwide. There is a substantial literature on shrimp farming systems (Boyd and Clay 1998; Neiland et al. 2001; Menasveta 2002), economics of shrimp production and trade (Traesupap, Matsuda, and Shima 1999; Keefe and Jolly 2001) and social, political and environmental problems associated with management of the shrimp farming industry (Bailey 1988; Primavera 1998; Vandergeest, Flaherty, and Miller 1999; Stonich and Bailey 2000; Bene 2005; Vandergeest 2007; Hatanaka 2010).

Much of the research on shrimp farming in the tropics has been critical of social and environmental impacts of intensive production systems (e.g., Bailey 1988; Vandergeest, Flaherty, and Miller 1999; Stonich and Bailey 2000), and concerns have been expressed regarding antibiotics, biological, and chemical contamination and associated impact on consumer health (e.g., US GAO 2001; Jonker, Ito, and Fujishima 2005; Sapkota et al. 2008). These concerns have contributed to the imposition of increasingly stringent seafood safety and environmental management systems by both governments and non-governmental actors in the global North. These management systems, ostensibly developed to ensure consumer health, sustainability, and adoption of best management practices and certification schemes regulating production, may have unintended consequences of putting small-scale enterprises and farmers in developing countries at a disadvantage, adversely affecting the poorest stakeholders in the global seafood chain.

In this paper, I use the global value chain (GVC) framework to examine the impact of food safety management systems established by governmental and non-governmental actors in the global North on shrimp producers, middlemen traders, processors, and exporters in Vietnam. The GVC framework requires a systematic examination of governance issues that structure relationships between actors, in this case shrimp farmers, middlemen, processors, exporters, and importers. Governance includes both market and non-market coordination of economic activities, however within the GVC framework, governance analysis emphasizes on non-market coordination (Gereffi, Humphrey, and Sturgeon 2005). Non-market factors include food safety standards as well as socio-cultural values and natural resource conditions. The resulting analysis will illuminate the asymmetrical nature of power between actors and how this shapes the distribution of development benefits from international shrimp trade. This paper contributes to the literature on international trade and global value chain analysis in several important dimensions. First, by examining the structures, governance and relationships between actors involved in global value chains for shrimp, the paper will illuminate organizational aspects and mechanisms of international trade to complement conventional economic studies which focus on trade of final products at the country level. This contribution is important since agri-food trade and seafood trade in particular often involve the transformation of intermediate products before crossing borders. Second, focusing on socio-cultural and economic dimensions of food safety standards, the paper will situate international trade in shrimp within the literature on agri-food chain studies that feature systems characterized by heavy regulation of public and private actors at different times and places. The recent trend of increasing stringency of food safety standards in developed countries will likely induce great transformation of agri-food chains and displace small-scale agri-food producers in developing countries from international markets. Third, the paper incorporates the political ecology approach to address material resource conditions in shaping the global value chains for shrimp. And finally the paper will explore the dynamics of export oriented development in Vietnam as an example of how developing countries respond to stringent world market requirements while maintaining domestic development priorities (e.g., poverty alleviation, ensuring livelihood opportunities for small-scale farmers).

Following this introduction the paper proceeds with an overview of the GVC theoretical framework. Research methods are presented in section three, and section four describes structures of global value chains for shrimp in Vietnam based on results of field research. Section five analyzes governance patterns and dynamic driving forces affecting global value chains for shrimp in Vietnam. Section six discusses implications for international food safety and socio-economic development in Vietnam especially international market access and livelihood opportunities for small-scale actors *vis a vis* current and likely future transformation of global value chains for shrimp. Finally, section seven presents conclusions based on study findings.

The GVC theoretical framework

Chain-based study approaches started to appear in academic literatures in the 1960s and 1970s (Girvan 1987; Kaplinsky 2000; Bair 2009) and were used for analyzing dynamic processes of global capitalism, national development, and industrialization (e.g., roles and strategies played by actors especially multinational corporations in global production and trade; the integration of core, semi-periphery and periphery countries in the world economy; the inter-connection of actors in international production and trade; dynamics of international division of labor and surplus distribution, etc.). Chain studies became popular during the 1990s as a result of the influential writings of Michael Porter (1985) with the value chain and value system concepts, and Gereffi and Korzeniewicz (1994) with the global commodity chains (GCC) (Kaplinsky 2000). By the late 1990s, a wide range of chain based studies have been conducted in the manufacturing, agricultural, extractive, and service sectors using overlapping names and concepts to analyze similar topics such as global commodity chains, value chains, value systems, global production networks, value networks, commodity systems, and systems of provision (Gereffi et al. 2001; Bair 2009). Given this great variation in terminologies and approaches, with support from Rockefeller Foundation, a group of academic researchers working on chain-based topics from different countries and disciplines attended a series of workshops and meetings in Bellagio, Italy in 2000 to work out theoretical issues (Bair 2009). The result was adoption of the concept "global value chain" (GVC) as a common framework favored over other alternative concepts (Gereffi et al. 2001; Sturgeon 2009).

Tracing the intellectual lineage from a political economy perspective, Bair (2009) contends that the GVC framework grew out of and through modification of the GCC approach, which itself grew out of and through modification of world-systems theory. Within the world-systems tradition, a commodity chain is defined as "a network of labor and production processes whose end result is a finished commodity" (Hopkins and Wallerstein 1986 p.159). According to Gereffi and Korzeniewicz (1994 p.2), "a GCC consists of sets of interorganizational networks clustered around one commodity or product, linking households, enterprises, and states to one another within the world-economy." Each global commodity chain is represented by nodes linked together to create networks, which are "situationally specific, socially constructed, and locally integrated" (Gereffi 1994 p.2). The GCC approach emphasizes the social embeddedness of economic organization and activities. The GCC concept captures "the whole range of activities involved in the design, production, and marketing of a product" (Gereffi 1999 p.38). By adopting the GCC as a unit of analysis, global commodity researchers depart from world system analysts who study the world economy as a whole containing core, semi-periphery, and periphery states/regions linking to each other through commodity chains. While world-systems analysis explains international division of labor and surplus distribution as a consequence of exploitative and unequal exchange relationships, GCC analysis explains "the distribution of wealth within a chain as an outcome of the relative intensity of competition within different nodes" (Gereffi and Korzeniewicz 1994 p.4).

Gibbon and Ponte (2005 p.77) defines the GVC as "the full range of activities, including coordination, that are required to bring a specific product from its conception to its end use and beyond". This definition is not much different if not identical to the value chain concept as "the full range of activities which are required to bring a product or service from conception, through the different phases of production, delivery to final consumers, and final disposal after use." offered by Kaplinsky (2000 p.121), combining Porter's economic terms of value chain and value system (Porter 1985). The GVC framework absorbs all elements of the GCC approach and modifies it with a theory of GVC governance derived from three distinctive theories of transaction costs economics, production networks, and strategic management (Gereffi, Humphrey, and Sturgeon 2005; Bair 2009). The modification associated with GVC governance is an important contribution because it acknowledges the possibility of multiple governance structures along a chain (Talbot 2009). Within the GCC original framework proposed, only a simple dichotomy of global value chain governance offered, either as producer-driven or buyer-driven (Gereffi1994). Whereas, after further refinement using the new theory of governance, the GVC (Gereffi, Humphrey, and Sturgeon 2005) suggests a set of five governance forms ranging from market relation to hierarchical relation, with three types of network governance in between (Talbot 2009). However, the binary view of GVC governance is still valuable since it focuses attention on overall governance of a chain (Ponte and Gibbon 2005). The new typology of GVC governance is important and best suited for examining individual links (the coordination of inter-firm transactions) in a chain (Ponte and Gibbon 2005; Sturgeon 2009; Talbot 2009).

The new theory of GVC governance (Gereffi, Humphrey, and Sturgeon 2005) centrally questions how relationships between trading firms are organized and coordinated to avoid opportunism and malfeasance, arising from nonredeployable investments locking business partners in mutual dependency. For transaction cost economists (e.g., Williamson 1975 1979), market governance will be dominant when transactions are nonspecific since products are standardized, both parties in a transaction can use their own experience to decide to continue or discontinue a trading relationship with little transitional expense. Williamson (1975 1979 1980) further argues that once products for trade are customized, transactions are specific and opportunism (asset-specificity) increases, vertical integration or hierarchy will invariably appear to remove transaction costs from the market. In between the two extremes, Williamson (1981) observes an intermediate organizational form with some sort of explicit coordination, but he argues that it will eventually convert to vertical integration.

Social network theorists especially, Granovetter (1985) and Powell (1990) reject the thesis of transaction cost economists and contend that a distinct network form of economic organization exists between market and hierarchical governance structures. A network of firms in a business relationship can be sustained because economic activity is embedded in social relationships (Granovetter 1985). Opportunistic and malfeasant actions can be constrained by a number of variables such as frequency of transactions, social and cultural norms, trust, social and spatial proximity, and the desire to maintain reputation and repeat business with business parties. Network governance based on trust, reputation, and socio-cultural values are commonly found in East Asia where trade between parties is implemented with and sustained by informal business relationships (Moore 1993). Within the strategic management school, Gereffi, Humphrey, and Sturgeon (2005) picked up the concepts of technological capability and firm-level learning for justifying the existence of network governance. The central element of strategic management adopted by Gereffi, Humphrey, and Sturgeon (2005) is that firm-level competences are scare and difficult to copy so that lead firms cannot internalize all functions to create vertical integration. Likewise, shifting to other suppliers in a free market approach is also not efficient for timely competition. In such cases, firms have motivation to develop and maintain networks with each other for access to expertise and competences, even when asset specificity is significant.

The GVC framework for a particular industry consists of four analytical dimensions: input-output structure, geography, governance, and institutions (Gereffi, Lee, and Christian 2009). The first dimension, input-output structure outlines the entire process of conceptual and material transformation of inputs into final products and delivery to consumer's end. In development practitioners' language (e.g., M4P 2008) this involves mapping out the value chain, showing typical segments in the chain, the key actors (and especially lead firms) involved, and their characteristics and functions in the chain. The second dimension, geography, refers to the geographical spread of a chain's activities. Geographical analysis allows researchers to understand ecological footprints of a global value chain in real places. For the third dimension, governance, can be used to analyze authority and power relationships between actors involving in the chain especially roles of powerful actors in controlling and disseminating profits and technological competences in the chain. And finally the institutional dimension involves analysis of the domestic and foreign institutions and policies that shape organization and operation of the chain.

Among these four dimensions, governance analysis has received the most attention (Dicken et al. 2001; Gibbon 2001; Bair 2009). In the simplest chain categorization, Gereffi (1994) defines two types of global value chain governance, either as producer-driven or buyer-driven, based on empirical evidence of global industrial re-structuring studies. Producer-driven value chains are found in capital and technology intensive industries such as automobiles, aircraft and computers, in which transnational manufacturers or large integrated firms play key roles in coordinating the entire production network (Gereffi 1994). Buyer-driven value chains are characteristic of labor-intensive consumer goods production in which large retailers, branding enterprises and trading companies control decentralized production networks. Given that drivers, either multinational producers or retailers and branding firms are all located in the core regions, looking from the developing world perspective, I argue that ultimately, there is only a single type of global value chains, one that is core – driven.

The five categories of chain governance called market, modular, relational, captive, and hierarchical were derived from the new theory of governance (Gereffi, Humphrey, and Sturgeon 2005). These categories were constructed based on three variables: the complexity of information and knowledge required for maintaining a particular transaction; the ability to codify and transmit information efficiently between the committed parties without transaction-specific investment; and the capabilities of potential and actual suppliers required for the transaction. Market governance is dominant when product specifications are simple, suppliers have capabilities to produce ordered products with little input from buyers, and transactions are easily codified with little accumulation of asset-specificity. Modular relation can be expected when the products in question are complex but transactions can be simplified with technical standards and suppliers have sufficient capabilities to follow specified standards, packages, and modules. Relational governance patterns typically are found when producers have high capabilities, transactions are complex and codification of product specifications is difficult. In such situations, transactional parties are locked in mutual dependency and relationships are sustained and regulated by reputation, social norms, spatial and cultural proximity, ethnic ties, etc. Captive governance is expected when suppliers depend on buyers because of their low capabilities, the product codifiability as well as the complexity of product specifications are both high. Under this circumstance, suppliers need some sort of control and intervention from lead firms, and lead firms lock suppliers in their mutual dependency to gain benefits. Lead firms/buyers also create enough incentives for suppliers so that switching to other chains results higher costs to suppliers. And finally hierarchical or vertical relationship is typical when product specifications cannot be codified, products are complex and competent suppliers cannot be found. Lead firms facing this situation are forced to directly develop and manage their value chains.

The global value chain approach has been used extensively to examine a wide range of manufacturing and service commodities such as apparel and textiles (Gereffi 1994), tourism (Clancy 1998), services (Rabach and Kim 1994), electronics (Kenney and Florida 1994; Sturgeon 2002), and auto components (Kaplinsky and Morris 1999). Most studies of manufacturing and service products focus on the governance dimension, especially exploring how lead firms (e.g., transnational brand name companies and large retailers) exercise control, drive, and coordinate global value chains. To a lesser extent, scientists and development practitioners also use the GVC approach to study global agricultural industries such as organic and ethical agricultural products (Raynolds 2004; Guthman 2007), fresh fruits and vegetables

(Dolan and Humphrey 2000; Gibbon 2001; Bush and Bain 2004), coffee, cocoa, and tea (Ponte 2002; Talbot 2002), and forest products (Gellert 2003).

Agri-food Chains

Similar to manufacturing chain analysis, studies of agricultural chains have shown how global agri-food systems are transformed into buyer-driven value chains with powerful roles of transnational corporations and large retailers in coordinating agri-food chains and displacing small producers from international markets. However, agri-food chain studies have brought in several important dimensions. In addition to transnational corporations and large retailers, other actors also play important roles in driving agri-food chains such as international traders (Gibbon 2001), the state (Gellert 2003), private certification networks (Bush and Bain 2004; Raynolds 2004), and non-governmental organizations (Raynolds 2002; Guthman 2007). Material resource conditions that constrain or create opportunities for organizing and coordinating agricultural value chains are also considered (Talbot 2002). These findings highlight the fact that multiple governance patterns commonly exist in global agri-food commodity chains (Talbot 2009; Gereffi, Lee, and Christian 2009), in which different segments of global commodity chains are controlled by different actors. Agri-food value chains are often a result of complex interactions amongst production, extension, research, activist advocacy, marketing and distribution efforts, and socio-cultural interactions (Guthman 2009).

Over the past two decades, applying the older version (GCC) of the GVC framework, a number of studies of the global shrimp industry have been carried out (e.g., Skadany and Harris 1995; Gronski 1997; Kagawa and Bailey 2006; Islam 2008). Studies conducted by Skadany and Harris (1995) and Gronski (1997) drew on insights from the industrial restructuring and value chain literatures (Vandergeest, Flaherty, and Miller 1999) to analyze political, economic, and technical forces influencing the emergence of the global shrimp industry, especially power of transnational and national corporations in defining and dominating concentration, expansion, and organization of the industry. Vandergeest, Flaherty, and Miller (1999) criticized these studies for not having given adequate attention to the specifics of shrimp production systems which are highly dependent on natural resources and called for incorporating political ecology to address the roles of material resource conditions in shaping the industry's organization. Research by Kagawa and Bailey (2006) examines relationships between shrimp importers in Japan and exporters in Thailand and Vietnam and found that business relationships linking Japanese importers and seafood exporters in Thailand and Vietnam are informal rather than formal and contracted. These findings are in line with network theories of global value chain governance discussed above. However, the major shortcoming of this study is that it only investigates a single link between importers in Japan and exporters in Thailand and Vietnam and does not tell us a whole story about how global value chains for shrimp operate. In this paper I will use the latest GVC framework to examine governance issues that structure relationships between shrimp farmers, middlemen, processors, exporters in Vietnam, and importers in foreign countries. The focal point of the study is to examine the impact of public and private standards/institutions for food safety and environmental management on GVC for shrimp in Vietnam.

Research methods

Primary data for this paper came from field research in Vietnam. From August 2009 to March 2010, I collected primary data in the Mekong Delta region, the major shrimp bowl of the country where about 91% of total shrimp farm area and 75% of total farmed shrimp production come from (VIFEP 2009). Based on discussions with national and local experts in the fisheries sector, I worked in three provinces. Ca Mau Province was chosen as the center for various forms of (modified/improved) extensive/traditional shrimp farming systems, which are the most common ones found in the country up to present. Soc Trang Province represents a setting where larger-scale enterprises engaged in intensive shrimp farming are promoted consciously by local authorities. Ben Tre Province was chosen because it has a mix of large and small enterprises engaged in extensive and intensive production systems. From the Research Institute for Aquaculture No1 (RIA1) in Hanoi, I made monthly visits with an average period of two to three weeks per trip to the Mekong Delta to collect data.

In total, I interviewed 63 shrimp farmers in the three selected provinces in the Mekong Delta by using semi-structured interviews. Interview questions focused on shrimp aquaculture production, their material conditions and resource endowments/constraints, how farmers interact with each other and with input suppliers, buyers of their product, and other actors involved in shrimp supply chains. I also collected information on farmers' knowledge and perceptions on public and private standards for food safety and environmental management imposed by local, national or foreign authorities, what problems they faced, and what measures they adopted to address these problems. From RIA1, I obtained an introduction letter signed by the RIA1 director and sent to provincial departments for agriculture and rural development to ask for their support in conducting the research. Initial field visits were made with the assistance of local staff at provincial or district levels to get acquainted with local areas and community leaders and farmers. Working through such authorities is necessary while conducting field research in Vietnam. Once working relationships were established I asked local leaders to introduce me to farmers who were willing to participate in the research. Interviews ranged from forty minutes to two hours and were conducted in a conversational style to allow for rapport and trust building between the interviewer and respondents. The results of the interviews were typed in the evening of the same day or the next day, paraphrasing respondents' answers. Whenever possible, interviewed respondents were asked to introduce me to other potential respondents, an approach known as the "snow-ball" technique for identifying respondents. In addition, I also asked for lists of shrimp farmers and telephone numbers of community leaders if available in order to establish relationships and identify potential research participants.

