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quae nos sustentat et gubernat,
et producit diversos fructus cum coloratis floribus et herba.

Laudes Creaturarum, Sancto Francisco (1224)

Abstract

The doctoral thesis ‘Impact of regulatory measures on international trade in meat products’ analyzes the differing effects of various regulatory measures on international meat trade and on welfare using different quantitative economic models. Regulatory measures are defined as instruments correcting for market inefficiencies which are associated with production, distribution and consumption of agri-food products.

The impact of regulatory measures on trade and welfare is assumed to be non-uniform: Regulations may have negative, no, or even positive trade and welfare effects. Therefore, the impacts of different specific regulatory measures are systematically compared with each other in two case studies. The applied quantitative models and their implementation are theoretically as well as economically derived and possible alternatives are discussed.

Employing a non-linear gravity model with fixed effects being estimated by Poisson pseudo-maximum likelihood, the differing quantitative effects of applied regulatory measures that govern international trade in meat are analyzed in the first case study. Additionally, regulations are identified which most adequately conform to the trade restrictiveness provisions of the Sanitary and Phytosanitary Agreement and the Technical Barriers to Trade Agreement. Especially production process requirements and requirements for handling meat after slaughtering are identified to be trade restrictive, whereas other analyzed requirements are even trade promoting.

Using a sample selection seemingly unrelated regression gravity model and a spatial Takayama-Judge partial equilibrium model, the second case study analyzes a change in a specific regulation related to biohazards to identify trade and welfare changes of different policy options. Poultry meat and avian influenza-related regulatory measures are used as examples. Spread and transmission risks according to the disease status of countries are considered. The econometric model shows that for non-heat-treated poultry meat a general ban leads to a near breakdown of trade, whereas complying with the principle of regionalization has a clear positive trade impact in comparison to a situation without any regulatory policy. For heat-treated poultry meat these plausible outcomes could not be replicated. The simulation model results confirm the negative welfare impact of currently implemented regulatory policies and indicate that significant trade reorganization occurs.

The thesis ends with a summary of the major findings and gives recommendations for further research. It surely advances existing literature in comparing systematically and quantitatively the trade and welfare effects of different regulatory measures, but it fails in giving standardized advice to policy makers how to generally identify the optimal regulatory solutions.

Keywords: Non-tariff measures, trade economics, gravity model, spatial partial equilibrium model, meat, poultry meat, avian influenza.

Kurzfassung

Die Dissertation ‚Einfluss von regulatorischen Maßnahmen auf den internationalen Handel mit Fleischprodukten‘ untersucht unter Zuhilfenahme quantitativer ökonomischer Modelle die Auswirkungen verschiedener regulatorischer Maßnahmen auf den internationalen Fleischhandel und auf die Wohlfahrt. Dabei werden regulatorische Maßnahmen als Instrumente zur Korrektur von Marktineffizienzen verstanden, die mit Produktion, Verteilung und Konsum von Agrarprodukten in Verbindung stehen.

Die Auswirkungen regulatorischer Maßnahmen auf Handel und Wohlfahrt können nicht als gleichgerichtet angenommen werden: Maßnahmen können negative, keine oder sogar positive Handels- und Wohlfahrtseffekte zur Folge haben. Deshalb werden in zwei Fallstudien die Effekte verschiedener spezifischer regulatorischer Maßnahmen systematisch miteinander verglichen. Die verwendeten quantitativen Modelle und ihre praktische Ausführung werden theoretisch und ökonomisch hergeleitet und mögliche Alternativen diskutiert.

In der ersten Fallstudie wird ein nicht-lineares Fixed-Effects Gravitätsmodell mittels Poisson Pseudo-Maximum Likelihood geschätzt. Dabei werden die sich voneinander unterscheidenden quantitativen Handelswirkungen verwendeter Maßnahmen zur Regulierung des internationalen Fleischhandels ermittelt. Darüberhinaus werden solche Maßnahmen identifiziert, die den Vorgaben des Abkommens über sanitäre und phytosanitäre Maßnahmen sowie des Übereinkommens über technische Handelshemmnisse hinsichtlich handelsverzerrender Auswirkungen am besten entsprechen. Besonders Bestimmungen über Produktionsprozesse und Bestimmungen über den Umgang mit Fleisch nach der Schlachtung werden als handelsverzerrend identifiziert, wohingegen andere untersuchte Maßnahmen den Handel sogar anregen.

In einer zweiten Fallstudie werden die Auswirkungen verschiedener regulatorischer Politiken auf Handel und Wohlfahrt mittels eines Sample Selection Seemingly Unrelated Regression Gravitätsmodells und eines räumlichen und partiellen Takayama-Judge Gleichgewichtsmodells aufgezeigt. Geflügelfleisch und Maßnahmen zur Bekämpfung der Ausbreitung von Vogelgrippe dienen als Besispiel, wobei das Risiko der Ausbreitung und der Übertragung von Vogelgrippe berücksichtigt wird. Die ökonometrische Analyse verdeutlicht, dass ein allgemeines Einfuhrverbot für nicht-hitzebehandeltes Geflügelfleisch den Handel mit diesem Produkt quasi zum Erliegen bringt, wohingegen die Anwendung des Prinzips der Regionalisierung deutlich handelssteigernd wirkt. Diese eingängigen Ergebnisse können für hitzebehandeltes Geflügelfleisch nicht bestätigt werden. Die Ergebnisse des Simulationsmodells bekräftigen die negativen Wohlfahrtswirkungen der zurzeit geltenden regulatorischen Instrumente, und machen deutlich, dass Handelsströme in Abhängigkeit vom jeweiligen Seuchenstatus der betrachteten Länder umgeleitet werden.

Abschließend werden die wichtigsten Erkenntnisse der Arbeit zusammengefasst und Vorschläge für weitergehende Untersuchungen gegeben. Die Dissertation geht klar über vorhandene Literatur hinaus, da in ihr erstmals Handels- und Wohlfahrtseffekte verschiedener regulatorischer Maßnahmen systematisch und quantitativ miteinander verglichen werden. Sie erreicht allerdings nicht das Ziel, politischen Entscheidungsträgern standardisierte Handlungsempfehlungen anzubieten, wie generell die besten regulatorischen Lösungen gefunden werden können.

Stichwörter: Nicht-tarifäre Handelsmaßnahmen, Handelsökonomik, Gravitäts-modell, räumliches partielles Gleichgewichtsmodell, Fleisch, Geflügelfleisch, Vogelgrippe.

Abbreviations

AI	Avian influenza
CAPRI	Common Agricultural Policy Regionalised Impact Modelling System
C.i.f.	Cost, insurance, freight
Cdf	Cumulative distribution function
CEPII	Centre d'Etudes Prospectives et d'Informations Internationales
CES	Constant elasticity of substitution
Cf.	Confer
Et al.	Et alii
Etc.	Et cetera
EC	European Communities
E.g.	Exempli gratia
EU	European Union
F.o.b.	Free on bord
FAI	Free of avian influenza
FAO	Food and Agricultural Organization
GATT	General Agreement on Tariffs and Trade
GDP	Gross domestic product
GL	Generalized Leontief
GMO	Genetically modified organism
GNP	Gross national product
HACCP	Hazard analysis and critical control points
HO	Heckscher-Ohlin
HPAI	High pathogenic avian influenza
HS	Harmonized System

I.d.	Id est
IID	Independent and identically distributed
IPFSAPH	International Portal on Food Safety, Animal and Plant Health
ISIC	International standard industrial classification
IV	Instrumental variable
LPAI	Low pathogenic avian influenza
LSDV	Least squares dummy variable
M.	Million
MCP	Mixed-Complementary Programming
ML	Maximum likelihood
MRL	Maximum residue level
NACE	Nomenclature générale des activités économiques dans les Communautés européennes
N.e.s.	Not elsewhere specified
NID	Normal and identically distributed
NLS	Non-linear least squares
N.p.	Not provided
NQ	Normal quadratic
NTM	Non-tariff measure
OECD	Organisation for Economic Co-operation and Development
OIE	World Organisation for Animal Health
OLS	Ordinary least squares
P.c.	Per capita
Pdf	Probability density function
PML	Pseudo-maximum likelihood
PPML	Poisson pseudo-maximum likelihood
RESET	Ramsey regression equation specification error test
ROW	Rest of world
RTA	Regional trade agreement

SITC	Standard international trade classification
SPS	Sanitary and phytosanitary
SUR	Seemingly unrelated regression
T.	Ton
TBT	Technical barriers to trade
TRAINS	Trade Analysis and Information System
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
US	United States
WTO	World Trade Organization
ZINBP	Zero-inflated, negative binomial Poisson

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1 General introduction

The steady decline of tariff rates as a result of eight multilateral trade negotiation rounds, and multiple regional, bilateral and unilateral tariff liberalization agreements have increased the relative importance of non-tariff measures (NTMs) such as regulations and standards in the international trade regime.[1] NTMs are defined by the multi-agency support team as policy measures other than customs tariffs that can potentially have an economic effect on international trade in goods and services, changing quantities traded, prices, or both (MAST 2008). The thesis' focal point is on an important subset of NTMs which are governmental regulations. Regulations can be understood as instruments correcting for market imperfections and inefficiencies which are associated with production, distribution and consumption of agri-food products. International meat markets are especially affected by those regulations, as trade in meat products is exposed to a wide number of market failures. Diseases, pandemics and meat and feed scandals in the last decade have increased consumers' and producers' awareness of external effects associated with trade in meat products. Therefore the product focus of the quantitative analyses within this thesis is on meat.