Using a similar approach, I interviewed 42 stakeholders other than shrimp farmers participating in various nodes of and performing different functions in shrimp value chains in different provinces in Vietnam (2 shrimp hatchery operators, 2 feed suppliers, 9 shrimp collectors/middle men, 10 seafood processors and exporters, 5 researchers, 9 government officials at district, provincial and national levels, 3 officers of seafood industry associations, and 2 NGO officers). Semi-structured interview checklists developed for farm level interviews were modified to keep relevant questions for each actor category. In moving downward to processors and exporters of the shrimp value chains in Vietnam as well as to higher administrative levels, more questions relating to foreign standards for food safety and environmental management were included since exporters and national level officers had more frequent contacts and deeper understanding of foreign market requirements. In addition to semi-structured interviews with the 105 actors mentioned above, I had many informal interviews and interacted at many social gatherings with other farmers and governmental officials where I was able to observe behavior and use informal conversations to cross check data collected through semi-structured interviews. Furthermore, in order to gain additional data and understanding, I also participated in 8 group meetings arranged by local communities, with a range of 15 and 25 participants at each meeting. The meetings lasted for two to three hours and provided monthly or annual assessments of shrimp farming operations.

Secondary data covering the period 1999-2010, when rapid expansion of the shrimp farming industry in Vietnam took place, also were collected. In many cases as a RIA1 employee since 1997, I was directly involved in collection of these data on technical, environmental, socio-economic and institutional aspects of coastal aquaculture development in Vietnam. These included data from farm surveys and group discussions I conducted in various provinces in northern Vietnam.

Though research questions were formulated differently, research components of these projects on better management practices, social and environmental impact assessment, stakeholder power analysis and institutional arrangement analysis in coastal aquaculture development are highly relevant for my current research. With the exception of Ca Mau Province, data from previous studies were not from provinces covered by this study, so no attempt is made to provide time series data. However, despite important differences between provinces and regions, developments in shrimp aquaculture development in one place can affect other places. Accordingly, I used email and telephone communications with local governments and RIA 1 staff who are working in those provinces where I had worked to understand what has happened there since my own direct involvement.

Other secondary data used were reports and statistics provided by government and non-governmental actors, including both corporate as well as national and international environmental groups and international development agencies.

Global Value Chains for Shrimp in Vietnam

Presently, global value chains for shrimp in Vietnam can be divided into four functional stages namely input and service supplies, grow-out production, shrimp collection, and shrimp processing and export. These four stages are embedded in natural material resource conditions, socio-cultural values, domestic institutions, and local communities. By 2009, the four functional stages are operating separately by different actor groups and there is only a tiny portion of shrimp production produced under vertical integration by processing and export companies. Key actors participate directly in global value chains for shrimp in Vietnam are shrimp hatchery operators, input suppliers, shrimp producers, a variety of middle traders (e.g., shrimp collectors and shrimp wholesale agents), processors, and exporters. A visual depiction of the GVC for shrimp in Vietnam is shown in Figure 1.

Input supply

The input supply stage involves shrimp hatchery operators, feed and veterinary drug suppliers and financial service providers. Most shrimp hatchery operators in Vietnam work with domestic black tiger shrimp (*Penaeus monodon*) with only a few hatching introduced white shrimp (*Litopenaeus. vannamei*). Shrimp hatcheries are small-scale and operated by family-based networks (VIFEP 2009). By 1990 about 500 shrimp hatcheries were established in Vietnam (Chinh 1995). The number reached a peak of 5,080 facilities in 2003 then dropped back to 4,300 establishments in 2005, producing 25 to 30 billion shrimp post larvae for grow-out shrimp production annually (VIFEP 2009). Hatchery operators buy wild shrimp broodstock captured by fishermen to start a hatching season. Shrimp seed are sold to middlemen or to grow-out shrimp farmers directly depending on buyers' requirements. Small-scale producers often get shrimp seed from local middlemen who buy shrimp seed from hatcheries. Large-scale farms often prefer to buy shrimp seed directly from hatchery operators. Large-scale farmers may send their people to stay in a hatchery during a spawning season to make sure that they will receive good quality seeds, whereas small scale producers have to take risk, depending on middlemen for this essential input. The price of shrimp seed is regulated by the market but bargaining power is skewed toward hatchery operators or middlemen, especially when dealing with small-scale producers.

Feed and veterinary drugs are essential input components for semi-intensive and intensive shrimp farming. Use of these inputs is very limited in extensive and various forms of modified farming systems. VIFEP (2009) estimates that there are 53 shrimp feed producing plants and 105 agencies registered for producing and supplying veterinary drugs and chemicals for shrimp farming in Vietnam, most of them located in the Ho Chi Minh city area. For selling feed and veterinary drugs to producers, chains of different agent levels are created in shrimp farming provinces and down to shrimp farming communities. For example, VIFEP (2009) suggests that there are 1,799 shops selling veterinary drugs, chemical and bio-products to shrimp farming communities in Vietnam. Feed and veterinary drug suppliers set selling prices based on their producing plant referring prices, their business investments, and profit sharing agreements with feed producing plants or veterinary supplying agents. They prefer to receive immediate payments once a transaction is processed. However, suppliers also loan feed and veterinary drugs to producers if they find evidence that buyers will be able to pay back. Suppliers normally charge higher prices compared to cash sales. For a shrimp crop lasting for 4 months on average, loaning inputs usually occurs in the third month to fourth months, when producers are able to harvest and sell products if serious risk such as disease problems occur. Large and successful farmers can more easily obtain inputs or credits than small and poor producers.

Financial services provided to shrimp industry operations involve national banks, local banks, farmer credit unions, and family, friend-based or input supplier-based networks. Capital shortage is one of the constraints often most reported by actors, especially small scale producers.

Interviews with farmers revealed that national and local banks used to be generous in providing credits to them when the shrimp farming industry started to develop and especially during the early 2000s. However banking institutions do not give priorities to the shrimp farming industry anymore. Alternative capital sources small-scale actors often access are credits from poverty alleviation or small enterprise development programs initiated by national, local governments or donor agencies. These programs charge lower interest rates but loan size is usually limited and the loan period is short. When facing a serious financial crisis, farmers especially the poor and unsuccessful households try to get loans from local money lenders or input suppliers with higher interest rates to operate their business. Success of this transaction depends on actors' social, cultural and local network relationships and farming credibility.

Shrimp production

The shrimp farm production stage mostly involves small-scale farming operators with limited participation of large-scale entrepreneurs and processors and exporters who engage in vertical integration. Presently shrimp farming in Vietnam is practiced in various forms such as extensive and modified extensive farming (in policulture, shrimp and rice farming in rotation, shrimp and mangrove forestry), semi-intensive, and intensive shrimp farming systems. The essential feature providing some differentiation along the extensive to intensive continuum is additional seed stocking, associated input investments, and management efforts. No artificial seed is stocked in traditional extensive farming and about up to 5 individuals per square meter are stocked in modified extensive farming systems. Semi-intensive and intensive farming associates with higher stocking density ranging from 6-20 individuals per square meter in semi-intensive and 21 to 80 individuals or higher in intensive farming systems. Different stocking densities imply different input levels and required technical management efforts. Adoption of farming systems is shaped by material resource conditions, technical and management capabilities, financial conditions as well as other social, economic, institutional, and community factors.

VIFEP's study (2009) estimates that the ratio of intensive/semi-intensive to extensive and improved extensive shrimp farming in Vietnam in 2007 was 11: 89 in terms of shrimp farm area. In the same year, an area of 624, 600 ha were used for shrimp culture, producing a total production of 383,600 metric tons (VIFEP 2009). Extensive and modified extensive farming productivity ranges from 230 kg per ha in the shrimp and mangrove forest system, and up to 450 kg/ha in modified extensive systems (VIFEP 2009). On average, semi-intensive and intensive productivity are reported at 1.5 metric tons/ha and 3.5 metric tons per ha, respectively. Combining VIFEP (2009) and annual reports of MARD (2009), I suggest that in 2007, Vietnam used 68,700 ha for semi-intensive and intensive, and 555,900 ha for extensive and modified extensive farming practices. Production from extensive and modified extensive systems range from 194,600 to 233,500 metric tons, accounting for about 51 to 61 % of total farmed shrimp production in 2007 (383,600 metric tons). The GSO (2007) reports 330,000 households operating shrimp farms, of which 79,600 units are in semi-intensive and intensive operations in 2006. Hence, it can be postulated that average size of extensive and modified extensive farms is around 2 to 2.2 ha, and average size of semi-intensive and intensive farms is from 0.7 to 0.8 ha.

Shrimp collection

Once producers harvest their crops, shrimp products will flow to the collection or middle trading stage. As Figure 1 shows, shrimp chains from extensive and small-scale producers are often longer and proceed through a number of middle trading levels (collectors) to a wholesale agent who is usually registered as a middle trading enterprise with provincial government. The longest middle trading process encountered involved extensive farmers in Ca Mau and Ben Tre provinces who told me that shrimp goes through 5 middle steps before reaching processing plants. This is because extensive farmers harvest shrimp based on the tidal regime (e.g., 4-5 days per regime) and each day they may harvest only 10 to 20 kg. A further constraint is imposed by the absence of roads. Traders will specialize in collecting shrimp from households and shift by boat to other middlemen located in the next community. Tapping more products from the first trader, the second trader will sell to another one, and so on. Intensive and large scale shrimp farms often sell products through one middlemen step (e.g., a wholesale agent) who will sell shrimp directly to processors. For small semi-intensive and intensive farms, middle trading typically involves two steps, for example, from a local collector through a wholesale agent and to processing plants.

Processing and export

Shrimp processors mainly get their supply from wholesale agents. Only a tiny portion of farmed shrimp is directly bought from semi-intensive and intensive producers by processors. Few processors get shrimp product directly from vertically integrated farms. Each processing and export company often works with a range of 5 to 15 wholesale agents depending on their processing capacity. To conduct shrimp material transactions, processors will offer buying prices to wholesale agents. Wholesale agents will adjust their investments and expected profit margin and set a price to upper middle collectors. Upper middle collectors will adjust their costs and expected profit margin and offer a buying price to producers.

The National Agro-forestry and Fisheries Quality Assurance Department (NAFIQAD) in 2010 reported that 479 seafood processing plants are approved for exporting seafood products to foreign countries, of which 330 plants met EU quality standards. The number of firms meeting quality standards and having been approved to export to East Asian countries is 370 plants to Japan, 459 plants to China, and 457 plants to Korea. There is no official record on how many processing and export firms work with shrimp processing and export. Statistical data on seafood export from 1997 to 2008 published by VASEP in 2008 only lists the 100 largest shrimp or other seafood exporters annually. Shrimp export revenue in 2007 was at $1.51 billion, of which the top 100 largest firms account for 99 % of exports. Among the ten largest seafood export companies, four of them are located in Ca Mau province (VASEP 2008).

Shrimp products are consumed in both export markets and domestic markets. The combined markets of Japan, the US, and the EU accounted for 77 % of annual shrimp export values of Vietnam in 1997 and 1998, increased to 86 % in 2000 and up to 89 % in 2003, and then dropped to 75 % in 2007 and 74 % in 2008 (VASEP 2008). Data compiled by VASEP (2008) shows that Vietnamese seafood exporting firms traded with 613 seafood importers in 2007, of which 111 come from the EU, 65 from Japan, 31 from the US, 283 from newly industrialized countries of Korea, China, Hong Kong and Taiwan, 78 from Southeast Asian nations, and the 45 remaining importers are from other importing countries. During the years from 1999 to 2006 annual shrimp exported to Japan and the US markets often accounted for about 70 % to 83 % of Vietnamese shrimp export value totals (VASEP 2008). Vietnamese shrimp products exported to foreign markets appear in various forms, however, most exported products have low value added, such as in the headless frozen shrimp form. With the exception of the highest price of $9.70/kg established in 2000, the nominal price of exported shrimp products aggregated at the national level ranges from $6.85/kg in 1998 to $9.36/kg in 2007 (VASEP 2008).

Governance of GVC for Shrimp in Vietnam

Figure 2 integrates global value chains for shrimp in Vietnam described in Figure 1 with the public and private regulatory networks affecting organization and governance of shrimp chains. Figure 2 consists of four quadrants generated by two dotted lines, one vertical and one horizontal. The two upper quadrants define public (governmental) and private (non-governmental) regulatory networks operating in Vietnam (upper left quadrant) and in foreign countries (upper right quadrant) which import Vietnamese shrimps. The two lower quadrants of Figure 2 contain key actors directly participating in global shrimp chains from Vietnam and the environments that shrimp chains are embedded. Segments of shrimp chains in Vietnam are presented in the left lower quadrant and global shrimp markets are in the right lower quadrant. From Vietnam, four groups of GVC are identified, connecting actors in the shrimp industry in Vietnam to EU, US, Japan, and other markets. Shrimp commodity flows from left to right, and governing power to coordinate GVC and the money flow will be from right to left indicating by arrows. Arrows in producer and exporter boxes express horizontal dynamics of transformation and consolidation of actors in these links of GVC induced by the impact of increasing stringency of global market requirements such as food safety and environmental regulation. For example, up arrows indicate successful actors “racing to the top” and down arrows depict failing actors being displaced from shrimp GVC and “sinking to the bottom”. Setting up shrimp GVC in three dimensional space, the two lower quadrants are in a horizontal dimension and the two upper quadrants are in a vertical dimension.

Governmental regulatory networks include governmental systems in charge of the shrimp industry development, and food safety and environmental administration in Vietnam as well as in foreign countries. The typical institutional set-up of governmental regulation of shrimp chains in

Vietnam consists of a number of organizations under MARD including research institutions (RIs), National Agriculture and Fisheries Extension Center (NAFEC), Fisheries Administration Directorate (FAD), Department of Animal Health (DAH), and NAFIQAD. Domestic seafood safety regulation belongs to Vietnam Food Administration (VFA) under the Ministry of Health (MOH). The relative positions shown in Figure 2 reflect organizations' regulatory management functions and actors that organizations work with in shrimp chains in Vietnam. For example RIs' main responsibilities are to develop technologies to be disseminated to hatchery operators and producers through NAFEC, while NAFIQAD is legally designated by Vietnam and foreign governments as the competent authority in Vietnam for quality assurance and management. Foreign governmental institutional setup for shrimp chain governance varies between countries but typical organizations regulating GVC chains include food safety administrations such as the Food and Drug Administration (FDA) and USDA Food Safety and Inspection Service in the US. Super governmental or inter-governmental organizations affecting governance of GVC chains for shrimp in terms of shrimp aquaculture, shrimp trade, and food safety management include many institutions such as the World Trade Organization (WTO) with the Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) Agreements, and FAO with the Codex Alimentarius Commission (CAC), and the World Organization for Animal Health (OIE). In Vietnam a SPS office was created under MARD to ensure that all regulations proposed by organizations under MARD framework are consistent with the WTO's SPS Agreement. Regulatory networks both in Vietnam and foreign countries containing actors who influence governance but do not directly possess products produced by shrimp chains.

According to Vandergeest (2007) non-governmental regulatory networks (NGOs) consists of two groups: one favors and supports market based certification initiatives typically as

World Wide Fund for Nature (WWF) and the other supports local and community based management approaches to address food safety, socio-economic, and environmental issues associated with the shrimp industry. These two NGO groups operate at local (LNGOs) or international level (INGOs), mostly focusing on environmental regulation and to some extent social issues associated with the global shrimp industry. Non-governmental regulatory networks also include financial institutions (FIs) such as the World Bank and Asian Development Bank, and industry organizations (IOs) such as Global Aquaculture Alliance (GAA) in the US, Global Good Agriculture Practices (GLOBALGAP) in Germany, British Retailer Consortium (BRC) in UK or VASEP in Vietnam. Industry organizations such as GLOBALGAP, BRC, and GAA work closely with large retailers such as Walmart to drive adoption of certification systems along shrimp chains.

Due to perceived weaknesses in the public sector and subjectivity critiques of industry organizations' certification systems, non-governmental organizations have developed private regulatory/certification systems and launched activist campaigns, forcing food retail corporations to address social and environmental responsibility and food safety by adopting third-party voluntary certification standards. At the global level, certification systems initiated by NGOs have become more and more popular in recent years. WWF benmark study (2007) documented that more than 30 certification schemes operated by different branding institutions including industry organizations and NGOs are in place in aquaculture. Since 2007, WWF in collaboration with other non-governmental and governmental institutions and local communities have been working towards creation of an Aquaculture Stewardship Council (ASC), similar to Marine Stewardship Council (MSC) for regulating capture fisheries and Forest Stewardship Council (FSC) regulating forest products through private standards. Industry organizations and retailers also have developed and imposed codes of conduct, management practices, and standards for food safety management as their competitive and risk management strategies. A typical industry and market based certification system in the global shrimp industry is that operated by the Aquaculture Certification Council (ACC), which certifies both shrimp farms and processing plants. Certification NGOs and industry organizations pursue different objective functions (such as maximizing social, environmental, or industry sustainability). These non-profit and non-governmental organizations act as branding companies in global shrimp value chains. Though there are actors in Vietnam participating in private regulatory certification systems, at the current stage the role and impact of private certification institutions on shrimp GVC in Vietnam is novel, especially at the shrimp farming stage.

Overall governance of shrimp GVC in Vietnam is consumer/buyer-driven; however, it is not static but dynamically develops though different time, place, and mechanisms, transforming power relationships between trading parties and generating different governing patterns and dominating actors in the chains. Several governing patterns ranging from market to hierarchy relations categorized by Gereffi, Humphrey, and Sturgeon (2005) are commonly found in shrimp GVC in Vietnam.

Governance patterns between Vietnamese processing and export companies and foreign shrimp importers range from market to relational and captive relationships. Seafood importers from Japan, the US, and EU have strong power in setting shrimp prices with Vietnamese exporting firms. In the industrial North, shrimp markets are dominated and controlled by powerful and large retailing companies/supermarkets. The more shrimp and low quality products developing country exporters supply to global markets, the greater will be the incentive and power for lead firms to coordinate shrimp GVC chains. Similarly the more irresponsible environmental and social management practices implemented by producers and exporters the stronger the critiques and incentive for public and private regulation networks to strengthen their role in GVC governance. As hazards such as foodborne diseases and human health risks or environmental and social damage became known, consumers and non-governmental organizations put pressures on foreign governments to regulate shrimp imports. Risks from public regulations for food safety, product traceability, and country of origin are imposed on lead actors and retailers/supermarkets in importing countries. Retailing corporations develop and implement customized product standards, designated certification systems, and product safety specifications and communicate to seafood importers who then will push on seafood processing and export companies in Vietnam. Competition between retailers in the market place to offer "sustainable" seafood further drives change.

Vietnamese seafood firms entered captive relationships with Japanese seafood importers in the 1980s and early 1990s. During this period, Vietnam's seafood processing and export enterprises (mostly owned by national or local governments) harvested abundant seafood resources but had low processing capabilities and no market access for seafood export. Having high demand for seafood and sharing an East Asian culture, Japanese investors and importers took the opportunities to assist Vietnam in establishment of seafood processing plants, equipment installation, and technical staff training. Japanese investors frequently sent their technical staff to Vietnam to support Vietnamese enterprises and make sure that seafood products were processed and packed in accordance with their orders. In the 1980s, more than 80% of Vietnamese seafood exported products went to Japan market (Loc 2006). With economic reform introduced in 1986 and the lift of the American embargo on Vietnam in 1994, Vietnamese seafood enterprises were able to find more markets for their seafood products and relax dependent trading relationships with Japanese seafood importers. However traces of dependent relationships are still present in some Vietnamese seafood enterprises in the early 2000s as documented by Kagawa and Bailey (2006). Relational ties are normally established between seafood firms in Vietnam and traditional importers in developed markets. While market relations are established between Vietnamese companies with new importers, especially in newly established value chains or markets.

Processing plants are commonly integrated with exporting enterprises and hierarchical relationships are the most common governing pattern between these two actors. These integrated firms act as leading actors in the upstream of the shrimp value chains in Vietnam. Incentives for processing and export actors to act as lead firms in Vietnam are also strengthened by measures of border inspections imposed by foreign governments *vis a vis* international trade, food safety, and product quality. These measures impose risks directly on seafood processing and export companies in Vietnam, mandating them responsibilities for governing upper links in shrimp chains. Shrimp products from Vietnam have to go through a series of border inspections before being accepted for imports and delivered through importers and retailers' systems to reach final consumers. If food safety or other defects are found, imports will be rejected by foreign governments and additional scrutiny immediately will be imposed on Vietnamese shrimp exporters. Furthermore, food safety alert messages will be sent through warning systems established by foreign governments to negatively affect Vietnam's whole shrimp industry.

Governance patterns between wholesale agents and processors are similar to those found in exporter and importer relationships, ranging from market relations to relational and captive relationships. Power relationships between these parties depend on shrimp seasons (scarcity or abundance), shrimp farming areas, and number of actors in operation. Processors usually have more power to influence transactions with wholesale agents and dominate in setting the price in peak of shrimp harvesting seasons. However, if shrimp become scarce due to crop failures or during off-season, the power of wholesale agents will rise to change established power relationships with processors and will have more influence in establishing the price.

Due to fragmentation and the small-scale nature of shrimp production, coordination of chain segments from wholesale agents down to producers and input suppliers presently is out of control of lead firms in international markets as well as in Vietnam. Governance between successive actors in these segments ranges from market relations to relational ties. Transactions between actors in the upper stream links (e.g., between producers and different levels of collectors) are normally conducted with verbal agreements without formal contracts but sustained by conventional socio-cultural norms, friends and family based networks. Going further upstream to producers, bargaining power is weakened. Producers are the most vulnerable actors because they are small scale and will face higher risks and endure high costs as shrimp reach harvesting size and there are no buyers. A further constraint weakens producers' power associated with technical aspects of shrimp farming operation: to avoid risks caused by diseases or environmental management problems (e.g., water supply), farmers have to stock and harvest shrimp at almost the same time.

In Vietnam, pressures on addressing seafood safety hazards management (e.g., antibiotics, chemical, and biological contaminations) to ensure continued access to exported markets have resulted in heavier public regulations on processors, middlemen traders, producers and input suppliers, implemented through the regulatory framework established under MARD. NAFIQAD is mandated responsibilities to control and inspect seafood processing companies and make sure that standards required by foreign markets such as Hazard Analysis Critical Control

Points (HACCP) systems, Sanitation Standard Operating Procedures (SSOP), Good Manufacturing Practices (GMP), and mandatory antibiotics and chemical residue monitoring programs be implemented. NAFIQAD also works with foreign food safety administrations to grant export permits (e.g., the health certificate required by EU market) to processing and export companies upon companies' standards meeting foreign food safety standards. Responsibility for supervising input suppliers, producers and middle trading actors is shared between departments of Fisheries Administration Directorate and Department of Animal Health from national to provincial level.

Explicit coordination of shrimp GVC from middle traders down to producers and input suppliers are challenging tasks faced by lead actors as well as public and private regulatory networks in Vietnam. Presently only wholesale agents/collecting units registered as companies under control of regulatory networks established by MARD system. The middle traders and collectors at upper levels in shrimp GVC are hardly controlled by administrative systems of MARD and seafood processors. At the shrimp farming level, with the presence of 330,000 small-scale shrimp producers in Vietnam, processing and export actors cannot trade directly with producers but have to work through a series of middle traders depending on which material resource conditions that shrimp value chains are located in.

Discussion and Implications for Food Safety and Socio-economic Development

In the globalization era, the world economy is organized in forms of GVCs, geographically spread across nations and functionally integrated and coordinated by powerful actors and institutions in the chains (Gereffi 1999; Gereffi et al. 2001). The shrimp farming industry in Vietnam is socially and economically constructed into such GVCs. Large retailers/supermarkets and importers representing consumers in developed markets are powerful actors, driving the chain. Various actors ranging from input suppliers, producers, middlemen, processors, exporters in Vietnam participate in shrimp GVCs but possess less power. Especially, small scale producers and enterprises are very vulnerable and with limited influence on organization and governance of shrimp GVC. Competition among shrimp producing countries in the developing world is high, whereas with high barriers to entry created and controlled by powerful actors, competition among shrimp markets is less intense. As shrimp proceeds through a sequence of value added activities, distribution of development benefits of the global shrimp industry is determined by competitive pressures and power relationships between actors. Based on the analysis presented here, both distribution of benefits as well as power relationships among actors involved in shrimp GVCs are subject to dynamic processes of change through time and space. Nonetheless, overall governance of shrimp GVCs has remained buyer-driven, a condition unlikely to change in the foreseeable future.

Similar to findings in other agri-food chain studies (Raynold 2004; Talbot 2002; Bush and Bain 2004), shrimp GVCs in Vietnam are heavily regulated and influenced by regulatory networks in Vietnam as well as in foreign countries. Public regulations in Vietnam and foreign countries are currently very active in coordinating and managing shrimp GVCs. Motivation for public administration within Vietnam to regulate shrimp GVCs can be explained easily. Consumers in the global North are increasingly aware of foodborne hazards as well as socio-economic and environmental sustainability issues. National governments in the global North are setting standards based on risk assessment approaches. Food safety regulations such as HACCP systems mandated in the U.S. since 1997 and the food safety and traceability principles specified in the EU regulation No 178/2002 in 2002 have the effect of providing discipline to market actors (retailers/supermarkets) in food provision. In addition, these market actors may impose their own standards as a mechanism to improve consumer confidence, acceptance, and approval. The net result is that the government of Vietnam has no choice but to follow these standards if they wish to gain access to lucrative foreign markets. Lead firms/retailers have the incentive to explicitly coordinate actors involved along shrimp GVCs in order to reduce obstacles to the smooth flow of product.

In Vietnam, through border inspection systems or periodical country visits by foreign food safety administrators, pressures for coordination of shrimp GVCs are put on the Vietnamese government and realized through the legal framework established under MARD. Similar to the forest GVC study by Gellert (2003), the state in Vietnam plays an important role in driving shrimp GVCs to ensure market requirements are met to maintain access to global shrimp markets. As foreign markets increase the stringency of seafood standards, the government networks have to put in place strict inspection and monitoring systems for regulating actors involved in shrimp GVCs. Historically Vietnam had been a centrally planned economy with a "big government" thus governmental networks exert strong control over economic activity, creating favorable conditions for the shrimp industry to effectively respond to international market requirements. The influence of private regulatory/NGO networks on organization and governance of shrimp GVCs in Vietnam is limited at present, though aquaculture certification institutions are active in international shrimp markets (Vandergeest 2007; Hatanaka 2010) as well as in Vietnam. Several aquaculture certification schemes at the demonstration stage have been initiated by international NGOs in Vietnam. At this stage, certification institutions and certification supporting NGOs are experimenting with a dual strategy. On the one hand, capacity building projects of best management practices/best aquaculture practices are being sponsored by NGOs and donor agencies to create preliminary foundations for certification standard development and implementation. If pilot projects are successful in selling certified products in global markets, a premium price may be offered to lure producers to adopt private market based certification systems such as the organic certification project in mangrove shrimp farming systems in Ca Mau province. This organic shrimp farming project was funded by the Swiss Import Promotion Program (SIPPO). Since 2002 organic shrimp in Ca Mau province was certified by the Naturland, a German certification institution accredited by the International Federation of Organic Agriculture Movements (IFOAM).

NGOs also organize campaigns to influence consumers, governments, and retailers/corporations in the industrial North to encourage adoption of third-party certification systems. Retailers will watch consumer responses to certification to see if certification provides competitive advantages or reduces risks. In the long run, certification rents will disappear if all producers/exporters supply certified products to global markets. If this comes to pass, certification standards will result in improved quality and consumer safety, as they were designed to do, but at the expense of increasing production costs for producers/suppliers. How aquaculture certification systems will impact the social and environmental sustainability associated with the shrimp farming industry in Vietnam is at present unknown. Standards set by governments, industry organizations or NGOs can become obligatory for shrimp producers, processors and exporters if powerful food retail corporations mandate them. The question must be asked whether such standards will have the effect of excluding small scale producers and processors from participating in shrimp GVCs, in Vietnam and in other nations of the global South, given their limited financial and technical capabilities.

How do food safety standards affect organization and governance of global shrimp chains in Vietnam and distribution of developmental benefits and welfare generated by the shrimp farming industry? My analysis in previous sections shows that public and private standards and regulations are not only just for food safety and environmental or social sustainability *per se*, they can affect organization and governance of global value chains for shrimp in the developing world and in Vietnam in particular. Power relationships between trading parties can be modified profoundly by regulations and standards. Important implications for international trade learned from this GVC analysis is that public and private regulatory standards have distributional impacts on various actors involved in global shrimp chains. Trade standards impact not only actors actively trading final products, in this case exporters in Vietnam and importers in foreign markets, but also intermediate actors who participate in producing various products used for producing the final products traded. Analysis of this study shows how international trade in shrimp between Vietnam and foreign countries is organized and operated through intermediate actors along shrimp GVCs. Small scale actors are likely to receive few benefits and their costs of compliance will be higher.

State-centered approaches to examine the impact of international trade in the globalization era definitely cannot capture dynamic elements uncovered within the GVC framework (Bair 2005). The study substantially complements conventional studies of international trade which usually works with final export production and value of shrimp trade.

Socio-cultural factors and material resource conditions create opportunities and constraints affecting organization and governance of shrimp GVCs in Vietnam. Most of Vietnam’s 330,000 shrimp farms in Vietnam are small scale and operated by rural households coming from a range of previous rural subsistence livelihoods such as rice farming, salt producing, and fishing with limited technical know-how and no capitalist mind of business operations. The government’s ability to coordinate producers is limited, as is that of shrimp processors. Many shrimp farmers operate from communities where there are no roads. Under these conditions, processors cannot work directly with shrimp producers but have to organize and coordinate shrimp chains through various levels of middleman traders. Government officials and shrimp farmers alike are critical of these traders, but they play a central role in the flow of product and money within the system.

Regulating middle traders to ensure foreign food safety and quality standards compliance is challenging but not impossible. Local authorities regulate middle traders who register with local governments as business firms and have poor records on other levels of middle traders. Shrimp processors and exporters are highly concerned when traders use banned drugs or improper preservation methods. Small scale producers and government authorities express their frustration and blame middle traders for deteriorating shrimp product quality through irresponsible practices. These actions can increase food safety hazards and market sanctions, and negatively affect business of processors and other actors (Loc 2006). Efforts to improve product quality need to address this critical link in shrimp GVCs. Many of the criticisms of middle traders are unfounded, reflecting the actions of only a small sub-set of traders. We contend that middle traders are important in organizing and coordinating shrimp GVCs in Vietnam. They understand farming communities, are willing to stay in rural settings, and are also able to communicate and conduct successful transactions with parties residing in urban areas.

Will small-scale operations be viable given the increasing trend of stringent standards for food safety and environmental management imposed by global markets? As the argument above shows, small-scale operations distribute the shrimp industry’s benefits to more local people creating opportunities for promoting rural community development. As standards for seafood safety and quality management in export markets become more stringent, many small processing and exporting firms face higher risks and have been unable to upgrade and operate their business successfully. The situation is further complicated by the fact that different markets and GVCs enforce different standards. Being pushed by stringent requirements from export markets, small-scale and poor performance processing and export companies will usually be displaced from the most lucrative value chains and will seek alternative pathways which may include domestic markets.

A moral beauty contest orchestrated by a variety of actors is shaping how processes of globalization affect agri-food production and consumption. On the one hand are the rights to consume safe and certified products in the industrial North, while on the other hand are the rights of small scale producers to earn a livelihood in the developing South. Affluent consumers in the industrial North will certainly benefit from increasing vertical organization and governance of shrimp GVCs. They demand more stringent standards to ensure food safety and protect consumer health as well as social and environmental sustainability. The irony of such efforts is that small scale producers and entrepreneurs may become marginalized in the process. This does not need to be the case, however. Along with strict food safety standards, a full accounting of social and environmental dimensions needs to be incorporated into certification standards.

Conclusions

Research results presented in the paper show that the shrimp farming industry in Vietnam is organized as global value chains driven by buyers/consumers represented by lead retailers/supermarkets in developed countries, especially the EU, Japan, and the U.S. These shrimp chains are embedded in socio-cultural relationships, regulatory frameworks that are domestic and foreign as well as public and private, and all are shaped by material resource conditions – the physical reality of small and physically isolated shrimp farms. Various actors in

Vietnam such as hatchery operators, feed suppliers, shrimp producers, middlemen traders, processors, exporters, as well as importers and retailers in foreign markets directly participate in the governance of global shrimp chains. Power relationships between actors are asymmetric and dynamically developed and transformed through times and places to chain established power balance and generate multiple governing patterns along global shrimp chains in Vietnam. Large retailers/supermarkets in the industrial North are powerful, whereas hundreds of thousands of small scale shrimp producers in Vietnam are most vulnerable. Analysis in the paper shows organizational aspects and mechanisms of international shrimp trade involving and affecting various intermediate actors within the chain, complementing the literature of international trade examining only trade of final products.

Though not possessing shrimp and pursuing different utility functions (e.g., maximizing food safety, environmental, social, production or business sustainability), a range of actors working in public and private regulatory institutions indirectly exert powerful influences on global value chains for shrimp. The power of these indirect regulators is internalized within global shrimp chains through different actors, times and places to affect organization and governance of the GVCs for shrimp. In Vietnam, public regulatory networks arranged within MARD take active roles in promoting and coordinating shrimp supply chains, especially in terms of food safety regulation to respond to international shrimp market requirements. Private/non-governmental regulatory networks have limited but potentially rising influence on organization and governance of shrimp chains.

Socio-cultural factors and material resource conditions create opportunities or constraints to the organization and governance of global shrimp chains in Vietnam. The government of Vietnam is facing great challenges in pursuing this export oriented shrimp farming industry: the trade-off between small scale operation for maximizing social and economic benefits for local communities and large scale and intensive operation to respond to high quality and safety standards raised by international markets.

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Figure 1: Global Value Chains or Commodity Flows for Shrimp in Vietnam

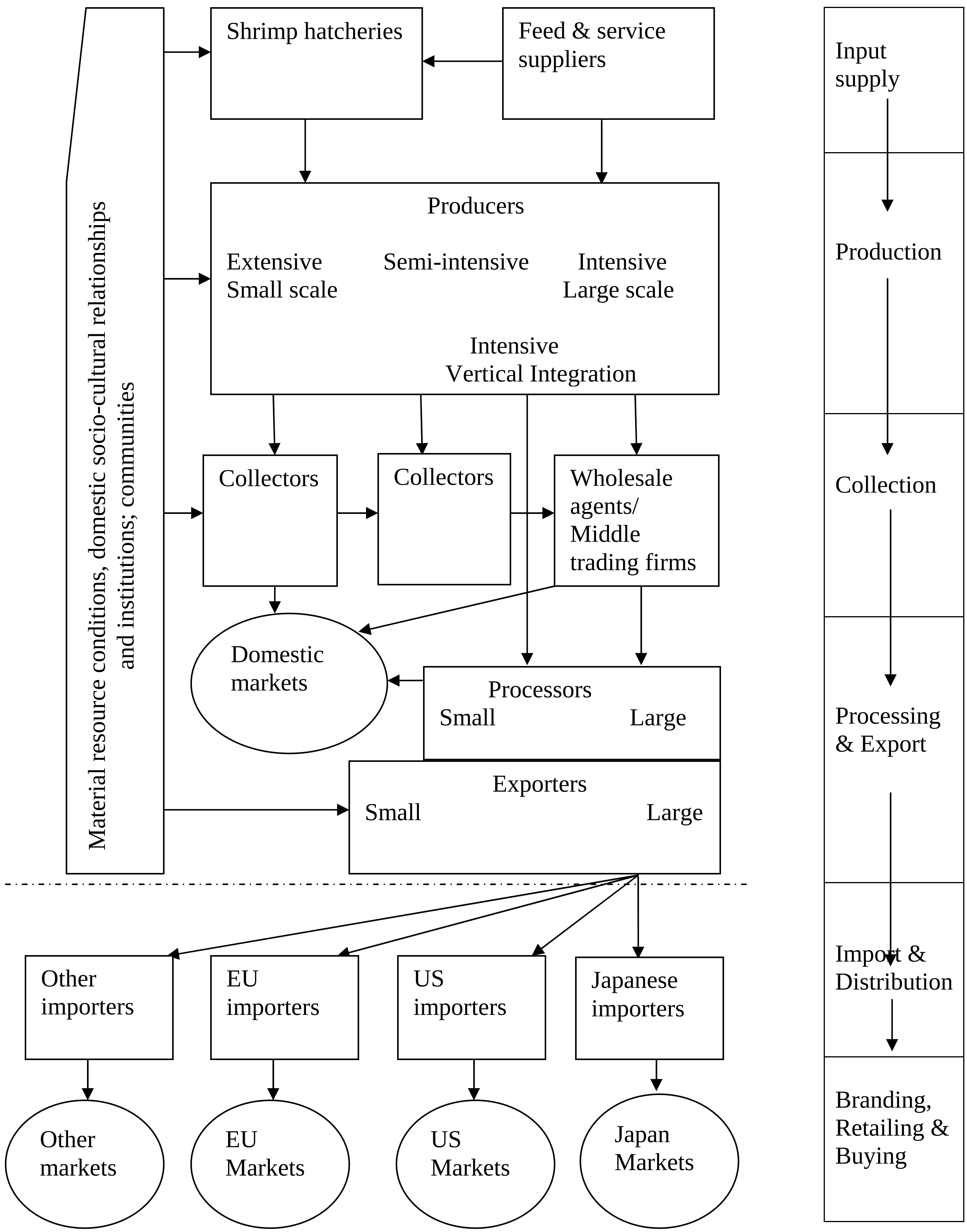
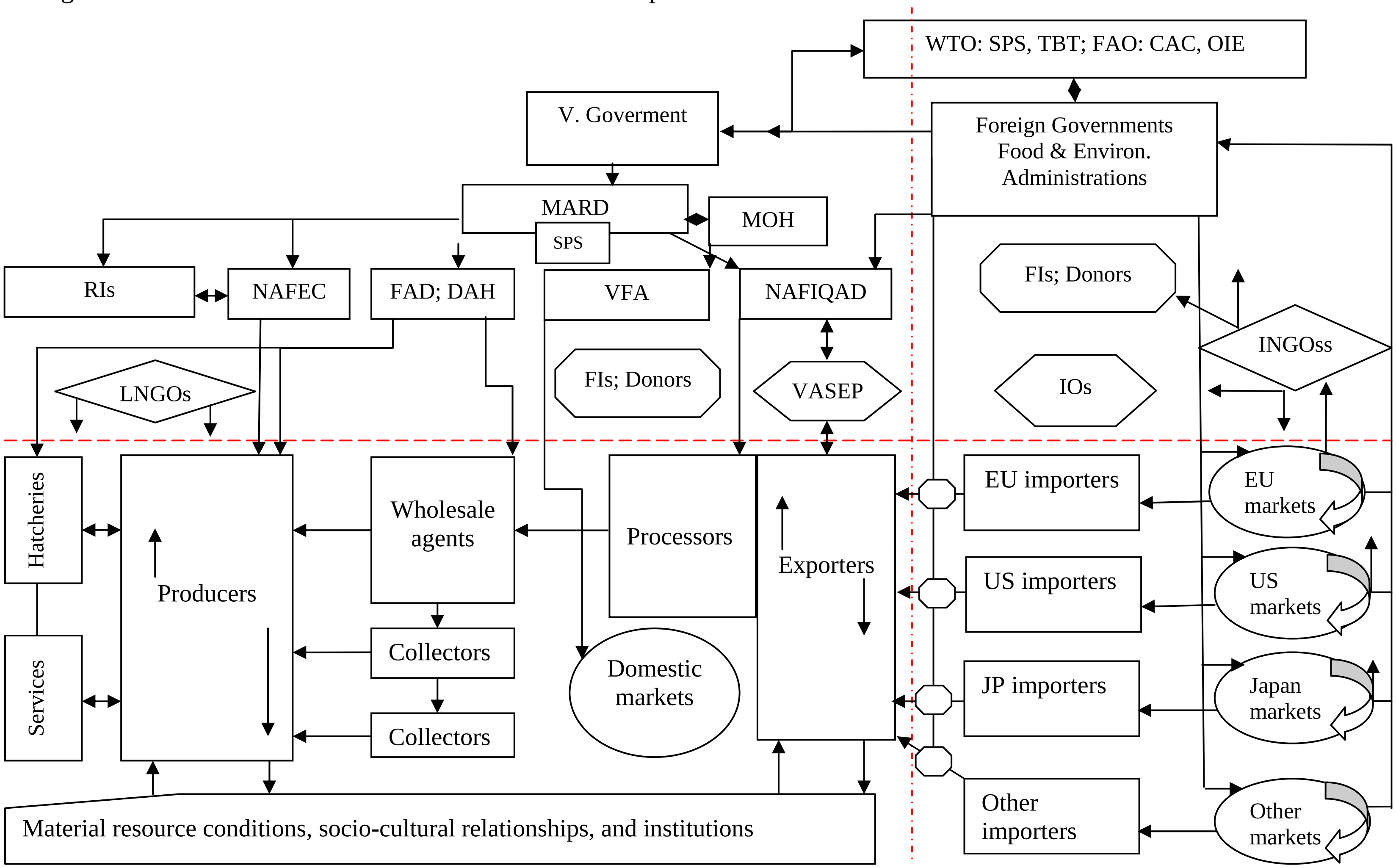