Governmental regulations are set within the frame of the regulatory system for agri-food products, and thus they are first of all domestic affairs. These domestic requirements determine which characteristics foreign as well as domestic products have to possess in order to be sold on the domestic market. The chosen national regulations often reflect national peculiarities such as institutional structures, technical and scientific resources, natural conditions, as well as consumption traditions such as consumer preferences and acceptable levels of food safety risks.

However, international coordination is required for World Trade Organization (WTO) member countries and is necessary for a functioning international trade in

[1] Within this thesis the notions regulations/regulatory measures/regulatory instruments are policy measures being defined and implemented by public authorities; they are used as synonyms. In contrast, standards are regulatory systems provided by private actors within the market chain.

meat products. At the international level, the relation between domestic regulations and international requirements is organized by the WTO trade rules in the Sanitary and Phytosanitary (SPS) Agreement and in the Agreement on Technical Barriers to Trade (TBT). The SPS and TBT Agreements apply to regulations on a product level, but production and process requirements also fall under these agreements if they are product-related, i.e. if the choice of the production method physically impacts the final product. The provisions under the SPS and TBT Agreement aim to ensure that regulations are not misued as disguised protectionist measures. Requirements for foreign products are not allowed to be more stringent than those for domestic ones and foreign products should generally be treated like corresponding domestic ones. The SPS Agreement, however, foresees the possibility of divergent rules for foreign food products if they impact human, animal and/or plant health and life in the importing country. The TBT Agreement includes similar provisions to meet legitimate national objectives, including security, human health and safety and the prevention of deceptive practices. In order to impose different and possibly tighter regulatory measures on foreign products, importing countries are required to provide scientific risk assessment, thereby justifying the necessity of the respective requirements.[2] Additionally, requirements have to be commensurate with regard to their objective and have to be least trade restrictive with regard to achieving their objective. While maintaining the sovereign right of countries to set their own governmental regulations, countries are encouraged to base their import requirements on internationally agreed regulations such as those from the Codex Alimentarius, the World Organisation for Animal Health or the International Plant Protection Convention.[3]

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[2] Annex IV of the SPS Agreement defines the scientific risk assessment procedure.

[3] The provisions of the General Agreement on Tariffs and Trade (GATT) govern the relation between domestic and foreign products, too. The principles of most-favored-nation treatment (GATT Article 1) and national treatment (GATT Article 3) command that ‘like products’ must not be treated differently neither when comparing imports originating from different countries nor when comparing imports with domestic products. A product is ‘like’ if it is not physical and detectable distinguishable from the comparative product.

Regulatory measures impact trade. It can be thought of many possible situations where regulations increase, decrease or leave trade unaltered.

First, regulations can cause costs, thus affecting supply and demand. Requirements demanded by importing countries cause compliance costs for exporters. Therefore, the exporters' comparative advantage in trade can be undermined. Compliance costs may arise because producers have to change their production processes in order to satisfy the requirements of the foreign market's regulations. In addition, country and sector specific factors, for example infrastructure, administrative services as well as market structure, influence compliance costs, and thus the magnitude of the regulations' impact. In the applied analysis of simulation models, the cost-causing impact of NTMs is depicted as tariff equivalent (Yue and Beghin 2009, Yue et al. 2006) or iceberg tariff (Krugman 1991, Samuelson 1952). When analyzing NTMs related to the protection of agri-food production from biohazards the risk-based approach has a long history in the literature. Pioneering research by Paarlberg and Lee (1998) was amplified through spatial coverage (Jansson et al. 2005), linkages to dynamic herd-size models (Niemi and Lehtonen 2011, Nogueira et al. 2011, Mangen and Burrell 2003), and richness in model and disease parameter specification (Peterson and Orden 2008, Wilson and Antón 2006, Yue et al. 2006). The demand curve may also shift in response to the introduction of regulatory measures (Polinsky and Rogerson 1983). If consumers are aware of a specific product characteristic regulated by a certain measure and they consider the product characteristic as poor for their utility, they will negatively internalize the expected damage linked to the characteristic in their consumption. Then consumers take over their own losses causing the demand curve to shift down by the consumers' perceived losses.

Second, regulations bring about benefits for both consumers and producers affecting demand and supply. Regulations may expand demand for a good through better information about the product or by enhancing the product's attributes

(Maertens and Swinnen 2009, Maertens et al. 2007, Polinsky and Rogerson 1983).[4] That means regulations produce trust between buyers and sellers; they transport the necessary information without which trade would not take place at all. Moreover, regulations are beneficial for consumers due to an increase in safety or quality of agri-food products, or for producers due to e.g. the prevention of a dispersion of animal or plant pests and diseases. Such consumer-producer benefits can be depicted by shifting demand and supply curves in simulation models (Beghin and Bureau 2001), which may offset corresponding demand and supply shifts in the other direction, thereby leading to a win-win situation for producers or exporters and consumers.

Having this in mind, the trade and welfare effect of regulatory measures is hence first and foremost an empirical question, and econometric estimation of gravity-type models as well as different types of simulation models have commonly been used in the literature to quantify the trade and welfare effects.

1.1 Problem statement and research objective

The existence of a multitude of different regulatory measures enables policy makers to make a selection and choose those measures that seem appropriate to achieve their desired predefined policy goals. The provisions of the SPS Agreement require that regulations targeting specific national agri-food safety objectives are minimal with respect to their trade effects (Article 5.4) and not more trade restrictive than required (Article 5.6). These provisions are aimed at reducing the trade costs associated with the implementation of the regulations and simultaneously maintain a desired national agri-food safety and quality level. The trade and welfare effects of the different possibly appropriate regulatory measures differ, and it is not well understood which measures are minimal with respect to their trade effects and consequently not more trade restrictive than required. Even

[4] Beghin et al. (2009) provide information on recent methods determining the consumers' willingness to pay and how to appropriately depict the consumers' behavior in face of regulatory measures.

more, the desired policy goals are not necessarily only formulated in consideration of the provisions of multilateral trade rules, leaving an opportunity for policy makers to select a regulatory measure that may follow other objectives keeping away foreign competition.

The objective of this thesis is first, to show that the trade effects of different existing regulatory measures governing trade in meat can differ considerably, being negative, not measurable, or even positive. The different measures' trade effects are quantified via case study work on meat products defined in the Harmonized System (HS) 02 code at a 4-digit level using a broad set of different regulatory measures and different policy goals. The selection of the appropriate measures determines the trade restrictiveness of the implementation of the desired policy goal.

A second objective is to analyze trade and country welfare effects of changes in importers' regulatory policies using as an example the poultry meat sector which was heavily influenzed by the avian influenza (AI) disease in the last decade. Poultry meat is split into uncooked meat which is defined as the HS code 0207 and cooked meat which is defined as the aggregate of the HS codes 160231, 160232, and 160239. This breakdown is made because the risk or threat associated with the prevalence of AI differs between both product categories. The trade and welfare effects of two different policy scenarios are quantitatively compared. Poultry meat is chosen because it is the fastest growing meat product in terms of global production in the last decade, but simultaneously its trade is regulated intensively due to the prevalence of the AI disease.

1.2 Methodological background

This thesis applies two methods – econometric and simulation modeling - for quantitatively determining the impact of governmental regulations on trade and welfare.

For quantifying the impact of regulatory measures on meat and poultry meat trade an econometric model is estimated which basically describes bilateral trade flows by a function of exporter and importer gross domestic product (GDP) and trade costs such as geographic distance and regulations. The application of this so-called gravity model goes back to Tinbergen (1962). He first employed the concept of the gravitational force to explain the volume of international trade. Different econometric techniques have been applied in the literature to estimate the gravity model, and advantages and drawbacks of the most relevant techniques are discussed. The first case study of this thesis employs a non-linear panel data gravity model which is estimated by fixed effects Poisson pseudo-maximum likelihood (PPML) in order to estimate the magnitude of different regulatory measures on meat trade. In a second case study a sample selection model based on Heckman (1979) and Helpman et al. (2008) is developed to receive coefficients measuring the impact of AI-related policy measures on bilateral poultry meat trade flows. In a first step, a Probit model is estimated by seemingly unrelated regression (SUR) maximum likelihood (ML). In a second step, the conditional expected trade flow given that the trade observation is positive is estimated by non-linear least squares (NLS).

For quantifying the welfare effect of AI-related policy variations a spatial partial equilibrium model is developed in the second case study that is based on a Takayama-Judge-type design (Takayama and Judge 1971). It contains a risk dimension to separate the policy variation impact from other effects and to calculate the policy measures' impact on welfare. The Takayama-Judge model goes back to Enke (1951), Samuelson (1952) and Takayama and Judge (1964) and reproduces the equilibrium prices and trade flows of spatially separated markets. The spatial price equilibrium renders prices, trade flows and quantities supplied and demanded. They satisfy the equilibrium condition of equalizing prices in the importing country with those in the exporting country plus transport costs, including costs associated with adhering to import requirements.