Figure 2: Governance of Global Value Chains for Shrimp in Vietnam



CHAPTER 2: FOOD SAFETY STANDARDS AND DEVELOPED COUNTRY SEAFOOD IMPORTS: FITTING THE GRAVITY EQUATION WITH ZERO-ACCOUNTING MODELS

Introduction

The impact of food safety standards on bilateral trade is commonly evaluated using the gravity econometric model. This model is popular in bilateral trade analysis because it is supported by both empirically successful studies as well as strong theoretical foundations based on the constant elasticity of substitution (CES) system (Anderson 1979), the monopolistic competition model (Bergstrand 1985 1989), the classical Heckscher-Ohlin model (Deardorff 1998), and recently the general equilibrium model (Anderson and van Wincoop 2003; Feenstra 2004).

The gravity model is traditionally estimated by the ordinary least squares (OLS) method in the form of the log-linear transformation (Burger, van Oort, and Linders 2009). This OLS specification of the gravity equation recently has been criticized since it truncates all zero trade values, resulting in biased estimates because dropped zero trade observations are rarely identically and randomly distributed. In addition, Silva and Tenreyro (2006) argue that the log-linear transformation of the gravity model can bias estimated results in the presence of heteroskedasticity because Jensen's inequality implies that $E(\ln y) \neq \ln E(y)$.

Recent applied economic research has explored alternative specifications to address the problems encountered by the conventional OLS estimation of the gravity model. Arbitrarily adding a small positive number to all trade flows is traditionally the most common approach to make the logarithmic transformation of zero trade observations be definable (Burger, van Oort, and Linders 2009). This approach is problematic since it does not rely on any theoretical and empirical justification (Linders and de Groot 2006). The second alternative for addressing the zero trade issue is to use a sample selection model, such as the Heckman model. Martin and Pham (2008) note that the Heckman maximum likelihood model performs well if one can find true excluded variables. However, Liu (2009) argues that since the Heckman gravity model adopts the log-linear specification as the conventional OLS estimation, it is still subject to heteroskedasticity due to the Jensen's inequality problem raised by Silva and Tenreyro (2006).

The third alternative approach treats bilateral trade data like count data and relies on the Poisson family regressions for estimating the gravity equation multiplicatively without taking the log linear transformation. For example, in a recent paper, Silva and Tenreyro (2006) propose to use the Poisson pseudo maximum likelihood (PPML) estimation. Burger, van Oort, and Linders (2009) further extend Silva and Tenreyro's PPML estimation by considering the negative binomial, zero-inflated Poisson, and zero-inflated negative binomial models. The Poisson regressions can solve the zero-omitted problem faced by the conventional log-normal OLS specification of the gravity equation and are robust to heteroskedasticity (Silva and Tenreyro 2006). However, according to Burger, van Oort, and Linders (2009) the standard Poisson model is sensitive to problems of overdispersion and excess zero trade flows. To date the choice and accuracy of alternative econometric specifications for accounting zero trade flows in bilateral trade analysis are mixed and there is not a commonly accepted solution (Burger, van Oort, and Linders 2009).

In this paper I use zero-accounting gravity models to evaluate the impact of food safety (chemical) standards on developed country seafood imports. The chemical standards on imported seafood established by developed countries on which I focus include chloramphenicol (minimum) required performance limit (CAP), oxytetracycline maximum residue limit ($oxytetracycline$), (fluoro)-quinolones maximum residue limit ($quinolones$), and DDT[1] pesticide residue limit (DDT). The study focuses on the three most important seafood markets namely the European Union's 15 members, Japan, and North America (including Canada and the U.S.). I support the view that standards act as barriers to international trade and hypothesize that increasing stringency (reducing required performance limit or maximum residue limits) of chemical standard regulations in developed countries has negative impacts on their bilateral seafood imports.

With improvements in analytical technologies and scientific understanding on food safety hazards, developed countries are able to impose more stringent food safety standards. The stringent transformation of food safety regulations has pushed agri-food exporting countries in general and developing countries in particular to face the dilemma of losing important export markets or improving food safety monitoring and management systems to make sure that their export products meet market requirements (Donovan, Caswell, and Salay 2001; Jaffee and Henson 2004).

Since the early 2000s, chemical standards including veterinary drug and other chemical residues have become the most serious challenges in the international seafood trade (Ababouch, Gandini, and Ryder 2005). This was made possible because of improvements in available

[1] Dichlorodiphenyltrichloroethane, this is one of the most well-known synthetic pesticides

analytical technologies and increasing awareness and concern of consumers and regulators on food safety and quality in developed countries. The paper makes a contribution to the ongoing discussion on whether food safety standards (non-tariff measures) act as catalysts or barriers to trade. The hypothesis of standards as barriers is tested via the conventional OLS gravity as well as the alternative zero-accounting specification of the gravity model. In addition, the paper brings in further discussions on applications of alternative gravity model specifications to address problems encountered by the conventional gravity model specification such as zero trade flows and heteroskedasticity.

The paper is organized as follows: after this introduction, the second section provides a review of the theoretically-based gravity model suggested by Anderson and van Wincoop (2003) and common zero-accounting alternative specifications of the gravity equation. The third section specifies empirical estimation models and data sources. Estimated results and conclusions are presented in the fourth and fifth conclusions.

Conventional OLS and Zero-Accounting Models of the Gravity Equation

Anderson and van Wincoop's gravity model:

Tinbergen (1962) was the first to apply the Newtonian law of universal gravitation in physics to generate the gravity econometric model for studying bilateral trade flows. This model links bilateral trade flows between countries i and j to their GDPs, bilateral distance, and other factors affecting trade barriers (Anderson and van Wincoop 2003). In its simplest form, the stochastic gravity econometric model states (Silva and Tenreyro 2006) that:

$$T_{ijt} = \mathrm{K}_0 \frac{M_{it}^{\beta 1} M_{jt}^{\beta 2}}{D_{ij}^{\beta 3}} \varepsilon_{ijt} \qquad (1)$$

where T_{ijt} is bilateral trade flow between countries i and j in period t, M_{it} and M_{jt} are the GDPs of country i and country j in period t, respectively; D_{ij} is the bilateral distance between country i and j; K_0 *is* a unknown constant; β_1, β_2, and β_3 are unknown parameters; and ε_{ijt} is a random error term . From this basic equation, other characteristics affecting bilateral trade such as common language, common border, colonial tie, regional trade agreements, tariffs, and food safety standards can be included as control variables. Equation (1) is traditionally converted into the linear form by taking logarithms of both sides and estimated by the ordinary least square (OLS) method:

$$lnT_{ijt} = \alpha_0 + \beta_1 lnM_{it} + \beta_2 lnM_{jt} - \beta_3 lnD_{ij} + \epsilon_{ijt} \quad (2)$$

$$where\ \alpha_0 = lnK_0\ and\ \epsilon_{ijt} = ln\varepsilon_{ijt}$$

The gravity equations (1) and (2) are not based on formal economic theory. However, since 1979 theoretical foundations of the gravity model have been developed by economists such as Anderson (1979), Bergstrand (1985), and Deardorff (1998). Recently, Anderson and van Wincoop (2003) argue that previous specifications of the gravity equations ignored *multilateral resistance terms* (MRTs) which can result in biasing estimated results. Based on the constant elasticity of substitution (CES) expenditure system, Anderson and van Wincoop (2003) suggest that unitary income elasticity with the theoretically grounded gravity model[2] be estimated as:

$$ln\frac{T_{ijt}}{M_{it}M_{jt}} = \alpha_0 - \beta_3 lnD_{ij} + lnP_i^{1-\sigma} + lnP_j^{1-\sigma} + \epsilon_{ijt} \quad (3)$$

$$P_i^{1-\sigma} = \sum_j P_j^{\sigma-1}\theta_j \exp(-\beta_3 lnD_{ij})$$

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[2] Equation (3) can be written in the level form as: $T_{ijt} = \mathrm{K}_0 \frac{M_{it}^{\beta 1} M_{jt}^{\beta 2}}{D_{ij}^{\beta 3}} P_i^{1-\sigma} P_j^{1-\sigma} \epsilon_{ijt}$

$$P_j^{1-\sigma} = \sum_i P_i^{\sigma-1}\theta_i \exp(-\beta_3 lnD_{ij})$$

where $P_i^{1-\sigma}$ and $P_j^{1-\sigma}$ are multilateral resistance terms (*MRTs)*; $\theta_{i(j)}$ is the nominal income share of countries i (j) in world nominal income; and σ is the elasticity of substitution between all goods.

The gravity equation (3) can be estimated by nonlinear or linear OLS with fixed effects suggested by Anderson and van Wincoop (2003). The relevance of including GDPs in the gravity equation has been questioned because it is not relevant to the micro-founded gravity model (Feenstra 2004; Disdier and Marette 2010). Hence, a common trend of recent bilateral trade studies applying the gravity regression is to exclude GDPs and estimate the gravity model (3) by the OLS method with time and country fixed effects (e.g., Burger, van Oort, and Linders 2009; Disdier and Marette 2010):

$$lnT_{ijt} = \alpha_0 + \alpha_t + \alpha_i + \alpha_j - \beta_3 lnD_{ij} + \epsilon_{ijt} \qquad (4)$$

where $\alpha_t,\ \alpha_i,\ and\ \alpha_j$ are time fixed effects and fixed effects representing *MRTs* of trading partner i and j's, respectively.

Silva and Tenreyro (2006) criticize that the OLS estimation of the log linear gravity equation (2) - (4) faces two important econometric problems: (i) the homoskedastic assumption of random errors may not hold because of Jensen's inequality and (2) the log linear transformation of zero trade observations is infeasible. As a matter of fact, there are often a large number of zero trade observations present in bilateral trade data. Researchers either have to drop zero trade observations or systematically add a small positive number to all trade observations for the log linear transformation being defined. Since zero trade flows are rarely randomly distributed, truncating these observations can lead to biased results. Similarly adding a small positive value to trade flows has no theoretical justification and can distort estimated results (Flowerdrew and Aitkin 1982). Because of these problems, the conventional OLS regression of the gravity equation will not yield consistent parameter estimates.

The Heckman specification:

The Heckman solution to the gravity econometric model retains the log linear transformation of the model and treats zero trade values as censored observations. The sample gravity model now contains both censored and uncensored observations, and is presented in a two equation context, including the selection equation (5) and the outcome equation (6):

$$Y_{ijt}^{*} = \alpha_0 + \alpha_t + \alpha_i + \alpha_j - \delta_3 lnD_{ij} + u_{ijt} \qquad (5)$$

$$lnT_{ijt}^{*} = \alpha_0 + \alpha_t + \alpha_i + \alpha_j - \beta_3 lnD_{ij} \epsilon_{ijt} \qquad (6)$$

where Y_{ijt}^{*} defines a latent variable deciding whether or not bilateral trade between two countries i and j in the sample is observed and lnT_{ijt}^{*} determines the logarithm of the volume of bilateral trade; u_{ij} is the error term associated with the selection process. We do not observe Y_{ijt}^{*} in the selection equation and the logarithm of the volume of trade lnT_{ijt}^{*} in the outcome equation. Instead we observe: $Y_{ijt} = 1 \; if \; Y_{ijt}^{*} > 0$; $Y_{ijt} = 0 \; if \; Y_{ijt}^{*} \leq 0$; and $lnT_{ijt} = lnT_{ijt}^{*} \; if \; Y_{ijt}^{*} > 0$ and lnT_{ijt} is not observed $if \; Y_{ijt}^{*} \leq 0$.

The Heckman model requires that error terms u_{ijt} in equation (5) and ϵ_{ijt} in the equation (6) follow a bivariate normal distribution with zero means, standard deviation σ_u and σ_ε and correlation ρ (Hoffmann and Kassouf 2005):

$$\begin{bmatrix} u_{ijt} \\ \epsilon_{ijt} \end{bmatrix} \sim N \left\{ \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho\sigma_u\sigma_\epsilon \\ \rho\sigma_\epsilon\sigma_u & \sigma_\epsilon^2 \end{bmatrix} \right\}$$

The model can be estimated by the two-step procedure suggested by Heckman (1979) or the one step maximum likelihood estimation. The one step approach estimates the selection and outcome equation simultaneously. Whereas, the two-step procedure first estimates the bivariate selection equation using a probit model and generates the inverse of the Mills ratio:

$$\lambda(\alpha_u) = \frac{\phi(\frac{\alpha_0 + \alpha_t + \ \alpha_i + \alpha_j - \delta_3 lnD_{ij}}{\sigma_u})}{\Phi\left(\frac{\alpha_0 + \alpha_t + \ \alpha_i + \alpha_j - \delta_3 lnD_{ij}}{\sigma_u}\right)}$$

where ϕ and Φ are the standard normal density function and the cumulative distribution function, respectively. The variable $\lambda(\alpha_u)$ is then included as an additional regressor, allowing the parameters β of the outcome equation to be consistently estimated by the OLS method.

The advantage of the Heckman model is that it can deal effectively with the zero trade observations and also allows researchers to distinguish the impact of bilateral barriers on the extensive as well as the intensive margins of trade (Cipollina, Laborde, and Salvatici 2010). An extensive review of the literature on the Heckman model carried out by Puhani (2000) shown that the one step maximum estimation empirically gives better results than the two-step Heckman estimator. Based on Monte Carlo simulations, Martin and Pham (2008) also show that the one step maximum likelihood estimation performs well if one can find true restricted variables. However with large datasets, the full maximum likelihood approach is computationally burdensome and in that case the Heckman two step estimation might be considered as the best procedure (Wooldridge 2002; Helpman, Melitz, and Rubinstein 2008). A small number of bilateral trade studies using both the two Heckman estimation approaches have been carried out by economic researchers recently (e.g., Linders and de Groot 2006; Helpman, Melitz, and Rubinstein 2008; Disdier and Marette 2010; Jayasinghe, Beghin, and Moschini 2010).

The Heckman estimation approach faces two essential problems. First, model identification is a critical issue. Since the selection function is nonlinear, the model is technically identified. However Cameron and Trivedi (2010) state that if the nonlinearity implied by the probit selection model is slight, then the identification is fragile and researchers need to look for exclusion restrictions. An excluded variable is the one that influences the selection process but does not affect the outcome equation. Second, the Heckman selection estimation does not address Jensen's inequality problem raised by Silva and Tenreyro (2006) and is apparently sensitive to the homoscedasticity and normality assumptions of error terms. If these assumptions fail to hold, estimated results of the gravity model using the Heckman procedure are biased and inconsistent. Monte Carlo simulations with a number of estimators conducted by Martin and Pham (2008) show that heteroskedasticity is an important source of bias. Under such a situation, Poisson family regressions are competitive approaches to the Heckman selection model since these models can also deal with zero trade issues efficiently and are less susceptible to the heteroskedasticity problem.

Poisson family regressions:

The application of Poisson family regressions to bilateral trade analysis is pioneered by Silva and Tenreyro (2006). In the prevalence of zero bilateral trade flows and heteroskedastic error terms resulting from Jensen's inequality, Silva and Tenreyro (2006) argue that the gravity model should be estimated multiplicatively using the Poisson Peudo Maximum Likelihood (PPML) estimation. Following Burger, van Oort & Linders (2009), I assume that $T_{ijt,}$ the bilateral trade flow between countries i and j in period t, has a Poisson distribution with a conditional mean μ which is a fuction of a matrix of bilateral and multilateral trade barriers, and the probability mass function

$$Pr\left[T_{ijt}\right] = \frac{\exp(-\mu)\mu^{T_{ijt}}}{T_{ijt}!}, (T_{ijt} = 0, 1, 2, \dots) \qquad (7)$$

where

$$\mu = \exp\left(\alpha_0 + \alpha_t + \alpha_i + \alpha_j - \beta_3 lnD_{ij}\right). \qquad (8)$$

The Poisson model requires the equidispersion property, meaning that the conditional variance must be equal to the conditional mean (Cameron and Trivedi 2010). However, this equidispersion property is commonly violated because the dependent variable of bilateral trade flows is often overdispersed, implying that the conditional variance exceeds the conditional mean. The presence of overdispersion might result in inefficient estimation of the Poisson model. A negative binomial (NB) model is frequently employed to correct for overdispersion (Burger, van Oort, and Linders 2009). The probability mass function of the negative binomial distribution (NB) is defined as

$$Pr\left[T_{ijt}\right] = \frac{\Gamma(\alpha^{-1}+T_{ijt})}{T_{ijt}!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\mu+\alpha^{-1}}\right)^{T_{ijt}} \qquad (9)$$

where Γ is the gamma function and α is the variance parameter of the gamma distribution. A likelihood ratio test of α can be used to test whether the negative binomial distribution is preferred over the Poisson distribution. According to Cameron and Trivedi (2010), the NB model is more general than the Poisson because it allows overdispersion and will reduce to the Poisson model as $\alpha \rightarrow 0$.

The PPML and NB models can both handle zero trade flows. However these models are no longer suitable when the number of observed zero values exceeds the number of zeros predicted by the estimated model (Burger, van Oort & Linders 2009). Under such a situation, extensions of the PPML and NB models, Zero Inflated Poisson (ZIP) and Zero Inflated Negative Binomial (ZINB) models can be used to overcome the encountered problems. The zero inflated Poisson regression consists of two parts. The first part contains a logit (probit) equation modeling the probability of zero bilateral trade flows (no trade at all). The second part takes bilateral trade flows including zero trade values as count data and estimates a Poisson model. The probability mass functions of the first part and second part of the zero inflated Poisson model are as equation (9) and (10), respectively:

$$Pr\left[T_{ijt}\right] = \psi_{ij} + \left(1 - \psi_{ij}\right)\exp(-\mu) \;\; \text{if } T_{ijt} = 0 \qquad (10)$$

and

$$Pr\left[T_{ijt}\right] = \left(1 - \psi_{ij}\right)\frac{\exp\left(-\mu\right)\mu^{T_{ijt}}}{T_{ijt!}} \quad if\ T_{ijt} > 0 \qquad (11)$$

where ψ_{ij} is the proportion of zero trade observations in the study sample ($0 \leq \psi_{ij} \leq 1$). It appears from equation (9) and (10) that, when $\psi_{ij}\ is$ 0 the ZIP model reduces to the Poisson model. In the presence of both overdispersion and zero inflated problems in the study sample, a zero-inflated negative binomial (ZINB) model can be defined in a similar fashion to the ZIP model:

$$Pr\left[T_{ijt}\right] = \psi_{ij} + \left(1 - \psi_{ij}\right)\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}} \qquad if\ T_{ijt} = 0 \qquad (12)$$

and

$$Pr\left[T_{ijt}\right] = \left(1 - \psi_{ij}\right)\frac{\Gamma(\alpha^{-1}+T_{ij})}{T_{ijt}!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\mu+\alpha^{-1}}\right)^{T_{ijt}} \quad if\ T_{ijt} > 0\ . \quad (13)$$

Similar to the Heckman selection model, the ZIP and ZINB models allow researchers to examine the impact of trade barriers on both the intensive (the probability of trade being observed) and extensive (the volume of trade being observed) margins of bilateral trade. In addition, the ZIP and ZINB models are robust and less sensitive to the heteroskedasticity and normality assumptions of the error terms. These models might be more appropriate to model bilateral trade flows with excess zero trade observations. However the choice of the econometric model specification should be based on standard statistical tests because "having many zeros in the dataset does not automatically mean that a zero inflated model is necessary" (Cameron and Trivedi 2010 p.605).

According to Burger, van Oort and Linders (2009), the likelihood ratio test of overdispersion can be used to test whether the PPML model is favored over the NB model. Similarly the Vuong statistic (Vuong 1989) can be employed to discriminate between the ZIP/ZINB model and its counterparts. The Vuong statistic follows a standard normal distribution with large positive values favoring the ZIP/ZINB model and large negative values favoring the PPML/NB model (Cameron and Trivedi 2010). For the choice of the model specification, researchers might apply additional goodness of fit statistics to evaluate the performance of different alternative models. For example, in addition to formal statistical tests, Burger, van Oort, and Linders (2009) also compare between the predicted value and observed value of the dependent variable to examine how well competing models perform. Unfortunately in their study they found that different goodness of fit statistics do not lead to the same conclusion.

Empirical Model Specification and Data Sources

In order to test the hypothesis that chemical standards act as barriers to international seafood trade, I first estimate the OLS gravity model suggested by Anderson and van Wincoop

(2003) and the Heckman model in the log linear form of the dependent variable, bilateral trade. I then estimate the gravity model in the level form using the Poisson family regressions: the PPML, NB, ZIP, and ZINB models.

The OLS gravity model specification is as follows:

$$lnT_{ijt} = \alpha_0 + \alpha_t + \alpha_i + \alpha_j + \beta_1 lndist_{ij} + \beta_2 CAP_{jt} + \beta_3 oxytetracycline_{jt} + \beta_4 quinolone_{jt} + \beta_5 DDT_{jt} + \beta_6 contig_{ij} + \beta_7 colony_{ij} + \beta_8 comlang_{ij} + \beta_9 eu15_{ij} + \beta_{10} nafta_{ij} + \varepsilon_{ijt} \qquad (14)$$

where T_{ijt} is bilateral seafood imports of Canada, the EU15 members, Japan , and the United States in period t; $dist_{ij}$ stands for the bilateral distance between countries i and j; $\alpha_t, \alpha_i, and\ \alpha_j$ are time and country fixed effects.

Four variables represent chemical food safety standards of interest: CAP_{jt} is cloramphenicol minimum required performance limit in part per billion (ppb) imposed by importing country j in period t; and $oxytetracycline_{jt}, quinolone_{jt},\ and\ DDT_{jt}$ are respectively maximum residue limits (MRLs) of oxytetracycline, quinolones (fluoro), and DDT pesticide in part per billion (ppb) in seafood regulated by importing country j in period t. Remaining variables are dummies taking binary values: $contig_{ij}$, $colony_{ij}$, and $comlang_{ij}$ respectively equal to 1 if two trading partners share a common border, having colonial tie, and having common official language, and equal to 0 otherwise; $eu15_{ij}$ and $nafta_{ij}$ are regional trade agreement dummies, respectively equal to 1 if both two trading countries i and j are in the European Union 15 members or belong to North American Free Trade Agreement, and equal to 0, otherwise.

The selection equation in the Heckman selection model contains all variables included in the OLS gravity model (14), while in the outcome equation the common language variable is excluded for robustness of model identification. The choice of common language as the excluded variable in the Heckman model is adopted from Martin and Pham (2008), and Disdier and Marette (2010). Disdier and Marette (2010) explain that trade of seafood products seems less influenced by cultural links as common language because these products are usually homogeneous goods. With regards to Poisson family regressions, all left hand side variables in the OLS gravity model (14) are also included in the PPML, NB models as well as the ZIP and ZINB models. The likelihood ratio test of overdispersion is deployed to discriminate the PPML and NB models, whereas the Vuong statistic is used to test whether the ZIP/ZINB model is favored over its counterpart.

Data for the empirical model estimation are drawn from various sources. Bilateral seafood import data come from the UNCOMTRADE database (the Harmonized System 1996, product code 03). Control variables using in the empirical modeling, such as distance, geographical continuity (common border), colonial relationship, and common language are extracted from CEPII'S distance database (CEPII, 2009). Dummy variables representing regional trade agreements, $eu15$ and $nafta$ are created based on information taken from online data. Our four main variables of interest representing chemical food safety standards, cloramphenicol standard CAP comes from Disdier and Marette (2010), Debaere (2005). Oxytetracycline standards are from Chen, Wang, and Findlay (2008). Quinolones (fluoro) standards are collected online from several sources such as Seafood Network Information Center (website: http://seafood.ucdavis.edu/), Bacler (2008), and Hue et al. (2006). DDT pesticide standards are from a technical report compiled by Southeast Asian Fisheries Development Centre (SEAFDEC) in 2008. Information on interested chemical standards are also cross-checked with legal documents promulgated by competent authorities in importing countries (e.g., the European Commission Decision 2002/657, the violation records posted on websites of food safety inspection authorities).

Estimated Results and Discussions

Table 1 shows the empirical results of the OLS and Heckman maximum likelihood models estimated in the log linear specification form. All zero observations have been omitted in the OLS model whereas all zero values are retained in the Heckman model. Fixed effects representing time period, reporters (importers) and partners (exporters) are included in both models. To control for heteroskedasticity and possible correlations of the same country pair across years, I use the country pair clustering option with White's standard error method (1980). The double log linear OLS model means that the coefficients can be directly interpreted as the marginal change in the dependent variable induced by a change in independent variables, *ceteris paribus*. Whereas, the Heckman ML estimation is nonlinear, its coefficients are just linear indexes and cannot be directly interpreted as marginal changes in the dependent variable caused by a change in independent variables. Therefore, average marginal effects of the Heckman model are computed by the STATA 11.0 software and presented in Column 4, 5, and 6 of Table 1.

The choice of average marginal effects is preferred over marginal effects at means of the independent variables because the Heckman model is the nonlinear regression method with marginal effects change from individual to individual observations. Average marginal effects are computed by averaging marginal effects of individual data values, whereas marginal effects at the means only computes effect of one data point of independent variables (Cameron and Trivedi

2010). The conditional marginal effect not the coefficient of the Heckman model is compatible with the coefficient of the OLS model (Hoffman and Kassouf 2005).

As shown in column 1 and column 4, results of the OLS and Heckman models are similar with regards to significance level, magnitude and sign of considered independent variables. These results might come from the fact that selection bias is statistically significant however not a serious problem because of ρ coefficient is small (0.087). For example, the coefficient of the bilateral distance in both the OLS and Heckman model is as commonly found in the gravity estimation literature. One percent increase in the bilateral distance results in a decrease of 1.32 percent in bilateral seafood imports as predicted by the OLS and of 1.28 percent as predicted by the Heckman model.

In both the OLS and Heckman models, four variables representing chemical food safety standards ($CAP, oxytetracycline, quinolones$ and DDT)[3] are positive and statistically significant which is the hypothesized sign. Stricter chemical standard regulations (lowering analytical limit or maximum residue limits in traded products) in developed countries have negative impacts on their seafood imports. With regards to the intensive margin (volume) of trade, conditioned on positive trade being observed, one unit reduction in cloramphenicol analytical limit (1 ppb) reduces bilateral seafood import 0.86 percent[4] predicted by the OLS model and 0.84 percent predicted by the Heckman model respectively.

Among the three chemicals with an established Maximum Residue Limits (MRL), the oxytetracycline standard has less severe negative impact on seafood import compared to that of quinolones and DDT pesticide. If oxytetracycline MRL drops 0.01 ppm (10 ppb), seafood

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[3] For simplicity from now I drop all subscripts of the study variables

[4] Semi-elasticity is computed by using the formula suggested by Hoffman and Kassouf (2005): percentage change in the dependent variable in the log form by one unit change in an independent variable is $[\exp(\beta) - 1] * 100)$

imports in the EU15, Japan and North America would decrease 1.3 percent as predicted by both the OLS and Heckman model. Whereas, dropping quinolones residue limit by 1 ppb would result in a decrease of 9 percent in bilateral seafood import in Canada, European 15 members, Japan, and the United States. DDT pesticide regulation also has a significant influence on reducing bilateral seafood import. Decreasing DDT maximum limit in seafood 0.01 ppm (10 ppb) would reduce 2.9 percent of bilateral seafood import.

Dummy variables representing common border ($contig$), colonial tie ($colony$) and European Union 15 membership are statistically significant and have the expected sign in both the OLS and Heckman model. Bilateral seafood imports between country pairs sharing a common border are predicted to be 110.11 % (the Heckman model) and 134.44 % (the OLS model) higher than those between other country pairs. Countries having historical colonial ties also bilaterally trade more than other country pairs, between 183.42 % (the Heckman model) and 210.16% (the OLS model) higher. Similarly European Union 15 members import a lot of seafood from each other (ranging from 327.33 % in the Heckman model to 359.49 % higher as predicted by the OLS model). In contrast, NAFTA membership does not help strengthen the bilateral seafood trade among its members. This is in line with findings in the trade literature that seafood trade among NAFTA shows a decreasing trend compared to that between a NAFTA member and other countries.

In addition to the conditional marginal effect, the Heckman model also provides information on the unconditional marginal effect (another dimension of the intensive margin of trade) and the marginal effect on the probability for bilateral trade being taking place (the extensive margin of trade). In this paper, unconditional marginal effects are computed by the STATA software under the assumption that the dependent variable (log of bilateral seafood import) is equal to zero when it is not observed. As reported in Column 5 of Table 1, unconditional marginal effects are smaller than their counterpart conditional marginal effects. For instance, the magnitude of the average marginal effect of CAP on the dependent variable (log of bilateral import) changes from 0.008 (conditional) to 0.005 (unconditional). As Hoffmann and Kassouf (2005) suggest, the unconditional marginal effect equals to the conditional marginal effect plus the effect associated to a change in the probability of being selected (e.g., into bilateral trade). It could be that marginal effects on small bilateral trade values (e.g., zero and small positive observations) are small, resulting in smaller values of unconditional marginal effects.

With regards to the extensive margin, chemical food safety standards under examination only have negligible impacts on the probability of bilateral imports. As reported in Column 6 of Table 1, coefficients of CAP and $oxytetracycline$ are not statistically significant, whereas coefficients of $quinolones$ and DDT are significant but with small magnitude. Reducing $quinolones$ one unit (1 ppb) would bring a reduction of 0.003 or 0.3 percent point to the probability of positive trade being observed. The bilateral distance variable has a negative relationship with the probability of positive trade being observed. One percent increase in the bilateral distance results in a drop of 0.121 percent points of the probability of bilateral import. Compared to other pairs, countries having a colonial relationship have a higher probability (an additional 0.051) to conduct bilateral seafood imports. The common language variable also has a similar effect on increasing the probability of trade (with an additional amount of 0.065). Surprisingly, the dummy variable representing NAFTA membership does not affect the intensive margins of trade but has a large effect on the extensive margin. This incidental finding might result from the unusual pattern of bilateral seafood trade between NAFTA member countries.

Results of the Poisson family regressions are reported in Table 2. Estimates of the PPML and NB models are shown in Column 1 and 2, respectively. The ZIP and ZINB models' coefficients of equations of the ZIP and ZINB models are included in Column 3 to Column 6 of Table 2. The ZIP and ZINB model each consist of two equations. The logit equation models the probability of the zero- trade group, and the Poisson or Negative Binomial equation predicts the probability of bilateral trade (including zero trade observations as an additional count) as count data. Since the dependent variable in Poisson family equations is linked to the exponential conditional mean, the coefficients can be interpreted as semi-elasticity (Cameron and Trivedi 2010)[5].

As shown in Table 2 with the exception of the NB model, the parameter estimate of the bilateral distance tends to be lower in the Poisson family regressions compared to those from the OLS and Heckman model. For example, one percent increase in the bilateral distance would be associated with a decrease of 0.67%, 0.65%, and 0.36% of bilateral seafood imports as respectively predicted by the PPML, ZIP, and ZINB models. The direction and magnitude of coefficients of variables representing chemical food safety standards ($CAP, oxytetracycline, quinolones, and\ DDT$) remain similar to those found in the OLS and Heckman equations. Quinolone standards continue to have strongest negative impact on bilateral imports. Decreasing 1ppb in Quinolone standards (increasing the stringency of regulation) results in a reduction of 6.7%, 11.5 %, and 7.2% of imports, predicted by the PPML, NB, and ZINB models respectively.

The impact of $NAFTA$ and common language variables on seafood imports predicted by the Poisson family regressions do not show a consistent direction. The parameter estimate of the

[5] Percentage change in the dependent variable in the log form by one unit change in an independent variable is $[\exp(\beta) - 1] * 100$). This formula is correct for independent variables in level form either continuous or dummy variables. For a continuous variable, semi-elasticity is approximately equal to ($\beta * 100$).

NAFTA variable changes from negatively and statistically significant in the PPML and ZIP models to positively and statistically significant in the ZINB model. The sign of dummy variables representing common border ($contig$), colonial tie ($colony$), and bilateral pairs of European Union 15 membership ($eu15$) in all Poisson family regressions appear as expected. However the magnitude of coefficient estimates of these variables is generally larger than those predicted by the OLS and Heckman models. For instance, bilateral seafood imports between countries sharing common border increases from 86.26%, 191.54%, 195.65%, and up to 1,219.71% as predicted by the PPML, NB, ZIP, and ZINB models. Similarly, the increase in imports between countries both in European Union 15 members ranges from 197.73% to 689.32%, 702.85%, and 1,011.17% as predicted by the ZINB, ZIP, PPML, and NB models.

Similar to the Heckman selection model, the ZIP and ZINB models also provide an explanation to zero trade values. However the difference between the two approaches is that the Heckman selection equation reports factors affecting the probability of positive trade being observed. In contrast, the logit equation in the ZIP and ZINB models show factors affecting the probability of having zero trade values. Consequently, the sign of independent variables reported in the two probability predicting equations are opposite to each other if the estimation is consistent. As reported in Column 3 and Column 5 of Table 2, distance has a positive effect on the probability of zero bilateral trade. Increasing bilateral distance associated with increasing the likelihood of zero trade being presented. Chemical standards (e.g., $quinolones$) have negative effects, meaning that stricter food safety regulations (decreasing standards) would increase the probability of having zero trade values. This prediction is consistent with what I find in the Heckman model estimation presented in Table 1.