1.3 Structure of the thesis

The core of the thesis consists out of two case studies. Each case study is preluded by a chapter discussing in detail theory and methodology used in the case studies.

Chapter 2 deals with theory and quantitative methods available to determine the impact of regulatory measures on trade and gives first reasons for the choice of the different applications of the gravity model in the two case studies. Section 2.1 provides a general overview on deriving the gravity model theoretically on a sound economic base. Section 2.2 discusses different econometric applications of the theoretically derived trade models. It provides available results on estimated impacts of border barriers in general and technical regulations in particular on (agri-food) trade. Section 2.3 highlights the findings of the chapter.

Chapter 3 describes the first case study. Given that only limited knowledge exists on specific trade impacts of different regulatory measures and given that policy makers have a wide range of different policy measures available to enforce their desired policy goals especially in the meat sector, this case study analyzes the trade impact of different regulatory measures imposed to achieve a desired level of sanitary health and quantifies different implied trade effects. In addition, the case study identifies those sanitary measures that most adequately conform to Articles 5.4 and 5.6 of the SPS Agreement, differentiated by classes of regulations and policy objectives. The choice of the econometric approach used to estimate the gravity model is discussed in section 3.1. In section 3.2 the case study contains the results of an extensive search and gathering of information on regulatory sanitary measures in the meat sector. 29 specific regulatory instruments are identified and rearranged into six classes which describe different agri-food safety purposes. The regulatory instruments are additionally assigned to one or more of four different policy goals that are part of the mandatory national WTO notifications. Section 3.3 presents the results of the analysis and different specification tests, before section 3.4 concludes.

Chapter 4 discusses theory and quantitative methods available to determine welfare impacts of NTMs. Two different types of simulation models are contrasted with each other in section 4.1 - the Takayama-Judge model and the Armington model. Section 4.2 discusses how to include regulatory measures and their associated costs and benefits into a Takayama-Judge-type partial equilibrium model, looking on the supply as well as on the demand side. Section 4.3 discusses the findings of this chapter.

Chapter 5 contains the second case study of this thesis. Given the growing importance of trade in poultry meat, many countries implement drastic measures to restrict poultry meat trade associated with a perceived or actual risk of transferring AI into their territory. The case study therefore aims at analyzing the impact of avian influenza-related policy measures on trade with poultry meat and the importers' and exporters' welfare by using an econometric and a simulation model. The econometric model evaluates AI-related policies in terms of their trade impact, differentiating between cooked and uncooked poultry meat, as policy makers differentiate between both product categories. Furthermore, feasible future policies are evaluated ex ante using a partial equilibrium model. The welfare changes due to variations in the importers' AI-related regulatory policies are analyzed, considering transmission risks according to the disease status of the considered countries. Section 5.1 describes the methodology of the gravity and the partial equilibrium model and explains the data used. Results of both models are presented and discussed in section 5.2. Section 5.3 concludes.

In chapter 6 the thesis presents a summary of the results and discusses limitations of the work. Finally, concluding remarks are drawn from the analysis.

2 Determining the trade impact of regulatory measures

It can be thought of many possible situations where import requirements can increase trade, decrease it or leave it unaltered.[5] The trade effect of regulatory measures is therefore a priori unclear. This makes the question about how these measures affect trade flows first and foremost an empirical one. The following chapter concentrates on analytical methods quantifying the impact of regulatory instruments on countries' trade flows and motivates the choice of the methods used in the analytical case studies of this thesis presented in chapters 3 and 5.

For quantitatively determining the trade impact of regulatory measures a specific form of an econometric model is applied most often in the literature which is called gravity model. [6] It describes bilateral trade flows by a function of exporter and importer GDP and world GDP (Deardorff 1998). Gravity models are quantity-based econometric models. Contrary to simulation models which utilize price terms directly, gravity models include price terms only implicitly via a function of observable and unobservable variables. Insofar gravity models do not allow for welfare economics, but the estimated trade flow impact can be transformed into price effects via marginal effects and elasticities to obtain tariff equivalents.

Under the assumption of trade frictions the assessment of impacts of any form of tariff or non-tariff measures is allowed, including regulatory measures, by the integration of different relevant variables potentially leading to "distance" between countries. In generally, gravity models ask for the impact of NTMs on (bilateral) trade flows. They consider the foregone trade that cannot be explained by tariffs and other potential explanatory variables. As such they do not only consider the trade volume per exporter, but can also take into account the number of trade

[5] This chapter is based on the two papers Schlueter (2008) and Demaria et al. (2011).

[6] The literature of applied economics discusses several methods of quantifying non-tariff trade measures: See Cipollina and Salvatici (2008), Ferrantino (2006), Bora et al. (2002), Beghin and Bureau (2001), Deardorff and Stern (1997).

relationships. This is of major importance as many potential trade relationships do not come about on a product-specific level, thus trade flows are zero.

The application of gravity models goes back to Tinbergen (1962) who employed the gravitational force concept to explain the volume of international trade. In his econometric analyses he shows that trade is determined by the economic size of trading partners as well as by their geographic distance. Anderson (1979) first presents a theoretical foundation for the gravity model. It is based on constant elasticity of substitution (CES) preferences with goods being differentiated by their origin. Subsequent extensions of economic gravity model theory have added Heckscher-Ohlin structures (Deardorff 1998, Dornbusch et al. 1980), monopolistic competition (Redding and Venables 2004, Bergstrand 1989, Helpman 1987), or Ricardian elements (Eaton and Kortum 2002).

Usually, gravity models are specified in a straightforward log-normal equation that is estimated by ordinary least squares (OLS). However, there are considerable problems associated with this specification and its estimation, as depending on the structure of the data the estimates might be biased and inefficient. First, trade is determined by relative trade barriers. Omitting unobserved country-pair heterogeneity such as multilateral resistance may cause biased estimates (Baldwin and Taglioni 2006, Anderson and van Wincoop 2003). Second, many potential trade relationships on a product-specific level do not exist. Standard sample selection bias may result from the need to drop the observations with zero trade flows when log-linearizing the gravity equation (Helpman et al. 2008, Silva and Tenreyro 2006). Third, potential unobserved firm level heterogeneity caused by an omitted variable which measures the impact of the number of exporting firms may produce biased estimates, i.e. the intensive (trade volume per exporter) and extensive margin (number of trade relationships) of the trade impact of trade frictions has to be taken into account (Silva and Tenreyro 2008, Helpman et al. 2008). And fourth, the assumption of homoscedasticity of the errors is questionable resulting in inefficient estimates (Martin and Pham 2008, Silva and Tenreyro 2006).[7]

This chapter first provides an overview on the literature presenting different theoretical derivations of the gravity model, and second summarizes recent literature on different estimation techniques that go beyond the log-normal gravity model specification and thus account for some or all of the aforementioned problems. The last section concludes.

2.1 Economic specification of the gravity model

The gravity model can be given a structural interpretation from a wide range of trade theories. This chapter reviews main developments in the theoretical specification of gravity models. Consider a frictionless trade equilibrium, where each country is a net exporter of some products to the world market and a net importer of others, prices for goods are the same for all consumers, and consumers are indifferent with regard to the products' origins. These assumptions are sufficient to develop a model which falls automatically in the simple gravity structure

$$M_{ij} = \frac{Y_i Y_j}{Y^w} \tag{1}$$

as shown by Deardorff (1998) and Bergstrand (1989), where M_{ij} presents the trade value from exporting country i to importing country j, Y_i is exporter GDP, Y_j is importer GDP and Y^w presents world GDP. The gravity model can be given a structural interpretation from a wide range of trade theories. This section reviews main developments in specifying gravity models theoretically.

[7] Baldwin and Taglioni (2006) summarize various canonical challenges in the gravity literature.

Gravity in Heckscher-Ohlin trade models

Deardorff (1998) extends the simple gravity equation by motivating it in the context of the HO trade theory assuming first frictionless trade, i.e. $net\ trade \leq gross\ trade$ as consumers are indifferent among all equally priced sources of supply. Second, he assumes trade restrictions; then factor prices cannot be equal across any two countries that trade with each other as prices of goods must differ between those countries to overcome the positive trade costs. Production lies outside the factor price equalization set when large differences in factor endowments across countries exist. As a result product specialization arises (Feenstra 2004, Dornbusch et al. 1980).[8] Deardoff (1998) employs a utility maximizing model, first with Cobb-Douglas preferences, then with constant elasticity of substitution (CES) preferences. As before, competition is assumed to be perfect. Cobb-Douglas preferences imply that identical fractions of income in each importing country j are spent on the product of country i, as the demand elasticities of utility for consuming the products of the exporting countries equal the expenditure shares of the importing countries. With Cobb-Douglas preferences, Deardoff (1998) derives again the simple gravity equation $M_{ij}^{cif} = \frac{Y_i Y_j}{Y^w}$, where M_{ij}^{cif} is the trade flow valued by c.i.f. prices[9], and $M_{ij}^{fob} = \frac{Y_i Y_j}{Y^w} \frac{1}{t_{ij}}$, where M_{ij}^{fob} represents the trade flow valued by f.o.b. prices[10], and t_{ij} represents trading costs including transport costs, tariffs and costs caused by NTMs. F.o.b prices equal c.i.f prices minus the costs for transportation and insurance between exporting and

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[8] Evenett and Keller (2002) criticize that the HO model predicts perfect product specialization in different countries only for large differences in product endowments. In contrast, increasing returns to scale models do not need the assumption of differences in factor proportions to derive perfect specialization.