The Poisson family regressions became an alternative solution to modeling the gravity equation after Silva and Tenreyro's work (2006). The standard Poisson estimator (PPML) suggested by Silva and Tenreyro (2006) addressed the unobserved heteroskedasticity, however the PPML model might bias the parameter estimates in the presence of excess zero values and overdispersion problem. Modified Poisson regressions such as the NB, ZIP, and ZINB models can be considered as potential alternatives to overcome these problems. However the choice of specific Poisson model specification should be based on formal statistical test as well as economic implications of the parameter estimates.

As presented in Table 2, four standard statistical tests namely the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), the likelihood ratio test of overdispersion, and the Vuong statistic are computed for determining the best Poisson model choice. Unfortunately all four statistical tests do not point to the same conclusion. By the AIC as well as BIC criteria the NB model is favored over the other competing models presented in Table 2. The likelihood ratio test of overdispersion also indicates that the NB model is favored over the PPML model. However, the Vuong test suggests that the ZINB model is more appropriate than the NB, ZIP, and PPML models. This finding is similar to what Burger, van Oort and Linders (2009) found in their empirical estimation that the model selection basing on formal statistics are indecisive.

Model choice should be based on both statistical test and practical economic implications. It can be argued that neither Poisson model is the best choice for the current study sample data because each Poisson model overestimates at least one parameter. For example, the positive impact of the EU15 dummy variable on seafood import is overestimated by the PPML, NB, and ZIP model, while the coefficient estimate of the variable representing a common border (contig) is highly inflated by the ZINB estimation. There is no formal statistical test to compare the Heckman model and the Poisson family model. From empirical results of the Heckman model estimation presented in Table 1, it can be argued that the Heckman model is the best choice for the current study sample. The parameter estimates of the Heckman model in Table 1 are commonly found in the trade literature.

Similar to the ZIP and ZINB models, the Heckman model allows researchers to address selection bias as well as provide an explanation why positive/zero trade occurs. Several issues need to be considered to verify if the Heckman selection procedure is the best choice. First, the Heckman estimation also uses the log linear transformation of the dependent variable, the problem of potential heteroskedasticity implied by Jensen's inequality remains. According to Silva and Tenreyro (2006), Jensen's inequality applies to all econometric equations estimated in the log normal form. However it seems that the seriousness of unobserved heteroskedasticity caused by the log linearized transformation is subject to the sample data. If the presence of unobserved heteroskedasticity is serious, the results of parameter estimates can be biased and inconsistent. With the option of country pair – clustering and White's standard errors, the Heckman ML estimation can mitigate the potential bias and inconsistency caused by the homoskedasticity assumption failure.

The second issue of concern in the Heckman estimation is the assumption on the bivariate normality distribution of random errors in the selection and outcome equations. And finally, for robust model identification, the Heckman model requires a true excluded variable that statistically affects the selection equation but does not enter the outcome equation. Insignificance of the common language in the OLS model, combined with the empirical observation that fish products are generally homogeneous goods signals that this variable can be used as an excluded variable. Unfortunately this variable shows inconsistent behavior in the Poisson family regressions. Therefore it is not a decisive conclusion that the common language variable is a true exclusion. If one can verify the issues discussed above, then the Heckman model can provide reliable parameter estimates, and therefore can be an appropriate alternative to address issues faced by the conventional gravity model estimation.

Conclusions

The main objective of this paper is to test if food safety (chemical) standards act as barriers to international seafood trade. Our empirical estimation results confirm this hypothesis and are robust to the OLS as well as alternative zero-accounting gravity models such as the Heckman ML procedure and the Poisson family regressions. Increasing the stringency of regulations by reducing analytical limits or maximum residue limits in seafood in developed countries has negative impacts on their bilateral seafood imports. Quinolones standard shows strong negative impacts on seafood trade aggregated at two-digit level. Chloramphenicol standards (CAP) have less negative impact on seafood import aggregated at the two digit level (product code 03 in the HS 1996 system).

For the choice of the best model specification to account for zero trade and heteroskedastic issues, the paper shows that it is inconclusive to base on formal statistical tests. This finding is similar to Martin and Pham (2008) and Burger, van Oort, and Linders (2009)'s findings. However based on the magnitude of coefficients, its economic implication, and the literature finding, the Heckman ML estimation provides the most reliable parameter estimates. Since the correlation coefficient (ρ) between the selection equation and outcome equation is small, dropping zero trade values do not result in serious bias. Nevertheless the Heckman estimation is superior to the OLS method since it offers two other dimensions, the statistical inference to the full population (including trading and not trading pairs) and the extensive margin of trade (the probability for positive trade being observed).

While compliance with these stringent food safety standards is increasingly difficult for developing countries, it also opens opportunities for successful firms and exporting countries to sharpen their competitive advantage (Henson and Jaffee 2008). These dynamic impacts of food safety standards should be further investigated, using the alternative zero accounting specifications of the gravity model discussed above.

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Table 1: Empirical results of the OLS and Heckman maximum likelihood estimations

Variables	OLS model	Heckman MLE model		Average marginal effects of Heckman MLE		
				On volume of trade		On probability of being selected
	Ln(import) (1)	Ln(import) (2)	Selection (3)	Conditional (4)	Unconditional (5)	(6)
lndist	-1.323***	-1.359***	-0.779***	-1.282***	-1.083***	-0.121***
	(0.089)	(0.09)	(0.058)	(0.089)	(0.058)	(0.009)
CAP	0.009***	0.009***	0.002	0.008***	0.005***	0
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0)
oxytetracycline	0.001***	0.001***	0	0.001***	0.001***	0
	(0)	(0)	(0)	(0)	(0)	(0)
quinolones	0.086***	0.088***	0.018***	0.086***	0.050***	0.003***
	(0.004)	(0.004)	(0.002)	(0.004)	(0.003)	(0)
DDT	0.003***	0.003***	0.001***	0.003***	0.002***	0.000***
	(0)	(0)	(0)	(0)	(0)	(0)
contig	0.852***	0.778***	0.375	0.742***	0.614*	0.06
	(0.265)	(0.261)	(0.387)	(0.254)	(0.332)	(0.063)
colony	1.132***	1.072***	0.320***	1.042***	0.714***	0.051***
	(0.174)	(0.157)	(0.101)	(0.155)	(0.12)	(0.016)
eu15	1.525***	1.524***	0.789***	1.452***	1.312***	0.129***
	(0.322)	(0.32)	(0.259)	(0.314)	(0.306)	(0.044)
nafta	-0.68	-0.707	4.488***	-0.926	0.267	0.537***
	(0.573)	(0.614)	(0.35)	(0.617)	(0.599)	(0.012)
comlang	-0.16		0.407***			0.065***
	(0.153)		(0.076)			(0.013)
R-squared	0.675					
rho		0.087***				
N	13519	30960				
Censored N		17441				
Uncensored N		13519				
Log pseudolikelihood		-36671.8				
Wald chi2(245)						

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors.

Table 2: Results of Poisson Family Regressions

Variables	PPML model	NB model	ZIP model		ZINB model	
			logit	import	logit	import
lndist	-0.668***	-1.732***	1.412***	-0.645***	0.322***	-0.359***
	(0.095)	(0.099)	(0.054)	(0.000)	(0.022)	(0.028)
CAP	0.007***	0.010***	-0.004	0.007***	-0.001	0.009***
	(0.001)	(0.003)	(0.004)	(0.000)	(0.003)	(0.004)
tetracycline	0.001***	0.001***	0.000***	0.001***	0.000	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
quinolones	0.067***	0.115***	-0.032***	0.067***	-0.007**	0.072***
	(0.006)	(0.005)	(0.003)	(0.000)	(0.003)	(0.003)
DDT	0.002***	0.004***	-0.001***	0.002***	0.000***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
contig	1.070***	0.622**	-0.885***	1.084***	-3.402	2.580***
	(0.267)	(0.293)	(0.328)	(0.000)	(2.589)	(0.142)
colony	0.608***	1.020***	-0.599***	0.590***	-0.610***	1.306***
	(0.234)	(0.196)	(0.106)	(0.000)	(0.095)	(0.102)
eu15	2.083***	2.408***	-1.418***	2.066***	-25.306	1.091***
	(0.401)	(0.282)	(0.296)	(0.001)	(10771.040)	(0.081)
nafta	-0.763*	-1.061	-27.992	-0.696***	-23.480	1.050***
	(0.417)	(0.956)	(1823547.000)	(0.001)	(78357.300)	(0.450)
comlang	0.018	0.895***	-0.688***	-0.008***	-0.237***	-1.118***
	(0.202)	(0.157)	(0.081)	(0.000)	(0.067)	(0.075)
Fixed effects	yes	yes	yes	yes	Yes	Yes
Observations	30960	30960		30960		30960
Log pseudolikelihood	-135800000.0	-133206.7		-		-140620.9
AIC	823223.0	266909.4		253000000		281371.7
BIC	823231.3	268977.9		253000000		281913.9
Overdispersion (α)		7.2***				940000000.0***
Vuong statistic				65.28***		52.9***

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors

CHAPTER 3: STANDARD HARMONIZATION AS CHASING ZERO (TOLERANCE LIMITS): THE IMPACT OF VETERINARY (CLORAMPHENICOL ANALYTICAL) STANDARDS ON CRUSTACEAN IMPORTS IN THE EU, JAPAN, AND NORTH AMERICA

Introduction

Over the last two decades, there has been increased concern among consumers and regulators in industrialized countries over food safety, health risks, and scandals associated with food consumption (Henson and Caswell 1999; Otsuki, Wilson, and Sewadeh 2001). Following the promulgation of the Sanitary and Phytosanitary (SPS) Agreement of the World Trade Organization (WTO) in 1994, countries are allowed to establish stricter SPS measures than international standards, provided that the standard regulations are based on adequate risk assessment (Wilson 2003) and do not arbitrarily discriminate or restrict trade (Wilson and Otsuki 2003). However, in responding to the food safety crisis, industrialized countries (e.g., the European Union) might take the precautionary principle, which suggests that "regulatory action against risk is taken, even when science has not established direct cause and effect relationships" (Otsuki, Wilson, and Sewadeh 2001 p.496). Given the decline of traditional trade barriers such as tariffs and quotas resulting from WTO negotiations (Deardoff and Stern 1998; Maskus and Wilson 2001), the proliferation of SPS and food safety standards as nontariff measures (NTMs) poses major challenges and becomes hot issues in international agri-food trade.

On top of international community concern is the trade impact of SPS and food safety standards established by developed countries. Trade effects of SPS and food safety standards are dynamic, which can be impediments to, and sometimes facilitators of agri-food trade (Moenius 2006; Disdier, Fontagné, and Mimouni 2008; Jayasinghe, Beghin, and Moschini 2010). Henson and Jaffee (2008) recognize that food safety standards can act as barriers to trade and at the same time can also act as catalysts for upgrading agri-food supply chains and repositioning exporting countries in better competitive advantage in global markets. Trade impacts of SPS and food safety standards differ across sectors (Moenius 2006), among products and between countries (Disdier, Fontagné, and Mimouni 2008), subject to specific standards.

Given their weaker institutional, technical, and financial capabilities, there is a pre-established view that food safety standards impede agri-food exports of developing countries to markets in industrialized countries (Athukorala and Jayasuriya 2003; Henson and Jaffee 2008; Anders and Caswell 2009). However the dichotomous categorization of trading partners by their development status as well as the simple black and white argument between food safety "standards as barriers" and "standards as catalysts" cannot capture the complex impact of food safety on trade (Jaffee and Henson 2004; Anders and Caswell 2009). Close examination of complex impacts of particular standards on products, markets, and countries is required (Anders and Caswell 2009).

This paper investigates the impact of advancing cloramphenicol analytical standards (veterinary drug residue regulations) on crustacean imports in the EU15, Japan, and the North America. The paper extends Disdier and Marette (2010)'s work by examining the following questions: i) Are different crustacean products in trade affected differently? ii) What is the impact of standards on crustacean exporters with regard to scale of export? iii) What is the impact of food safety standards when separating exporting countries by development/income status? Do developing countries with lower financial, technical capabilities as well as lower welltrained human resources receive more negative effects because of increasing stringency of cloramphenicol analytical standards?

The current paper will make an important contribution to the literature on the impact of food safety standards on seafood trade in several ways. Though seafood trade plays an important role especially in developing countries (e.g., an important source of foreign currency earning and employment opportunities for rural people) and seafood trade regimes are rapidly tightening, there are only a few studies investigating the impact of food safety standards on seafood trade (Anders and Caswell 2009). Using the micro-founded gravity model, the paper will contribute to this literature by exploring the dynamic impacts of food safety standards on crustacean trade. Unlike Disdier and Marette's study (2010) I explore complex impacts of chloramphenicol standards on different crustacean products aggregated at 6 digit level, scale of exports, and top crustacean exporters in Asia.

It is important to note that cloramphenicol is banned in many developed and developing countries because it has carcinogenic potential in humans. Since an acceptable daily intake (ADI) has not been allocated, consequently no maximum residue limits (MRLs) have been established for cloramphenicol in the EU15, Japan and the North America. Instead cloramphenicol required performance limits (standards) are established based only on analytical technology improvements and have no cause and effect relationship with health risk and consumer welfare.

Veterinary (Cloramphenicol Analytical) Standards and Impacts on Seafood Trade

Regulation of veterinary drug residues in aquaculture originated food has become an important issue in the last two decades. Given the saturation of capture fisheries, increasing seafood trade depends on the increase of farmed production of fish. In intensive aquaculture systems, producers have a tendency to use veterinary drugs to treat fish diseases or environmental problems for reducing crop failures. However, inappropriate use of veterinary agents may result in drug residue contamination in seafood products, affecting the safety of the product and exposing consumers to health risks (GESAMP 1997). Consumers and regulators in developed countries have expressed concern over the use and misuse of veterinary drugs in agri-food production including aquaculture and its health implications (Wilson, Otsuki, and Majumdar 2003).

Cloramphenicol is a broad-spectrum antibiotic, which was historically used as a veterinary drug for farmed animal disease treatment purposes, and it is currently used in human treatment (WHO 2003). The Joint FAO/WHO Expert Committee and a number of other agencies (e.g., International Agency for Research on Cancer; European Committee for Veterinary Medicinal Products; United States Food and Drug Administration) have conducted a series of chloramphenicol assessments (WHO 2003). According to WHO (2003), concerns have been expressed about the potential genotoxicity, carcinogenic, and aplastic anemia impact of cloramphenicol in humans. However, an ADI has never been established and consequently a MRL has not been set for cloramphenicol because there is insufficient information on toxicity. Adopting the precautionary principle many developed countries including Canada, the EU, Japan and the U.S. banned the use of cloramphenicol in the treatment of food-producing animals for food safety reasons (GESAMP 1997). Since it is banned, countries often enforce the zero (tolerance) limit policy, implying that no detectable residue of chloramphenicol in food is acceptable (FAO 2004).

Though countries banning the cloramphenicol use in food-producing animal production adopt the zero tolerance policy, the policy is enforced differently, depending on their food safety cultures, available analytical technology, financial, and human resources. In the EU, in the early 1990s via Directive 86/469/ECC, EU members were required to implement a monitoring program with a required detection limit of 10 part per billion (ppb) for cloramphenicol residues in meat and fish products (Degroodt et al. 1992). With the enhanced methods of mass spectrometry (MS) and liquid chromatography-mass spectrometry (LC-MS), the EU detected cloramphenicol residues in food at 1.5 ppb in 2001 (Debaere 2005; Disdier and Marette 2010) and the detection limit continued to drop to 0.3 ppb after 2001, when the European Commission introduced the concept of Minimum Required Performance Limits (MRPLs) in Decision 2002/657/EC and Decision 2003/181/EC.

Following the EU, other major seafood importers including the U.S., Canada and, later, Japan have also applied the enhanced analytical methods to detect cloramphenicol residues in seafood at lower levels. The United States screened shrimp/crustaceans for cloramphenicol residues since 1990s (Weston 1996). The United States detected cloramphenicol residues in shrimp/crustaceans at a limit of 5 ppb until 2001 (Neuhaus, Hurlbut, and Hammack 2002) and the detection limit dropped to 1 ppb in 2002 and to 0.3 ppb since 2003 (Debaere 2005; Disdier and Marette 2010). By 2001, the official method used by Canada allowed detection of cloramphenicol residues at 2.5 ppb (Neuhaus, Hurlbut, and Hammack 2002). However, the detection limit was dropped to 0.3 ppb since 2002 when Canada adopted the EU approach (Debaere 2005; Disdier and Marette 2010). An agreement signed by Vietnamese and Canadian food safety inspection authorities in 2006 signaled that Canada’s cloramphenicol detection limit was lowered to 0.2 ppb since 2007.

In Japan, according to the Japanese Ministry of Health, Labor and Welfare, veterinary drug residues are regulated by Food Sanitation Law and Quarantine Law. The cloramphenicol detection limit in seafood in Japan was at 50 ppb in 2001 and this limit was unchanged until 2006 (Debaere 2005; Disdier and Marette 2010). However, the Japanese government revised the basic Food Safety Law and also amended the Food Sanitation Law in 2003 after a number of food-related scandals were discovered (Jonker, Ito, and Fujishima 2005). With the amendment of the Food Sanitation Law which went into enforcement in June 2006, Japan adopted a system featuring a "positive list" with MRLs established for specific residues (Jonker, Ito, and Fujishima 2005). Cloramphenicol appeared in "Table 1" of the amended Food Sanitation Law, listing agricultural chemicals and veterinary drugs that should not be detected in any food. Inspection records posted on the website of the Japanese Ministry of Health, Labor and Welfare suggest that since 2007, the detection limit of cloramphenicol in seafood in Japan was harmonized with the EU minimum required performance limit of 0.3 ppb.

The harmonization of cloramphenicol analytical methods at much stricter standards in the EU and other industrialized countries has profound impacts on international seafood trade, especially on seafood exports from developing countries. With advanced methods, during 2001 and 2002 the EU detected cloramphenicol and nitrofuran residues in imported shrimp from a number of Asian countries (e.g., China, India, Thailand, and Vietnam). The EU increased sampling of exports from violated countries for inspection, and in the worst case the EU suspended the import of Chinese shrimps into the EU in 2002 (Ababouch, Gandini, and Ryder 2005) until competent authorities in China took adequate responses and the results of further testing shown no contamination. Since Canada, Japan and the United States also imposed similar stringent testing methods, cloramphenicol contamination in imported seafood was discovered in Canada (2003, 2005), the U.S. (2004, 2006) and Japan in 2006 (Disdier and Marette 2010). Ababouch, Gandini, and Ryder (2005) show that since 2001, veterinary drug residues have become the most serious chemical risk for exported seafood consignments being rejected at border control of importing countries.

Debaere (2005) shows that the EU zero tolerance policy for cloramphenicol in shrimp has led to a disruption of shrimp trade flows from Europe toward the United States. Using the Heckman selection procedure to include zero trade flows in the gravity trade model, a recent study by Disdier and Marette (2010) also suggests that advancing cloramphenicol analytical standards has a negative impact on crustacean imports into the EU15, Japan and the North America during a period from 2001 to 2006. A controversial issue Disdier and Marette (2010) demonstrates in their work is that while a stricter cloramphenicol analytical standard has a negative impact on crustacean imports, it is welfare improving in both domestic (importers) and international consideration. In addition, Disdier and Marette (2010) treat the cloramphenicol analytical standards (e.g., MRPL established by the EU) as if they were MRLs.

Theoretical Framework and Model Specification

The paper relies on the theoretically-based gravity model developed by Anderson and van Wincoop (2003). The gravity model has been a workhorse for analyzing bilateral trade flows for over 40 years (Baier and Bergstrand 2007). The earlier applications of the gravity model to international trade flows, e.g., Tinbergen (1962), Linnemann (1966) and Aitken (1973), were drawn from an analogy to Newtonian physics without economic theoretical foundations. Based on constant elasticity of substitution (CES) preferences, a theoretical foundation for the gravity model has been presented and enhanced by, e.g., Anderson (1979), Bergstrand (1989), and Deardoff (1998). Relying on the CES expenditure system, Anderson and van Wincoop (2003) has proved that factors affecting bilateral trade flows between partner i and j can be decomposed into three components: (i) the bilateral trade barrier between partner i and partner j, (ii) i's resistance to trade with all partners, and (iii) j's resistance to trade with all partners. Mathematically Anderson and van Wincoop's gravity trade theory is:

$$ln\frac{E_{ijt}}{y_{it}y_{jt}} = \alpha_0 + \alpha_1 lndist_{ij} + \alpha_2 contig_{ij} + \alpha_3 colony_{ij} + lnP_i^{1-\sigma} + lnP_j^{1-\sigma} + \varepsilon_{ijt} \quad (1)$$

where:

$$P_i^{1-\sigma} = \sum_j P_j^{\sigma-1}\theta_j \exp(\alpha_1 lndist_{ij} + \alpha_2 contig_{ij} + \alpha_3 colony_{ij})$$

$$P_j^{1-\sigma} = \sum_i P_i^{\sigma-1}\theta_i \exp(\alpha_1 lndist_{ij} + \alpha_2 contig_{ij} + \alpha_3 colony_{ij})$$

where E_{ijt} is bilateral trade flows between i and j in period t; α_0 is an unknown constant; $y_{it(jt)}$ is income of country i (j) in period t; the variable $dist_{ij}$ is bilateral distance between the biggest cities of the two countries. The dummy variable $contig_{ij}$ is set to 1 if pairs of countries sharing border. Similarly, $colony_{ij}$ is the dummy variable if two countries have had a colonial relationship; $P_i^{1-\sigma}$ and $P_j^{1-\sigma}$ are *multiple resistance terms (MRTS)*; $\theta_{i(j)}$ is the nominal income share of i (j) in world nominal income; σ is the elasticity of substitution between all goods; and ε_{ijt} is random error, assuming to be independent and identically distributed. Other control variables, such as food safety standards, regional trade agreements affecting bilateral trade can be added to equation (1).

It appears from equation (1) that bilateral trade depends not only on bilateral barriers/costs. Omitting the *MRTs* from the specification, the results of gravity estimation are biased. Since *MRTs* in equation (1) are functions of all bilateral trade resistance, Anderson and van Wincoop (2003) estimate equation (1) via nonlinear least squares. An alternative to the nonlinear least squares estimation of equation (1) is the use of the fixed effects approach for controlling multilateral resistance terms (Baier and Bergstrand 2007). In the gravity model of Anderson and van Wincoop (2003) as equation (1), they restrict coefficients of the gross domestic products (GDPs) to one. Baier and Bergstrand (2007)'s fixed effects approach keeps Anderson and van Wincoop's theory by scaling the left hand side variable of equation (1) by the products of incomes. However, including incomes in the gravity model has recently been questioned for its distance to trade theory (Feenstra 2004; Disdier and Marette 2010). The size effects of incomes can be captured by using the fixed effects estimation approach (Disdier, Fontagne and Mimouni 2008).

Following the recent literature of gravity trade analysis (e.g., Disdier and Marette 2010; Helpman, Melitz and Rubinstein 2008; Disdier, Fontagne and Mimouni 2008), the theoretically-based gravity model in the log normal form as suggested by Anderson and van Wincoop (2003) and using the fixed effects estimation approach is:

$$ln(E_{ijt}) = \alpha_0 + \alpha_{ip} + \alpha_{jp} + \alpha_t + \alpha_1 lndist_{ij} + \alpha_2 contig_{ij} + \alpha_3 colony_{ij} + \alpha_4 comlang_{ij} + \alpha_5 EU15_{ij} + \alpha_6 NAFTA_{ij} + \alpha_7 CAP_{jt} + \alpha_8 oxytetracycline_{jt} + \varepsilon_{ijt} \quad (2)$$

Here E_{ijt} is crustacean imports of country *j* (Canada, EU15, Japan, and the US) from country *i* by time *t* from 2001 to 2008. The source of crustacean import data is from UNCOMTRADE database at the six-digit level of the HS1996 classification, consisting of frozen rock lobster and other sea crawfish (030611), frozen lobsters (030612), frozen shrimps and prawns (030613), frozen crabs (030614), non-frozen rock lobster and other sea crawfish (030621), non-frozen shrimps and prawns (030623), and non-frozen crabs (030624). Importer by product fixed effect, exporter by product fixed effect, and time fixed effect are α_{ip}, α_{jp}, and α_t respectively.

Variables representing bilateral distance, common border, and having colonial relationship are defined as above section. $comlang_{ij}, eu15_{ij}$, and $nafta_{ij}$ are dummy variables if two countries have had an official common language, belongs to European Union 15 members and NAFTA members, respectively. The cloramphenicol standard (CAP_{jt}) is defined as the minimum required performance level (MRPL), which is the detection limit in parts per billion (ppb) for each country from 2001 to 2008. Similar to Disdier and Marette (2010) we assume that all EU15 members applied the same cloramphenicol analytical standard for each year from 2001 to 2008. And the $oxytetracycline_{jt}$ variable is defined as MRLs in parts per million (ppm) applied by each importing country from 2001 to 2008. We control for tetracycline (oxy) because this antibiotic is commonly used in crustaceans aquaculture. Unlike chloramphenicol, ADIs and MRLs for tetracycline (oxy) are established by the CAC and the importing countries. Each importing country in the study sample does not change MRLs of oxytetracycline during our study period (2001-2008); however, different importing countries impose different tetracycline (oxy) standards for seafood.

Data for $dist_{ij}$, $contig_{ij}, colony_{ij}$ $comlang_{ij}$ are extracted from the CEPII database. Cloramphenicol standards come from Disdier and Marette (2010), Debaere (2005), the European Commision Decision 2002/657/EC, and the violation records posted on website of food safety inspection authorities of importing countries (e.g., Japanese Ministry of Health, Labor and Welfare). Oxytetracycline standards are from Chen, Yang, and Findlay (2008).

I also define the following variables: seven *product dummies* which take value 1 if product is frozen rock lobster and other sea crawfish; frozen lobsters; frozen shrimps and prawns, and so on). *Top30* is the world top 30 crustacean exporters (crustaceans aggregation) during 2001 to 2008 according to UNCOMTRADE data. Six dummies representing individual top world crustacean exporting country in Asia, namely China, India, Indonesia, Malaysia, Thailand, and Vietnam, are defined in a similar fashion. All six countries are considered developing countries according to the World Bank's development status classification. However, Malaysia and Thailand have higher income levels and better seafood supply chain organizations compared to the other countries. With the exception of Malaysia, crustacean products exported from China, India, Indonesia, Thailand, and Vietnam are subject to high scrutiny by importing markets (e.g., see Debarer 2005; Ababouch, Gandini, and Ryder 2005).

To understand the impact of advancing cloramphenicol analytical standards on different crustacean products, different scale of crustacean exporters, and different top crustacean exporters with different income status, the gravity equation (2) is modified by including appropriate interactions of *CAP* and the dummy variables of interest described above.

The gravity trade models represented by equations (1) and (2) are traditionally estimated using ordinary least squares (OLS) with only positive trade values included. However, it has recently been recognized that the conventional OLS estimation can bias the results of estimation because of two econometric problems, including heteroskedasticity of error terms and dropping zero values of bilateral trade. For controlling heterogeneity, Cheng and Wall (2005) propose to use the panel fixed effect estimation. This approach does not address the second problem, zero trade issue of the left hand side variable in the gravity model. According to Burger, van Oort, and Linders (2009) and Jayasinghe, Beghin, and Moschini (2010), different alternatives have been suggested to deal with the zero trade problem including: (i) keep observations with zero bilateral trade in the sample and add a small positive number (e.g., 0.01 to 1) to all trade flows so that the logarithm is definable; (ii) estimate the gravity trade model using the Tobit approach; (iii) estimate the model with the Poisson Pseudo maximum likelihood (PPML) recommended by

Silva and Tenreyro (2006); and (iv) apply the sample selection approach developed by Heckman (1979) to the model estimation.

In this paper I address the heteroskedasticity issue with the panel fixed effects approach and take into account the zero-trade issue using the Heckman maximum likelihood estimation. I opt for the Heckman framework to address the zero trade issue over the other alternatives because it better fits the data set under investigation. Adding a small number to all trade flows to address the zero trade issue is inadequate because it lacks both theoretical and empirical justification (Linders and de Groot 2006). The PPML approach includes zero trade observations and estimate the gravity equation (1) and (2) in levels as count data, following a Poisson regression even when the dependent variables are not integers (Santos Silva and Tenreyro 2006). The problem is that the PPML estimation treats all zero equally, rather than missing observations (Jayasinghe, Beghin, and Moschini 2010). In addition, according to Martin and Pham (2008) the PPML approach can be problematic, resulting in biased estimates when a large number of zero observations is present in the data set (about 83% of observations in my data set are zero).

Dropping zero trade observations from the gravity equation will make the sample nonrandom and bias the estimation results because error terms in equation (2) are correlated with explanatory variables. The Heckman approach to deal with the zero trade issue consists of two equations. The first equation (the selection equation) is estimated through a probit model, examining the binary likelihood whether bilateral trade occurs (positive trade is observed) or not (zero trade is observed). The second equation (the outcome equation) is estimated through the OLS regression as equation (2) with the expected value of the error (called the inverse of the Mill's ratio) is included as an extra explanatory variable. The key feature of the Heckman sample selection model is that the error terms in the outcome equation are correlated with the error terms in the selection equation.

According to Cameron and Trivedi (2010), two equations in the Heckman selection model can be estimated simultaneously using the maximum likelihood estimation (MLE) or estimated successively with the Heckman two-step estimation. For the current paper, the MLE procedure is preferred because it allows controlling for heteroskedasticity and country pair correlations via a country pair clustering. In the Heckman model, the same independent variables in the selection equation commonly appear in the outcome equation. However for more robust identification and avoiding multicolinearity, at least one independent variable that appears in the selection equation should not be included in the outcome equation (Helpman, Melitz and Rubinstein 2008). Ideally, this excluded variable affects the selection but not the outcome equation. Following Disdier and Marette (2010) I use the dummy variable $comlang_{ij}$ as the excluded variable (that only appears in the selection equation).

Results and Discussions

As described above, the main objective of this study is to evaluate the impact of cloramphenicol analytical standards on crustacean imports in Canada, the EU15, Japan, and the United States using the Heckman selection estimation. The following four Heckman models are empirically estimated: the Heckman model 1 estimates equation (2) using common language as the excluded variable (only appearing in the selection equation); the Heckman model 2 adds interactions of cloramphenicol standards (CAP)[1] and 7 product dummies to the Heckman model 1; the Heckman model 3 specifies the interaction of CAP and the top 30 world crustacean exporters' dummy to the Heckman model 1; and finally the Heckman model 4 is defined by

[1] For simplicity from this section all subscripts are removed when referring to study variables.

adding interactions of six dummies representing six top world crustacean exporters in Asia and the *CAP* variable to the Heckman model 1.

Direct comparison between Disdier and Marette's model (2010) and the models estimated in this paper is impossible because the dependent variable is different (Disdier and Marette's dependent variable is crustacean imports aggregated at 4 digit level). However for comparison purposes, I also estimate the OLS gravity model of Anderson and van Wincoop with all zero trade values dropped and the Heckman model of Disdier and Marette (2010). Results of the OLS, Disdier and Marette's model, and the Heckman 1 models are reported in Table 1. First of all, results of the OLS estimation (Column 1 of Table 1) are in line with the gravity literature. The bilateral distance statistically and negatively affect crustacean imports, and dummy variables representing common border, North America Free Trade Agreement (NAFTA) have positive impacts on bilateral trade. Variables for colonial tie, European Union 15 membership, and common language do not have significant impacts on crustacean imports. However the results of the OLS estimation are biased and inconsistent because all zero trade observations are dropped.

Column 2-3 and 4-5 of Table 1 present coefficients of the outcome equation and the selection equation of Disdier and Marette (2010)'s model and the Heckman 1 model respectively. Correlation coefficient (ρ) between random errors of the outcome and selection equation is statistically significant, suggesting that selection bias must be corrected. Unlike coefficients of the OLS regression, coefficients of the Heckman model cannot be interpreted as the marginal impact of independent variables on the dependent variable. For this reason, marginal effects[2] of Disdier and Marette's model and the Heckman model 1 are reported in Table 2 together with coefficients of the OLS.

Similar to Disdier and Marette (2010), my results in Table 2 show that increasing the cloramphenicol analytical standard (lowering detection limits) has negatively affected crustacean import flows. Conditional on positive trade values being observed, lowering one unit of cloramphenicol analytical standards (1 ppb) results in a decrease of 3.6%, 3.0%, and 3.4% in bilateral crustacean imports in Canada, EU15 members, Japan, and the United States as predicted by the OLS model, Disdier and Marette's model, and the Heckman 1 model, respectively[3]. This effect is smaller than that predicted by Disdier and Marette (2010) with one unit decrease in *CAP* brings a 13 % reduction of crustacean imports.

In contrast to Disdier and Marette (2010), estimated results in Table 2 show that cloramphenicol standard regulations also affects the probability to import crustaceans. For instance, the Heckman 1 model predicts that the probability to import crustaceans drop 0.002 or 0.2 percent point if *CAP* standard is lowered one unit (1 ppb). This result is similar to the finding of Jayasinghe, Beghin, and Moschini (2010) that the sanitary and phytosanitary (SPS) variable statistically has a significant impact on both the value and probability of trade. Combining both the impact of CAP on the extensive margin (probability) and the intensive margin (value) of trade, my results imply that stricter cloramphenicol standards can displace exporters from developed markets; however, once they are able to export, the negative impacts on the volume of trade are lesser than that predicted by Disdier and Marette (2010).

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[2] Average marginal effects are reported. These are computed by averaging marginal effect of individual observations.

[3] Since CAP and oxytetracycline are in level form and the dependent variable in the log form, coefficients in the OLS model and marginal effects in the Heckman model are semi-elasticity.

Countries sharing common border have a tendency to increase bilateral crustacean imports. Compared to Disdier and Marette (2010), the impact of the common border variable on import flows is doubled, changing from 84% increase found in Disdier and Marette (2010) to 191% increase in import flows as predicted by the Heckman model 1. On the other hand, the impact of bilateral distance and colonial tie on import flows is lowered than that found in Disdier and Marette (2010). One percent increase in the bilateral distance associates with a decrease of 0.28% of import flows (Column 5) in contrast to 1.19 % decrease of crustacean import volume as found by Disdier and Marette (2010).

Additional variables to Disdier and Marette (2010), oxytetracycline standards, the EU15 dummy, and the NAFTA dummy also have significant influences on crustacean import flows. Lowering one unit (1ppm) of oxytetracycline residue limit would cause import flows to drop 170%. *CAP* has a stronger negative impact on crustacean imports than oxytetracycline since 1 ppb decrease of oxytetracycline only reduces 0.17% of imports. As presented in Table 2, the EU15 and NAFTA dummy variables have positive impacts on import flows and the magnitude is in line with the gravity trade literature findings.

For investigating how chloramphenicol analytical standards impact different crustacean products, scale of crustacean exports, and countries with different income status, the Heckman model 1 is appropriately augmented to generate the model 2, model 3, and model 4. Empirical estimation results of these models are presented in Table 3. As shown in Table 3, the sign and magnitude of control variables in the estimated models (distance, tetracycline (oxy), continuity, colonial tie, regional EU15, NAFTA, and common language) are consistent and similar to empirical results of the Heckman 1 model reported in Table 1.

As reported in Column 1 and 2 of Table 3, six interactions (one was automatically omitted to avoid perfect multicolinearity) of cloramphenicol standards (*CAP*) and products both have a significant impact on the quantity and probability of imports. These results suggest that the *CAP* variable impacts differently on imported products under investigation. Marginal effects of the *CAP* and oxytetracycline variables on the intensive and extensive margins of trade over study products are computed and reported in Table 4. *CAP* and oxytetracycline standards have the most negative and significant impact on frozen rock lobster and other sea crawfish (HS 30611), frozen shrimps and prawns (HS 030613), and non-frozen crabs frozen crabs (HS 30624) regarding both importing value as well as importing likelihood. For example, conditional on positive trade being observed, lowering 1 unit of *CAP* (1 ppb) approximately associates with a decrease of 6.8%, 0.9%, and 2% of rock lobsters, shrimps and prawns, and non-frozen crabs import flows, respectively. Cloramphenicol standards do not statistically have negative impacts on import flows of frozen lobsters (HS 30612), frozen crabs (HS 30614), non-frozen rock lobsters (030621).

These findings suggest several implications. First, stricter cloramphenicol analytical standards have stronger negative impacts on shrimps and prawns (HS 30613), and crabs (HS 30624). These findings can be supported by the fact that a high portion of these products come from aquaculture where cloramphenicol antibiotic might be misused by farmers. With regard to rock lobster products (HS 30611), unlike shrimps and prawns, most of rock lobsters come from capture fisheries. Non-frozen rock lobsters (HS 30621) are not negatively affected by increasing stringency of cloramphenicol standards whereas its frozen counterpart (HS 30611) receives most negative impacts. It is likely that frozen-rock lobsters might be contaminated with cloramphenicol residue in post-harvesting (e.g., middle trading and processing) stages of rock lobster supply chains.