[9] The c.i.f. price is the price of a good delivered at the frontier of the importing country including the costs of the good, insurance and freight.

[10] The f.o.b. price is the price of a good at the customs frontier of the country from which it is exported and means 'free on board price'.

importing countries' borders. Deardorff (1998) argues that even though the trade value with f.o.b prices declines with increasing transport costs, bilateral expenditures on international trade do not go down with higher trade costs when assuming Cobb-Douglas preferences. In contrast, deploying homothetic CES preferences yields a gravity structure which ensures that increasing bilateral distance between trading partners reduces trade expenditures. Homotheticity provides for ratios of demanded goods depending on relative prices only, and not on consumers' income. Bilateral trade then equals the simple gravity equation multiplied by an expression called remoteness term. In its simplest form, remoteness can be understood as income weighted distance from all other countries, divided by world income (Coe et al. 2007, Wei 1996). Deardorff's (1998) remoteness index is a ratio of the relative distance between exporting country i and importing country j and the average of all importers' relative distances from exporter i:

$$R_j = \frac{\left(\dfrac{t_{ij}}{\left(\sum_i \alpha_i t_{ij}^{1-\sigma} \right)^{\left(\frac{1}{1-\sigma}\right)}} \right)^{1-\sigma}}{\sum_j \theta_j \left(\dfrac{t_{ij}}{\left(\sum_i \alpha_i t_{ij}^{1-\sigma} \right)^{\left(\frac{1}{1-\sigma}\right)}} \right)^{1-\sigma}}, \qquad (2)$$

where the numerator is country j's relative distance from country i, and the denominator is the average of all importers' relative distances to exporting country i. Parameter σ is the elasticity of substitution between all goods with $\sigma \geq 1$; the closer substitutes countries' goods are to each other, the higher is the elasticity, and the greater is the extent to which bilateral trade flows are constrained by trade costs. Parameter α_i represents the share of income consumers in each country spent on goods from country i, and $\theta_j = \frac{Y_i}{Y^w}$. The remoteness term ensures that with increasing bilateral transport costs between two trading partners expenditures on bilateral trade are smaller than under the assumption of Cobb-Douglas preferences. However, homothetic CES utility functions have a decisive disadvantage when some of the trade data is zero, e.g. when examining trade on a disaggregated product level. As homothetic CES utility specifications do not allow for zero utility when income is positive and the product is consumed in other countries, and thus zero trade is theoretically infeasible, the assumption of homotheticity is infeasible.

Non-homothetic CES utility functions may help to overcome this problem. Considering a non-homothetic CES utility function, the expansion path has an intercept that is unequal to zero but is still linear (quasi-homothetic preferences), and/or is not longer a straight line (strictly non-homothetic preferences). That means, the expansion path can be shifted below the origin, which implies that consumers buy the product only if income exceeds a certain threshold. Non-consumption of specific products and thus zero trade flows are theoretically probable. Non-homothetic preferences have been identified to impact trade substantially (Francois and Kaplan 1996, Hunter 1991, Hunter and Markusen 1988). Tchamourliyski (2002) provides evidence that ignoring non-homotheticity overstates the importance of distance for trade considerably.

Gravity in Ricardian trade models

Davis (1995) opens the gravity equation for technological differences across countries and inserts Ricardian elements into the theoretical derivation. Even though the Ricardian trade model is less prevalent in the theoretical discussion about gravity models, it can deliver simple structural equations for bilateral trade when applied in relation to geographic barriers. Eaton and Kortum (2002) derive a multi-country Ricardian trade model with perfect competition, constant returns to scale, and geographic barriers. The model is based on a two-country Ricardian trade model with a continuum of goods (cf. Dornbusch et al. 1977). Specialization is governed by geographic barriers as well as by technology. Efficiency varies across commodities and countries. The technological heterogeneity is depicted in a probabilistic formulation which is chosen to be Fréchet, $F_i\left(z\right)=e^{-T_i z^{-\gamma}}$, where $F_i\left(z\right)$ is the country-specific probability distribution of its efficiency in production, $T_i>0$ and $\gamma>1$. The parameters T_i and γ allow to develop a model with many countries that differ in the basic Ricardian sense of absolute and comparative advantage across a continuum of goods. The country-specific parameter T_i enables the model to display absolute advantages across products; T_i appoints the location of the efficiency distribution and is interpreted as state of technology in country i. The parameter γ reflects heterogeneity across goods in countries' relative efficiencies and is assumed to be common to all countries; it appoints the comparative advantage within the continuum of goods. A lower γ implies more variability and thus brings about a stronger force for trade against the trade impediments of geographic barriers. Eaton and Kortum (2002) imply perfect competition and mobility of inputs within a country. A CES utility function is maximized subject to a budget constraint which aggregates spending. They obtain the following equation:

$$\ln\frac{M'_{ij}}{M'_{jj}}=-\gamma\ln D_{ij}+S_i-S_j, \tag{3}$$

where M'_{ij} are transformed trade flows from country i to country j, $D_{ij}\geq 1$ is the tariff equivalent of bilateral border barriers (Samuelson's (1952) iceberg tariffs), and S_i is country i's state of technology adjusted for its labor costs. Substituting D_{ij} in equation (3) with proxies for geographic barriers of the standard gravity literature enables to estimate the impact of regulatory instruments.

Gravity in Armington-like trade models

Anderson and van Wincoop (2003) pick up the idea of relative transport costs presented in Deardorff (1998). Based on Anderson‘s (1979) expenditure system with homothetic CES preferences and Armington-like product differentiation,[11] Anderson and van Wincoop (2003) develop a gravity model which is the product of the simple gravity structure and a relative transport cost term called multilateral resistance. Consumers in importing country j maximize a homothetic CES utility function:

$$U_j = \left(\sum_i a_i^{1-\sigma/\sigma} \left(x_{ij} \right)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}, \tag{4}$$

s.t. budget constraint $\sum_i p_{ij} x_{ij} = Y_j$.

When preferences are supposed to be identical and homothetic, the utility function’s share parameter a_i is the same for all importing countries j concerning a specific exporter i. The value of goods consumed in importing country j with origin in country i is $x_{ij} p_{ij} = M_{ij}$. Parameter p_{ij} is the c.i.f. price in the importing country and can alternatively be written as $p_{ij} = p_i t_{ij}$, with t_{ij} being Samuelson’s (1952) iceberg trade costs which are proportional to the quantity of trade (including transportation costs and a set of border barriers such as regulatory instruments). The supply price p_i can be understood as f.o.b. price. Parameter σ represents the elasticity of substitution for all pairs of goods, and Y_j is country j’s income. Maximizing the utility function with respect to the budget constraint brings about the expenditure share. Multiplying the expenditure share with aggregate

[11] Anderson (1979) first derives the gravity equation from models assuming product differentiation by country of origin, which ensures intraindustry specialization in a world of perfect competition and constant returns (cf. Armington 1969).

expenditure in importing country j produces the value of imports from exporter *i.* The general equilibrium structure of the model implies that revenues equal expenditures, thus markets are cleared. Prices are normalized and the market clearance condition is used to solve for the product of share coefficients a_i and prices p_i. This is possible because the share parameter is the same for all importers with respect to a specific exporter. After some substitution and conversion, and under the assumption of symmetric trade barriers in bilateral trade, Anderson and van Wincoop's (2003) gravity equation becomes

$$M_{ij} = \frac{Y_i Y_j}{Y^w}\left(\frac{t_{ij}}{P_i P_j}\right)^{1-\sigma}, \qquad (5)$$

where $P_j = \left(\sum_i P_i^{\sigma-1} t_{ij}^{1-\sigma} \theta_i\right)^{\frac{1}{1-\sigma}}$, $Y^w = \sum_j Y_j$, and $\theta_j = \frac{Y_j}{Y^w}$.

The first expression on the right-hand-side of the equal sign in gravity equation (5) is the well known simple gravity structure. The second expression in this equation relates bilateral trade costs t_{ij} to a product consisting out of multilateral resistance variables, P_i and P_j, which are not observable. They can be interpreted as the average trade barrier of exporting and importing countries with all their trade partners (Anderson and van Wincoop 2003, Baier and Bergstrand 2002).[12] The multilateral price terms P_i and P_j can be estimated consistently using either a complex non-linear estimation technique, or by introducing country-specific fixed effects (cf. Feenstra 2004, Rose and van Wincop 2001).

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[12] The concept of 'multilateral resistance' is also used in Hummels (2001) and Bergstrand (1989, 1985).