Results of the Heckman model 3 (controlling for the interaction of top 30 world crustacean exporters and cloramphenicol standards) reported in Column 3 and 4 of Table 3 show that top 30 crustacean exporters experience a more negative impact of increasing stringency of cloramphenicol analytical standards. Conditional on positive trade being observed, import flows from top 30 world crustacean exporters decrease approximately 4% whereas import flows from other country in the study sample only reduce 2.8% (Table 5) if cloramphenicol standards are lowered one unit (1ppb). This trend of difference is also applied to the unconditional marginal effect and marginal effect on the probability of having positive import flows.

In order to examine complex impacts of cloramphenicol standards on top exporters, I include interactions of the *CAP* variable and six dummies representing China, India, Indonesia, Malaysia, Thailand, and Vietnam. With the exception of Malaysia, crustacean imports from these Asian countries are subject to greater control at border of importing countries because of higher product contamination profiles (Debarer 2005; Ababouch, Gandini, and Ryder 2005; Disdier and Marette 2010). Interestingly, as shown in Column 5 of Table 3, coefficients of the interactions of China and *CAP*, and Indonesia and *CAP* are positive and statistically significant. These results suggest that these two top exporting countries receive more negative impacts compared to other countries in the study sample once cloramphenicol standards become more stringent. In contrast, coefficients of Malaysia and Thailand interactions with the *CAP* variable are negative and significant, implying that these countries receive less negative impacts when importing countries lower their cloramphenicol analytical standards. The impact of the *CAP* variable on Indonesia and Vietnam is not different from the impact on other partner countries under investigation.

Average marginal effects of the *CAP* variable on trade flows over these countries are reported in Table 5. Conditional on positive trade being observed, China's crustacean exports would approximately reduce 6.2% while other countries only decrease 3.3% if cloramphenicol standards are lowered one unit (1ppb). Similarly, with the same level of increasing stringent cloramphenicol regulation, import flows from India drop 5% while other countries only drop 3.4%. In contrast to the experience of China and India, with higher income level and more advanced human and technical capabilities, Malaysia and Thailand do not face any loss in crustacean trade while other countries face a decrease of 3.4% of trade if *CAP* standards in developed countries drop one unit (1 ppb). Since the interactions of the *CAP* variable and Indonesia and Vietnam dummies are not statistically significant in the Heckman model 4 presented in Column 4 of Table 3, I do not compute marginal effects over these two countries.

Conclusions

For protecting consumers' health, over the last two decade, developed countries have imposed more stringent veterinary drug standards. For example, in 1990 the EU promulgated Council Regulation 2377/90/EEC on establishing procedures for setting maximum residue limits of veterinary medicinal products in foodstuffs. Other developed countries such as the U.S., Canada, and Japan have also taken similar efforts to tighten veterinary drug regulations. With improvements in analytical technologies, developed countries are able to detect chemical residues in food products at very low levels.

The findings from this study show that enhancing stringency of food safety standards as importing countries chase zero detection limits of cloramphenicol residues has negative effects on international crustacean trade. This is in line with the view that standards act as barriers to international trade commonly found in the gravity trade literature.

Food safety standards imposed by developed countries dynamically affect import flows of different crustacean products. The finding that shrimps and prawns received stronger negative impacts implies that farmed products are sensitive to cloramphenicol standard stringency. In intensive aquaculture farming systems producers might misuse chloramphenicol antibiotic to treat disease or environmental problems for preventing crop failures. Drug residues in seafood could expose consumers to health or drug resistant risks. By contrast, frozen rock lobster products receiving more negative impacts resulting from increasing chloramphenicol regulation stringency might point to other source of *CAP* contamination. Since the finding shows that non-frozen rock lobsters are not negatively and statistically affected by enhancing *CAP* standards, it is likely that these products are contaminated during post-harvest handling and processing steps. Seafood exporters need to improve supply chain management to ensure that final products meet developed countries' market requirements.

From the empirical models, I find evidence that scale of export is also sensitive to increasing standard stringency. Cloramphenicol analytical standards discipline top crustacean exporting countries more than other countries. Top crustacean exporters may face more scrutiny at border control and inspection, a point which is especially true for top Asian exporters (e.g., China, India, Indonesia, Thailand, and Vietnam) that frequently appear in the food safety monitoring and rapid alert radar of importing countries. The empirical results call for further examination on differential effects of food safety standards imposed by developed markets on developing countries.

The results of this study add new understanding of the implementation and effects of food safety standards by noting that food safety standards have dynamic impacts on international trade from developing countries. Developing countries with higher income level and better seafood industry organizations such as Malaysia and Thailand might be able to comply with stringent standards to meet stringent market requirements and strengthen their competitive advantage and place them in a better competitive position in international markets. Some developing countries such as China and India in this study experience more trade loss when food safety standards become stricter.

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Table 1: Results of the OLS, Disdier and Marette (2010), and Heckman 1 models

Variables	OLS model (1)	Disdier and Marette model		Heckman model 1	
		Lntrade (2)	Selection (3)	Lntrade (4)	Selection (5)
Lndist	-0.393***	-0.641***	-0.681***	-0.577***	-0.530***
	(0.105)	(0.110)	(0.032)	(0.109)	(0.037)
CAP	0.036***	0.038***	0.013***	0.042***	0.014***
	(0.005)	(0.005)	(0.002)	(0.005)	(0.002)
oxytetracycline	1.717***			2.060***	0.642***
	(0.201)			(0.212)	(0.063)
Contig	1.270***	1.536***	0.581***	1.408***	0.628***
	(0.248)	(0.248)	(0.125)	(0.253)	(0.119)
Colony	0.283	0.407*	0.209***	0.553***	0.334***
	(0.223)	(0.208)	(0.080)	(0.208)	(0.076)
eu15	0.228			0.689**	0.830***
	(0.316)			(0.335)	(0.098)
Nafta	1.702***			1.603***	0.855**
	(0.485)			(0.508)	(0.487)
Comlang	0.115		0.062***		0.155***
	(0.202)		(3.350)		(0.060)
Rho		0.322***		0.324***	
Lambda		0.707***		0.698***	
Number of obs	20321	116725		116725	
Log pseudolikelihood		-74223.93		-73257.4	
Wald test of(rho = 0): chi2(1)		50.76***		63.75***	

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors.

Table 2: OLS Parameter Estimates and Marginal Effects of the Disdier and Marette (2010), and Heckman 1 Models

	OLS model	Disdier and Marette (2010) model: On intensive margin of trade			Heckman 1 model: On intensive margin of trade		
		Conditional	Unconditional	On probability of trade	Conditional	Unconditional	On probability of trade
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
lndist	-0.393***	-0.256***	-0.405***	-0.097***	-0.281***	-0.322***	-0.074***
	(0.105)	(0.089)	(0.026)	(0.004)	(0.101)	(0.030)	(0.005)
CAP	0.036***	0.030***	0.012***	0.002***	0.034***	0.013***	0.002***
	(0.005)	(0.004)	(0.001)	(0.000)	(0.004)	(0.001)	(0.000)
oxytetracycline	1.717***				1.701***	0.628***	0.089***
	(0.201)				(0.192)	(0.054)	(0.009)
contig	1.270***	1.220***	0.669***	0.097***	1.071***	0.654***	0.104***
	(0.248)	(0.228)	(0.138)	(0.024)	(0.233)	(0.132)	(0.023)
colony	0.283	0.290	0.174**	0.031**	0.370**	0.263***	0.051***
	(0.223)	(0.186)	(0.072)	(0.013)	(0.188)	(0.074)	(0.013)
eu15	0.228				0.243	0.563***	0.144***
	(0.316)				(0.296)	(0.126)	(0.020)
nafta	1.702***				1.154***	0.876*	0.149
	(0.485)				(0.377)	(0.479)	(0.101)
comlang	0.115			0.031***			0.022**
	(0.202)			(0.010)			(0.009)

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors.

Table 3: Results of the Models Controlling for Product Groups, Top Crustacean Exporting Group, and Top Exporters in Asia

Variables	Model 2: contro for products		Model 3: control for top exporters		Model 4: control for top Asian exporters	
	Lntrade (1)	Selection (2)	Lntrade (3)	Selection (4)	Lntrade (5)	Selection (6)
lndist	-0.605***	-0.536***	-0.569***	-0.526***	-0.563***	-0.525***
	(0.109)	(0.038)	(0.109)	(0.038)	(0.111)	(0.038)
CAP	0.079***	0.020***	0.035***	0.011***	0.041***	0.013***
	(0.008)	(0.003)	(0.007)	(0.002)	(0.006)	(0.002)
oxytetracycline	2.125***	0.648***	2.062***	0.643***	2.055***	0.641***
	(0.214)	(0.064)	(0.212)	(0.063)	(0.212)	(0.063)
contig	1.382***	0.621***	1.411***	0.630***	1.417***	0.634***
	(0.252)	(0.119)	(0.253)	(0.119)	(0.253)	(0.119)
colony	0.583***	0.334***	0.574***	0.343***	0.551***	0.336***
	(0.208)	(0.076)	(0.209)	(0.076)	(0.208)	(0.077)
eu15	0.772**	0.836***	0.716**	0.846***	0.698**	0.833***
	(0.331)	(0.098)	(0.334)	(0.098)	(0.335)	(0.098)
nafta	1.575***	0.851*	1.648***	0.872*	1.616***	0.857*
	(0.512)	(0.488)	(0.508)	(0.487)	(0.507)	(0.486)
comlang	-	0.159***		0.152*		0.153**
		(0.060)		(0.060)		(0.060)
Product 30612*CAP	-0.072***	-0.010***				
	(0.011)	(0.004)				
Product 30613*CAP	-0.065***	-0.009***				
	(0.008)	(0.003)				
Product 30614*CAP	-0.073***	-0.013***				
	(0.009)	(0.003)				
Product 30621*CAP	-0.085***	-0.014***				
	(0.009)	(0.004)				

Product 30623*CAP	-0.068***	-0.015***				
	(0.010)	(0.004)				
Product 30624*CAP	-0.060***	-0.022***				
	(0.010)	(0.003)				
Top30*CAP			0.014*	0.006**		
			(0.008)	(0.003)		
China*CAP					0.028**	0.002
					(0.012)	(0.004)
India*CAP					0.016***	0.004
					(0.006)	(0.003)
Indonesia*CAP					0.008	0.025***
					(0.008)	(0.003)
Malaysia*CAP					-0.025***	-0.006**
					(0.009)	(0.003)
Thailand*CAP					-0.020*	0.006
					(0.012)	(0.004)
Vietnam*CAP					0.009	0.006
					(0.008)	(0.004)
rho	0.327***		0.324***		0.320***	
lambda	0.703		0.699		0.688	
Number of obs	116725		116725		116725	
Log pseudolikelihood	-73138.2		-73235		-73228.5***	
Wald test of(rho = 0): chi2(1)	66.25***		63.9***		62.5***	

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors; Product 30611: frozen rock lobster and other sea crawfish; 30612: frozen lobsters; 30613: frozen shrimps and prawns; 30614: frozen crabs; 30621: non-frozen rock lobster and other sea crawfish; 30623: non-frozen shrimps and prawns; and 30624: non-frozen crabs.

Table 4: Marginal effects of RPL and MRLon the intensive and extensive margins of trade control for products

	RPL			MRL		
	On volume of trade		On probability of trade	On volume of trade		On probability of trade
Products	Conditional (1)	Unconditional (2)	(3)	Conditional (4)	Unconditional (5)	(6)
30611	0.068***	0.025***	0.003***	1.756***	0.735***	0.107***
	(0.007)	(0.003)	(0.000)	(0.193)	(0.067)	(0.010)
30612	0.001	0.003***	0.001***	1.738***	0.402***	0.066***
	(0.009)	(0.001)	(0.000)	(0.192)	(0.038)	(0.007)
30613	0.009*	0.011***	0.002***	1.782***	0.977***	0.102***
	(0.005)	(0.001)	(0.000)	(0.194)	(0.083)	(0.010)
30614	0.003	0.003***	0.001***	1.756***	0.588***	0.086***
	(0.006)	(0.001)	(0.000)	(0.193)	(0.052)	(0.009)
30621	-0.009	0.001	0.001**	1.735***	0.351***	0.062***
	(0.006)	(0.001)	(0.000)	(0.192)	(0.032)	(0.006)
30623	0.008	0.004**	0.001	1.784***	0.747***	0.111***
	(0.007)	(0.002)	(0.000)	(0.194)	(0.066)	(0.011)
30624	0.020***	0.002*	0.000	1.744***	0.397***	0.077***
	(0.007)	(0.001)	(0.000)	(0.193)	(0.038)	(0.008)

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors; Product 30611: frozen rock lobster and other sea crawfish; 30612: frozen lobsters; 30613: frozen shrimps and prawns; 30614: frozen crabs; 30621: non-frozen rock lobster and other sea crawfish; 30623: non-frozen shrimps and prawns; and 30624: non-frozen crabs.

Table 5: Average marginal effects of RPL on dummy variables representing top crustacean exporters and top exporters in Asia

Dummy variable	Dummy values	On Value of Trade		On probability of trade
		Conditional (1)	Unconditional (2)	(3)
Top30 exporters	0	0.028***	0.008***	0.001***
		(0.006)	(0.001)	(0.000)
	1	0.040***	0.028***	0.003***
		(0.006)	(0.003)	(0.001)
China	0	0.033***	0.013***	
		(0.005)	(0.002)	
	1	0.062***	0.037***	
		(0.011)	(0.005)	
India	0	0.034***	0.013***	
		(0.005)	(0.002)	
	1	0.050***	0.033***	
		(0.005)	(0.003)	
Indonesia	0			0.002***
				(0.000)
	1			0.007***
				(0.001)
Malaysia	0	0.034***	0.013***	0.002***
		(0.005)	(0.002)	(0.000)
	1	0.013	0.007**	0.001**
		(0.009)	(0.003)	(0.000)
Thailand	0	0.034***	0.013***	
		(0.005)	(0.002)	
	1	0.012	0.018***	
		(0.011)	(0.005)	
Vietnam	0			
	1			

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors; average marginal effects are not computed for the interacted variables that are not statistically significant in the Heckman model 4.

CONCLUSIONS AND POLICY IMPLICATIONS

Conclusions

The three essays of this dissertation examine market and non-market factors affecting international seafood trade. The essays are connected by the theme of international seafood trade. The first essay sets a broad background to understand complex and potential impacts of food safety standards on exporting countries. The second essay explores zero-accounting econometric approaches for quantifying the impact of food safety standards on international seafood trade (hypothesizing that standards act as barriers to trade). Taking into account the findings of the first and second essay, the third essay examines the complex impacts of chloramphenicol analytical standards on international crustacean imports in developed markets (Canada, EU, Japan, and the U.S.) by applying the Heckman selection model.

Using the Vietnamese shrimp farming industry as a typical case representing developing countries, the first essay of the dissertation shows how various stakeholders respond to seafood standards imposed by developed markets. The finding in the first essay demonstrates that stricter and dynamic food safety and environmental standards developed and imposed by public and private actors in developed countries increase coordinating power of leading actors and transform Vietnamese shrimp farming industry into global value chains, driven by large retailers/buyers in the global North. Food safety and environmental standards imposed by the North as well as socio-cultural and natural environmental resource conditions affect and constrain the capability of exporting countries in organizing and transforming supply chains to meet more stringent market requirements.

Applying alternative zero-accounting gravity econometric models, the second essay tests the hypothesis that food safety standards act as barriers to international seafood trade and assesses the choice of alternative gravity model specifications to account for zero trade flows. The empirical estimation results confirm this hypothesis and are robust to the OLS as well as alternative zero-accounting gravity models (the Heckman maximum likelihood (ML) procedure and the Poisson family regressions). Increasing the stringency of regulations by reducing analytical limits or maximum residue limits in seafood in developed countries has negative impacts on their bilateral seafood imports. For the choice of the best model specification to account for zero trade and heteroskedastic issues, the second essay provides inconclusive evidence to base on formal statistical tests. However based on the magnitude of estimated coefficients, its economic implication, and the literature finding, the Heckman ML estimation provides the most reliable parameter estimates.

Using the Heckman ML specification in the gravity econometric model, the third essay finds that enhancing stringency of cloramphenicol analytical standards has negative effects on international crustacean imports in developed countries (Canada, EU, Japan, and the U.S.), decreasing the value and probability of their crustacean imports. Impacts of food safety standards on trade are complex with regard to scale of crustacean exports, crustacean products exported, and income level of developing country. Frozen shrimps and rock lobster products are sensitive to increasing standard stringency (decreasing chloramphenicol analytical limits), and top crustacean exporters are disciplined more than smaller exporters. Developing countries with higher income levels receive less negative impacts of enhancing food safety standards than developing countries with lower income levels.

Policy Implications

With reductions of tariffs and quotas resulting from WTO agreements, non-tariff measures such as food safety and environmental standards have become hot issues in international seafood trade debates. Findings of the first essay suggest that in order to comply with more stringent market requirements initiated by public and private actors in the global North, actors in the seafood industry of Vietnam will have to transform the seafood industry into global value chains that are responsive to by large and powerful actors in the global North. Consequently, small scale actors (e.g., producers, processors) who have limited financial and technical capabilities will be marginalized and seafood production and trade will concentrate into relatively few hands. Hence while imposing more stringent food safety and environmental standards might reduce food safety hazards and enhance environmental sustainability, it may result in negative social consequences (e.g., displacing small producers and enterprises from markets) for seafood exporting countries (especially poor developing countries) in the global South.

Investigating the impact of food safety standards on seafood trade aggregated at the country level with the gravity econometric approach, findings of the second and third essays confirm that food safety standards act as barriers to international seafood trade. Enhancing food safety standards (lowering analytical limits or maximum residual limits) is associated with reducing the value and probability of bilateral seafood trade. The economic implication is that these effects, caused by increasing transaction costs due to stricter food safety enforcement, will shift seafood the supply curve backward.

How food safety standards impact economic welfare will depend on the slope (elasticity) of seafood supply and demand curve. For instance, Disdier and Marette (2010) find that enhancing chloramphenicol analytical standards has a negative impact on crustacean imports, which they claim results in both increased domestic and international welfare. While combining the gravity and welfare approaches for evaluating food safety standards is interesting and an important first step in this area, the finding of Disdier and Marette (2010) is flawed since chloramphenicol regulations imposed by developed country markets are based on analytical technology improvements and do not rely on findings of scientific risk assessment methods. Further research should be conducted to evaluate the trade and welfare impacts of non-tariff measures such as food safety standards.

Food safety standards act as barriers to trade, however findings of the dissertation also suggest that the impact of standards on trade is complex that might change from product to product as well as from country to country with different development status and industry organization levels. Developing countries with higher income levels can respond better to stricter food safety standards enforced by public and private actors in the global North. Capacity building and trade facilitation support should be mobilized to support poor developing countries while stringent food safety standards are putting into enforcement.

References

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