Gravity in monopolistic competition trade models

Recent empirical literature on effects of regulatory instruments on trade is mostly based on monopolistic competition and increasing returns (Disdier et al. 2008a, Carrère 2006, de Frahan and Vancauteren 2006). Markets are characterized by a large number of firms, each of them completely specialized in different product varieties as returns to scale are assumed to be increasing. There is free entry of markets whenever economic profits are positive, so in the long run equilibrium profits have to be zero. First mathematical formulations of the monopolistic competition model were made by Lancester (1979, 1975), Dixit and Stiglitz (1977), and Spence (1976). Helpman and Krugman (1985) developed an increasing returns to scale model and Bergstrand (1989) allowed additionally for factor endowment differentials and non-homothetic preferences. Feenstra (2004) shows that assuming free trade, identical prices in all countries, and identical and homothetic demand across countries, a good produced in any country is consumed in any country according to the country's purchasing GDP. Prices are normalized. Then y_i^k measures the production value of product variety k in country i. Let GDP in each country be $Y_i = \sum_k y_i^k$, where $k = 1, 2, ..., N$ is the number of varieties of goods produced in country i. World GDP is $Y^w = \sum_i Y_i$. If trade is balanced, $\theta_j = \frac{Y_j}{Y^w}$ denotes country j's share of world expenditure, and thus country j's share of world GDP. Then trade of product k from exporter i to importer j is given by $M_{ij}^k = \theta_j y_i^k$. Summing over all products k, Feenstra (2004) obtains

$$M_{ij} = \sum_k M_{ij}^k = \sum_k \theta_j y_i^k = \theta_j Y_i = \frac{Y_j Y_i}{Y^w}, \tag{6}$$

which is again the simple gravity equation that was seen in equation (1).

2.2 Econometric application of the gravity model

This section discusses how the above described trade models are applied in econometric approaches, and provides available results on estimated impacts of border barriers in general and technical regulations in particular on (agri-food) trade. An overview of presented methodology is displayed in Table 1 at the end of this section. The simple log-linear regression model estimated by OLS seems to be quite appropriate to explain the existence of gravity in international trade. But some model specifications and especially the properties and condition of the data makes it necessary to look at more sophisticated econometric procedures. Recent literature provides estimation techniques accounting for the problems associated with the standard estimation procedure. Possible solutions being discussed in this section comprise the non-linear estimation model, fixed effects and random effects model, the sample selection model, Poisson, as well as the negative binomial Poisson and the zero-inflated, negative binomial Poisson model.

Log-linear regression models and ordinary least squares

In a log-linear form, allowing the coefficients of the right-hand-side variables to vary from unity, the simple gravity model looks like

$$\ln M_{ij} = c + \beta_1 \ln Y_i + \beta_2 \ln Y_j \,, \qquad (7)$$

where $c = -\ln Y^w$. Tinbergen (1962) uses a simple regression model to explain the value of bilateral trade by the economic size of trading partners and their distance. In its simplest form, he estimates the log-linear model

$$\ln M_{ij} = \beta_0 + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 \ln D_{ij} + u_{ij} \qquad (8)$$

on cross-sectional trade data of 18 countries for the year 1958, where D_{ij} is the geographic distance between two trading partners and u_{ij} is the error term which is independent and identically distributed with zero mean and constant variance $IID\left(0,\sigma^2\right)$. In further extensions, he includes dummy variables for neighboring countries, for membership in the Commonwealth and membership in the Benelux. Estimation is done by OLS. He estimates a substantial negative trade effect of increasing distance between countries, while all included dummy variables have slightly positive impacts on bilateral trade performance. McCallum (1995) uses the log-linear gravity model to estimate the trade impact of the border between Canadian provinces and United States (US) states. He includes a dummy variable which equals one for interprovincial trade and zero for province-to-state trade. Cross-sectional data for the year 1988 is applied. The estimates of the border effect reveal that interprovincial trade is an astonishing 22 times larger than cross-border trade.

However, four considerable problems are associated with this specification, as depending on the structure of the data the estimates might be biased an inefficient. First, omitting unobserved country-pair heterogeneity such as multilateral resistance may cause biased estimates as trade is also determined by relative trade barriers (Baldwin and Taglioni 2006, Anderson and van Wincoop 2003). Second, the occurrence of zero trade flows makes log-linearization infeasible and results in sample selection bias when dropping these observations (Helpman et al. 2008, Silva and Tenreyro 2006). Third, as a result of potential unobserved firm level heterogeneity which allows the number of exporting firms to vary across importing countries, it has to be taken into account that the regulatory measures' trade impact may have to be decomposed into the intensive and extensive margin (Helpman et al. 2008, Silva and Tenreyro 2006). And fourth, the assumption of homoscedastic errors is questionable when trade flows for small and remote countries approaching zero are combined with large trade flows in the estimation (Martin and Pham 2008, Silva and Tenreyro 2006).

The following three models (non-linear regression model, fixed effects model, random effects model) tackle the problem of unobserved country-pair heterogeneity, and thus deal with the first problem mentioned above.

Non-linear regression models

Assuming monopolistic competition and a CES expenditure system with identical and homothetic preferences, Anderson and van Wincoop (2003) develop a theory-consistent, non-linear gravity model which is estimated by NLS and specifies a trade cost factor which is able to include different variables for regulatory instruments. As McCallum (1995), they compare international trade flows between Canadian provinces and states in the US with intranational trade between US states among themselves and Canadian provinces among each other in a cross-sectional data structure. Their estimated model being derived from equation (5) looks as follows:

$$\ln\left(\frac{M_{ij}}{Y_i Y_j}\right) = \beta_0 + \beta_1 \ln d_{ij} + \beta_2\left(1-\delta\right) - \left(1-\sigma\right)\ln P_i - \left(1-\sigma\right)\ln P_j + \varepsilon_{ij} \quad (9)$$

s.t. $P_j^{1-\sigma} = \sum_i P_i^{\sigma-1}\theta_i e^{\beta_1 \ln d_{ij} + \beta_2\left(1-\delta_{ij}\right)} \quad \forall \quad j$,

where $\beta_1 = \left(1-\sigma\right)\rho$, $\beta_2 = \left(1-\sigma\right)\ln b$, σ is the elasticity of substitution between all goods, δ is a dummy variable equal to one for interprovincial trade and zero for state-province trade, $\theta_i = \frac{Y_i}{Y^w}$, and ε_{ij} is an error term which is $IID\left(0,\sigma_\varepsilon^2\right)$, where σ_ε^2 is the error's variance. In Anderson and van Wincoop (2003) the trade cost factor (cf. equation (5)) is modeled as $t_{ij} = b_{ij} d_{ij}^{\rho}$, where $b-1$ is the tariff equivalent of the US-Canadian border barrier which can be modified in a way to capture specific regulatory measures (cf. de Frahan and Vancauteren 2006) and d_{ij} is the distance between both trading regions. Anderson and van Wincoop (2003) solve for the multilateral resistance variables P_i and P_j implicitly and estimate the coefficients β_0, β_1, and β_2 using NLS. On the country GDP variables they impose unitary coefficients.

The impact of multilateral resistance variables on the regression outcome is evident when comparing results of Anderson and van Wincoop (2003) with results of McCallum (1995). One explanation for the tremendous border effect in McCallum (1995) is his ignorance of multilateral resistance (and country heterogeneity caused by unobservables). Anderson and van Wincoop estimate McCallum's gravity equation once again for the year 1993 and get a 16.4 times larger intraprovince trade than province-to-state trade. Estimating their own gravity model for 1993 including multilateral resistance reduces the Canadian border effect to 10.5, suggesting that estimates of the simple linear regression model are biased.

Fixed effects models

One feasible alternative for NLS estimation of Anderson and van Wincoop's (2003) gravity model is the incorporation of country-specific or country-pair-specific fixed effects which capture unobserved country or country-pair heterogeneity such as multilateral resistance (Feenstra 2004, Rose and van Wincoop 2001). Fixed effects models yield similar results to the case when multilateral resistance variables are included directly. In gravity application, fixed effects cover unobserved variables which are specific to cross-sectional units (exporter and/or importer components) and/or to time periods (Egger 2000). In the three-dimensional panel setting with country-specific fixed effects, the fixed effects model has the form

$$m_{ijt} = x'_{ijt}\beta + \alpha_i + \alpha_j + u_{ijt}, \qquad (10)$$

with α_i and α_j being fixed effects of the exporting and importing countries which are constant over time, m_{ijt} and x_{ijt} being vectors of logarithmic dependent and explanatory variables, β being a vector of coefficients which are time-invariant and constant for all bilateral combinations, and u_{ijt} being the combined cross-sectional and time series error term which is $IID\left(0,\sigma_u^2\right)$. The intercept varies for each cross-sectional unit, but slope coefficients are constant across units. The fixed effects α_i and α_j may include country-specific size and price effects (such as multilateral resistance variables). Whereas the explanatory variables have to be strictly exogenous conditional on the fixed effects, i.e. $E\left(u_{ijt} \mid x_{ijt}, \alpha_i, \alpha_j\right) = 0 \ \forall$ t, the fixed effects are allowed to be any function of the explanatory variables: $E\left(\alpha_i \mid x_{ijt}\right) \neq 0$ and $E\left(\alpha_j \mid x_{ijt}\right) \neq 0$. For estimating fixed effects models, equation (10) is transformed in a way that observations in deviation from individual means are produced:

$$m_{ijt} - \overline{m}_{ij} = \left(x_{ijt} - \overline{x}_{ij}\right)' \beta + \left(u_{ijt} - \overline{u}_{ij}\right), \tag{11}$$

where $\overline{m}_{ij} = T^{-1} \sum_t m_{ijt}$, and the individual fixed effects α_i and α_j are dropped out through the demeaning procedure. The transformed model can be estimated by an OLS estimator, which is then called the within estimator (Verbeek 2004). Using the within estimator means everything that is time-invariant is eliminated from the model. Unfortunately, direct estimation of country-specific effects of potentially important explanatory variables like NTMs which are time-invariant is then not possible anymore. However, running the least squares dummy variable (LSDV) estimation

$$m_{ijt} = \sum_i \alpha_i d_{ij} + x'_{ijt} \beta + u_{ijt}, \tag{12}$$

where $d_{ij} = 1$ if $i = j$, and $d_{ij} = 0$ if $i \neq j$, additionally yields estimates for the coefficients of included fixed effects, and time-invariant observables which are not perfectly correlated with d_{ij} are not dropped. This regression, however, can be very cost-intensive in terms of degrees of freedoms as coefficients of many regressors have to be estimated.

Disdier et al. (2008a) and Disider et al. (2008b) analyze impacts of regulations notified under the SPS and TBT Agreement on agricultural trade flows. Their gravity model is built upon monopolistic competition and CES utility functions. A two-dimensional cross-sectional dataset is employed, meaning the time subscript is skipped. Fixed effects variables are included on an HS 2-digit sector level. Products are aggregated on an HS 4-digit level, as well as data on SPS and TBT notifications and tariffs. Zero trade flows are being treated as missing. LSDV estimation is employed. Results show that SPS and TBT measures altogether have a negative impact on trade in agricultural products. Especially exports from developing and least developed countries are negatively affected, whereas trade within Organisation for Economic Co-operation and Development (OECD) countries is not influenced significantly. The analysis also shows that even European Union (EU) member countries notify less SPS and TBT measures than other OECD countries, these measures are more trade restricting than the ones adopted by other OECD countries. Research on estimating the effect of a specific regulation employing a fixed effects model is done by Wilson and Otsuki (2001), Otsuki et al. (2001a) and Otsuki et al. (2001b). All three articles estimate the impact of a maximum residue level (MRL) of aflatoxin on trade in different products like cereals, nuts, dried fruits and vegetables which are mostly exported from African countries to the EU. The authors employ a panel dataset for the years 1989 to 1998 and 1995 to 1998. Estimation results show that tighter European regulations for aflatoxin would reduce African exports to the EU substantially. The difference between possible exports under the regulations established by the Codex Alimentarius and exports likely under the discussed new European rules would amount to 63%. Moenius (2004) utilizes a fixed effects model to analyze whether harmonized standards yield greater trade flows than country-specific product and process standards. A panel dataset is constructed for 471 industries in 12 different countries on a 4-digit standard international trade classification (SITC) level for the years 1985 to 1995. Moenius (2004) concludes that generally harmonized standards are favorable in comparison to country-specific standards. However, country-specific standards do not present a trade barrier per se. The author differentiates between manufactured and non-manufactured goods (like agricultural goods). The negative trade effect prevails just for the latter.

Random effects models

Like the fixed effects model, the random effects model is an unobserved effects model. The difference between both models is that in the former the included unobserved heterogeneity effects are allowed to be correlated with the observed explanatory variables, whereas in the latter they have to be independent of the explanatory variables (Egger 2005). The random effects model is represented according to

$$m_{ijt} = \mu + x'_{ijt}\beta + \alpha_i + \alpha_j + u_{ijt}, \tag{13}$$

$u_{ijt} \quad IID\left(0,\sigma_{\varepsilon}^{2}\right)$, $\alpha_i \quad IID\left(0,\sigma_{\alpha_i}^{2}\right)$, and $\alpha_j \quad IID\left(0,\sigma_{\alpha_j}^{2}\right)$,

where the dependent and explanatory variables are logarithmic. The composite error term $u_{ijt} = \alpha_i + \alpha_j + \varepsilon_{ijt}$ is made up from (cross-sectional) exporter and importer random drawings α_i and α_j and a residual component ε_{ijt} which is uncorrelated over time. The intercepts are different across individuals, but they can be treated as drawings from a distribution with mean μ and variances $\sigma_{\alpha_i}^{2}$ and $\sigma_{\alpha_j}^{2}$, respectively.

De Frahan and Vancauteren (2006) employ a Tobit random effects model on a panel dataset for the years 1990 to 2001 and estimate the model using weighted ML. They analyze the effect of harmonization of EU food regulation on intra-EU trade on a product-specific level. The trade data on agri-food products is grouped according to the 4-digit nomenclature générale des activités économiques dans les Communautés européennes (NACE) industrial classification. When analyzing trade data on disaggregated product levels bilateral trade flows may be zero, caused by missing data or due to non-existent trade. Dropping these observations leads to nonrandom selection bias which causes specification errors and biased estimates in econometric analysis (Heckman 1979). The Tobit model is particularly appropriate to estimate a model including zero trade flows because it censors observations at zero. However, before being log-linearized, zero trade flows have to be changed to any small positive number, e.g. to one, which presents an a-theoretic transformation of the data.

The Tobit model goes back to Tobin (1958) and was extended in the following decades (Amemiya 1984). The standard Tobit model in a panel setting is presented according to the equations

$$
\begin{aligned}
& m_{ijt}^{*} = x_{ijt}'\beta + u_{ijt}, \\
& m_{ijt} = m_{ijt}^{*} \quad if \quad m_{ijt}^{*} > 0, \qquad (14) \\
& m_{ijt} = 0 \quad if \quad m_{ijt}^{*} \leq 0,
\end{aligned}
$$

where the latent response variable m_{ijt}^{*} is the assumed solution to the model and can be positive, zero, or negative. The observed variable m_{ijt} is positive if the latent variable is positive, or it is zero if the latent variable is zero or negative. The error term u_{ijt} captures the unobserved heterogeneity and is assumed to be $IID\left(0,\sigma_u^2\right)$. Estimation is usually done by ML. De Frahan and Vancauteren (2006) conclude that harmonization of food regulation stimulates intra-European trade at different levels of product aggregation significantly. The strength of the positive impact depends on the particular food sector considered. Fontagné et al. (2005) estimate a Tobit random effects model for analyzing the impact of environmental trade barriers across 161 product groups (agricultural and non-agricultural products) in a setting of 114 exporting and 61 importing countries. Trade data is cross-sectional for the year 2001. Results of Fontagné et al. (2005) support findings of Moenius (2004): The trade impact of regulatory measures depends on the level of processing of the traded product. While the effect of environmental trade barriers on fresh and processed goods is mostly negative, it is insignificant or even positive for most manufactured goods. Eaton and Kortum (2002) estimate a cross-sectional multi-country Ricardian trade model. Trade flows of manufactures of 19 OECD countries are included for the year 1990. They estimate negative impacts for the distance parameter, and positive values for the included dummy variables.

Sample selection models

The sample selection model solves for the second shortcoming, namely the way non-existent trade flows are dealt with. An extension of the sample selection model also solves for the third identified problem, which is accounting for unobserved firm level heterogeneity.

The more disaggregated the product classification the more zeros appear in the datasets. The sample selection (or Heckman or Tobit II) model takes advantage of the presence of non-existent trade flows by making a selection of country-pairs trading and not trading with each other (sample selection). The model consists of two parts which are usually estimated via two separate equations.

First, the selection equation investigates the binary decision whether or not to trade by a Probit maximum likelihood model:

$$\rho_{ij} = \Pr\left(h_{ij} = 1 \mid x_1\right) = G\left(x_1, \beta_1\right), \qquad (15)$$

where ρ_{ij} is the probability that country i exports to country j conditional on the observed variables x_1 describing different sorts of trade costs potentially including fixed effects, and h_{ij} is a binary variable indicating whether a trade flow from country i to j is positive ($h_{ij}=1$) or zero ($h_{ij}=0$). The function $G(.)$ is a cumulative distribution function (cdf) of the bivariate normal distribution and is therefore in the interval $[0,1]$.

Second, the trade flow equation, or the conditional expected trade flow given that the trade observation is positive, is given by

$$E\{m_{ij} \mid h_{ij}=1\} = x_2\beta_2 + \sigma_{12}\lambda_{ij}\,, \tag{16}$$

where m_{ij} is the logarithmic observed trade flow from country i to country j given that the observed trade flow h_{ij} is positive, and x_2 denotes a vector of logarithmic observed trade cost characteristics. As in the selection equation (15), the unobserved errors are assumed to be distributed bivariate normal.[13] The covariance σ_{12} of the unobserved errors (or unobserved trade costs) of the selection and the trade flow equation is estimated as a coefficient in equation (16). Following Heckman (1979), Heckman's lambda $\lambda_{ij}=\frac{\phi(x_1\beta_1)}{\Phi(x_1\beta_1)}$ controls for sample selection and can be calculated after estimating equation (15); the calculated estimate $\hat{\lambda}_{ij}$ replaces λ_{ij} in equation (16).

[13] In principle, x_1 and x_2 can be identical, returning to the standard Tobit I model (Verbeek 2004). However, the estimation of the trade flow equation (16) requires the exclusion of a variable if the identification of the trade flow equation's coefficients β_2 shall not rely on both equations' normality assumption for the error terms (i.e. for the unobserved trade costs). Helpman et al. (2008) argue that the excluded variable has to be uncorrelated with the trade flow equation's error terms: The excluded variable must influence trade only through fixed trade costs because variable trade costs impact the extent of the volume of trade, thus variable trade costs are not uncorrelated with equation (16).

Helpman et al. (2008) extend the Heckman approach by not only controlling for sample selection through variable λ, but also accounting for unobserved firm level heterogeneity. The basic idea of firm level heterogeneity is that firms differ in their productivity levels in a way that only sufficiently productive firms are able to export by overcoming market entry costs such as NTMs. In their model the impact of trade frictions is decomposed into the trade volume per exporter and the number of exporters. Helpman et al. (2008) include an additional control variable accounting for the selection of firms into the export market. The trade flow equation then is

$$E\left\{m_{ij} \mid h_{ij} = 1\right\} = x_2\beta_2 + \sigma_{12}\lambda_{ij} + \omega_{ij}, \qquad (17)$$

where ω_{ij} controls for the fraction of firms exporting from i to j (which is possibly zero).[14]

Even though the Heckman and the Helpman approaches provide a natural way of dealing with zero counts, the trade flow equation (16) or equation (17) have to be transformed logarithmically which may cause biased estimates (Silva and Tenreyro 2006, Haworth and Vincent 1979). Another problem with this kind of model is the strict assumption of normality, unrealistically assuming homoscedastic error terms for all pairs of origins and destinations.

Poisson models

In contrast to the sample selection model, the Poisson specification of the gravity model handles all four above mentioned problems. First, omitted country-pair heterogeneity such as multilateral resistance is adhered to by including fixed effects. Second, because of its multiplicative form, the Poisson specification provides a natural way of dealing with zero trade flows. Third, unobserved firm

[14] Parameter ω_{ij} can be calculated from the estimates obtained by the sample selection equation (15), cf. equation (14) in Helpman et al. (2008).

level heterogeneity can be provided for in the model. And fourth, Poisson regression estimates are consistent in the presence of heteroskedasticity and are reasonably efficient, especially in large samples.

Given the vector of logarithmic observed trade cost characteristics x, the expected value of the trade flow M_{ij} is given by

$$E\left\{M_{ij} \mid x\right\} = \exp\left(x\beta\right). \tag{18}$$

This functional form is a good choice in modeling gravity equations because it produces non-negative conditional expectations without constraining the explanatory variables. When the trade flow variable M_{ij} is assumed to follow a Poisson distribution, a likelihood function can be derived whose first and second order moment conditions can be solved to obtain the vector of coefficients (Gourieroux et al. 1984).

The multiplicative form of the Poisson model allows estimating the gravity equation without logarithmic transformation of the trade flow observation M_{ij}. However, the Poisson assumption imposes restrictions on the conditional moments of the explained variable:

$$E\left(M_{ij} \mid x\right) \quad \propto \quad V\left(M_{ij} \mid x\right). \tag{19}$$

That means the conditional mean is assumed to equal the conditional variance (equidispersion).

In their econometric application Silva and Tenreyro (2006) deploy the Poisson model estimation on a dataset including typical explanatory variables of gravity models such as GDP per capita, population, distance, remoteness and several dummies. Cross-sectional data are used for the year 1990 for 136 countries, each of them exporting and importing. The authors compare results of OLS, Tobit, and

NLS estimation with the PPML outcome. Pseudo-maximum likelihood (PML) can be understood as a general methods of moments estimator with moment conditions corresponding to the first and second order conditions of maximum likelihood. If the ML estimator is based on a wrong likelihood function, but the conditional mean or variance (first and second order moments) are correctly specified, the estimation can be based on these moment conditions without knowing the correct distribution of the errors. The pseudo-likelihood function is specified appropriately as long as it is based on a probability density function (pdf) that is a member of the family of linear exponential functions, such as the normal or the Poisson pdf (Mittelhammer et al. 2000). PML then produces consistent and efficient estimates (Verbeek 2004, Mittelhammer et al. 2000).

Silva and Tenreyro (2006) find substantial differences in estimated coefficients, suggesting that heteroscedasticity influences results and that log-linearization leads to significant biases. This outcome is supported by Siliverstos and Schumacher (2008) who compare OLS with Poisson estimates. They use 3-digit international standard industrial classification (ISIC) trade data of the years 1988 to 1990 for 22 OECD countries and conclude that estimation of the log-linearized gravity equation leads to inconsistencies, whereas the non-linear approach is more appropriate. However, Olper and Raimondi (2008) find support in their agricultural trade data that Heckman’s two stage procedure (first stage: Probit model, second stage: OLS model) based on a fixed effects model produces similar results as PPML estimation.

Even though the four shortcomings are solved by the Poisson model, the presence of unobserved heterogeneity which is caused by unobserved trade costs is not taken into account by it, and consequently the conditional variance is most often higher than the conditional mean (overdispersion). According to Gourieroux et al. (1984), overdispersion brings out consistent, but inefficient estimates. A negative binomial Poisson regression model, which belongs to the family of modified Poisson models, can be employed in order to address the occurrence of overdispersion appropriately.

Negative binomial Poisson models

The expected value of the observed trade flow in the negative binomial Poisson model equals the one in the Poisson regression model, i.e. equals equation (18). However, the variance is not only specified according to a function of the conditional mean, but an additional term α is included which serves as a dispersion parameter:

$$V\left(M_{ij} \mid x\right) = \left(1 + \alpha^2 \exp\left(x\beta\right)\right) \exp\left(x\beta\right) \tag{20}$$

(Verbeek 2004, Cameron and Trivedi 1986). The additional dispersion parameter α allows the conditional variance to exceed the conditional mean and it determines the degree of the variance's dispersion. As a result, the unobserved heterogeneity is incorporated into the negative binomial Poisson model (Cameron and Trivedi 1986).

The incidence of overdispersion realistically allows explaining the occurrence of zeros by two different processes, leading to an extension of the pure negative binomial Poisson model.

Zero-inflated, negative binomial Poisson models (ZINBP)

As Burger et al. (2009) point out, overdispersion can hold for an explanation of an excessive number of zeros in the dataset. The number of zeros is excessive if it is greater than the Poisson or the negative binomial distribution predicts. The occurrence of excessive zeros can be explained by a second, 'non-Poissoneness' process (Johnson and Kotz 1969). It originates in the fact that not all pairs of countries have the potential to trade, be it due to a lack of resources or due to trade embargos. In this case the trade probability is zero by definition. In contrast, 'Poissoneness' zeros stem from the fact that distances and differences in preferences and specializations may be too big, i.e. a negative cost shock makes the trade volumes equal to zero even if in this case the trade probability is theoretically different from zero.

To account for these two different processes, the zero-inflated model considers the existence of two latent groups within the population; a group being 'non-Poisson', i.e. having a strictly zero probability to trade, and a group being 'Poisson', i.e. having a non-zero probability of observing positive trade flows. Three different groups of pairs of countries can be defined. First, pairs of countries having exactly a zero probability to trade and thus do not trade at all; second, pairs of countries with a non-zero probability to trade but which nevertheless do not trade; and third, pairs of countries with a non-zero probability to trade which are actually trading.

The two processes underlying the model are estimated in two parts. Equal to the first step in the Heckman model, the ZINBP model contains a Probit regression to estimate the probability of no bilateral trade at all ('non-Poisson' zeros). The second step is a negative binomial Poisson regression given that each of the country-pairs included have a non-zero probability ('Poisson' zeros).

The ZINBP model exceeds the sample selection model in several ways. It accounts for unobserved heterogeneity in the population with a zero count. Additionally, the ZINBP model is less restrictive, as it does not rely on stringent normality assumptions, nor does it require the exclusion of an explanatory variable in the second stage of the model. Furthermore, the bias created by the logarithmic transformation in the trade flow equation is not created in the zero-inflated, negative binomial Poisson model.

Xiong and Beghin (2011) replicate the analysis of Otsuki et al. (2001b) on the trade impacts of a change in European aflatoxin standards on African exports considering two important improvements. They include time variation in pesticide MRLs and they take into account the presence of zero trade flows in bilateral trade. The sample includes 14 European countries as importers and nine African countries as exporters as well as the three products edible groundnut, groundnut oil, and shelled groundnut. Xiong and Beghin (2011) compare the results of different estimators and conclude that the omission of the "multilateral resistance" terms induces severe biases to the estimates. They point out that the Poisson-like estimators are not robust when zero trade flows are pervasive. Unlike in previous econometric analyses of EU aflatoxin policies, Xiong and Beghin (2011) find out that harmonization and tightening of aflatoxin regulations within the EU has no significant effects on African groundnut exports. This empirical result surely challenges the conventional view that a stricter food safety regulation negatively impacts trade.

Table 1 Gravity model analyses

Author	Regions	Time period	Products	Specific regulation	Model	Estimator	Dependent variable	Explanatory variables
Linear regression models								
Tinbergen (1962)	18-42 countries	1958, 1959	Total bilateral trade	No	Log-linear model	OLS	Log of bilateral trade value	Log of gross national product (GNP) exporter and importer; log of distance; dummies: contiguity - Commonwealth - Benelux - Gini coefficient
McCallum (1995)	10 Canadian provinces, 30 US states	1988	Total bilateral trade	No	Log-linear model	OLS	Log of bilateral trade value	Log of GDP exporter and importer; log of distance; dummies: border
Non-linear regression models								
Anderson and van Wincoop (2003)	10 Canadian provinces, 30 US states	1993	Total bilateral trade	No	Log-non-linear regression model	NLS	Log of size-adjusted bilateral trade value	Distance; multilateral resistance; dummy: border
Fixed effects models								
Otsuki et al. (2001a)	9 African exporters, 15 European importers	1989-1998	Cereals, dried fruits, nuts, vegetables	MRL of aflatoxin	Log-linear model with fixed effects	LSDV	Log of bilateral trade value	Importer fixed effetcs; log of GNP per capita (p.c.) exporter and importer; log of distance; log of aflatoxin level; dummies: year - colonial ties
Otsuki et al. (2001b)	9 African exporters, 15 European importers	1989-1999	Edible groundnut, groundnut oil, groundnuts for oilseeds	MRL of aflatoxin	Log-linear model with fixed effects	LSDV	Log of bilateral trade value	Exporter fixed effects; log of GNP p.c. exporter and importer; log of distance, log of aflatoxin level; log of rain; dummies: colonial ties - year
Wilson and Otsuki (2001)	31 exporters, 15 importers	1995-1998	Wheat, rice, maize, dried and preserved fruits, nuts	MRL of aflatoxin	Log-linear model with fixed effects	LSDV, weighted least squares	Log of bilateral trade value	Exporter fixed effects; log of GNP exporter and importer; log of distance; log of aflatoxin level; dummies: colonial ties - membership in regional trade agreement (RTA) – year

Fixed effects models (continued)								
Moenius (2004)	12 countries	1985-1995	471 industries, four-digit SITC level	Shared standards versus country-specific standards	Log-linear model with fixed effects	OLS, instrumental variable (IV)	Log of bilateral trade value	Country-pair-year fixed effects; log of number of shared standards; log of country-specific stock of standards; time trend
Disdier et al. (2008a)	183 exporting countries, OECD importers	2004	690 agricultural products	Count data, frequency index, and AVE of regulations	Log-linear model with fixed effects	OLS or LSDV	Log of bilateral trade value	Exporter and importer fixed effects; log of distance; tariffs; ad valorem equivalent (AVE) of SPS and TBT regulation; dummies: border - language - colonial ties
Tobit models with random effects								
de Frahan and Vancaute-ren (2006)	10 European importers, 15 European exporters	1990-2001	10 agricultural sub-sectors	Coverage ratios of bilateral harmoni-zation	Log-linear random effect Tobit model	Weighted ML	Log of bilateral trade value	Random effects; log of output in exporting and expenditure in importing country; log of distance; measure of competitiveness; coverage ratio of bilateral harmonization; dummies: contiguity - language
Fontagné et al. (2005)	114 exporters, 61 importers	2001	161 product groups (also non-agricutural)	Environmen-tal-related notifica-tions	Log-linear random effect Tobit model	Random effects estimator	Log of size-adjusted bilateral trade value	Random effects; log of difference in p.c. GDP; log of telephone density; log of distance; tariff; population density; environmental trade barriers; dummies: contiguity - culture - landlock – least developed country – developed country – OECD
Eaton and Kortum (2002)	19 OECD countries	1990	Trade of manufactures	No	Log-linear model with random effects	Random effects estimator	Log of transformed trade value	Exporter and importer random effects; interval of distance; dummies: contiguity - language – regional trade agreement - destination
Sample selection models								
Helpman et al. (2008)	107 countries	1970-1997	Total bilateral trade	Regulation costs	Two-step model with fixed effects	Probit ML and NLS	Bilateral trade value	Fixed effects; distance; dummies: border - island - landlock - language - legal origin - colonial ties - currency union - RTA - religion - WTO membership

Poisson pseudo-maximum likelihood regression models								
Silva and Tenreyro (2006)	136 countries	1990	Total bilateral trade	No	Poisson fixed effects model	PPML	Bilateral trade value	Fixed effects; distance; dummies: contiguity - language - colonial tie - RTA
Siliverstos and Schumacher (2008)	22 OECD countries	1988-1990	Total bilateral trade and 25 disaggregated sectors	No	Non-linear model	PPML	Bilateral trade value	Capital-labor endowment ratio exporter; GNP p.c.importer; GNP exporter and importer; distance; dummies: membership in European Communities - contiguity - colonial ties – language
Olper and Raimondi (2008)	22 OECD countries	1994-2003	Agricultural bilateral trade	No	Poisson fixed effects model	PPML	Bilateral trade value	Fixed effetcs; distance; dummies: language - contiguity - border
Negative binomial Poisson maximum likelihood regression models								
Burger et al. (2009)	138 countries	1996-2000	Total bilateral trade	No	Poisson fixed effects model	PPML	Bilateral trade volume	Fixed effects; distance; institutional distance; sectoral complementarities; dummies: language - contiguity - history - RTA
Zero-inflated, negative binomial Poisson maximum likelihood regression models								
Burger et al. (2009)	138 countries	1996-2000	Total bilateral trade	No	Two-step model with fixed effects	Probit ML and PPML	Bilateral trade volume	Fixed effects; distance; institutional distance; sectoral complementarities; dummies: language - contiguity - history – RTA
Xiong and Beghin (2011)	14 European countries, 9 African countries	1998-2003	Trade in edible groundnut, groundnut oil, and shelled groundnut	Pesticide MRL	Two-step model with fixed effects	Probit ML and PPML	Bilateral trade volume	Fixed effects; MRL pesticides; GDP p.c. importer; supply exporter; distance; dummies: colonial ties - language

Source: Authors' compilation.

2.3 Conclusion of the chapter

The literature review in this chapter presents the variety of economic underpinnings of the gravity model and highlights methodological approaches to estimate the impact of border barriers such as regulatory measures econometrically.

The review reveals that the theoretical foundation of the gravity model has improved substantially since its first explicit formulation by Tinbergen (1962). The gravity model can be derived from Heckscher-Ohlin and Ricardian trade theories as well as from monopolistic competition models and Armington-like specifications. The methodological improvements turn the gravity model into an instrument that is used extensively in applied trade economics. Despite these improvements challenges remain for impact assessment of technical regulations. Combined, the assumption of homothetic CES preferences and the inclusion of zero trade flows are theoretically inconsistent. A possible solution can be to switch to non-homothetic CES preferences, which has not been done so far in the empirical literature on impact analysis of specific border barriers.

Econometric application of gravity models has improved as well. Various approaches for estimating impacts of border barriers are applied and their merits and disadvantages are discussed. Depending on the structure of the data, simple log-linear regression models are not able to control for heterogeneity caused by unobservable determinants, do not handle zero trade flows appropriately, do not account for firm level heterogeneity, and do not consider heteroscedasticity. Therefore, it is highly probable that they produce biased and/or inconsistent estimates.

The advantage of non-linear regression models over linear models is the chance to include better fitting functional forms and the possibility to provide for complex, non-linear explanatory variables like multilateral resistance or firm level heterogeneity which capture some of the heterogeneity caused by unobservables. Fixed effects models and random effects cover all country heterogeneity. When dealing with disaggregated product data and zero trade is prevalent, Tobit models seem to produce consistent and unbiased estimates. However, log-linearizing makes it necessary to add the value one or any small number a-theoretically to zero trade flows. Sample selection models and their extensions also solve for the problem of non-existent trade flows and additionally account for unobserved firm level heterogeneity. However, they do not tackle the problem associated with the occurrence of heteroscedasticity in trade data. This is done in Poisson-type models which furthermore are able to resolve the problem of zero trade flows because they do not require the logarithmic transformation of the left-hand-side trade flow values. Yet, the presence of unobserved heterogeneity is not taken into account by the Poisson model resulting in estimates which may be overdispersed. The negative binomial Poisson regression model solves for this problem by including a dispersion parameter. The incidence of overdispersion allows explaining the occurrence of non-existent trade flows by two different processes, the ‘Poisoness’ process and the ‘non-Poissoness’ process, leading to an extension of the negative binomial Poisson model, the zero-inflated, negative binomial regression model.

As seen, a multitude of approaches useful for analyzing the impact of NTMs in general and regulations in particular exist in the literature. Overall, there is no unifying method and the different approaches all have their advantages and disadvantages in terms of practicability, coverage and ability to capture certain features of regulatory measures. The empirical evidence of the trade effects of NTMs is mixed. The review of the econometric studies focusing on specific (agri-food) products points out that some specific NTMs have a negative impact on trade flows of the respective product. Other studies do not report a negative trade effect of NTMs, and finally, when harmonization of regulations and standards is considered, the study results even show positive trade impacts.

3 Regulatory policies in meat trade: Is there evidence for least trade-distorting sanitary regulations?

Multilateral trade rules as in the SPS Agreement on trade in food and agricultural goods offer guidelines to policy makers on how to make use of regulatory instruments governing agrifood trade.[15] The provisions of the SPS Agreement require that regulations targeting specific national agri-food safety objectives are minimal with respect to their trade effects (Article 5.4) and not more trade restrictive than required (Article 5.6). Accordingly, Wilson and Antón (2006) define the most welfare-efficient SPS measure as one that is least trade distorting but protective in terms of providing the desired health and safety level. However, only limited knowledge exists on the specific trade impacts of different regulatory instruments available to enforce desired policy goals. Furthermore, the trade impact of regulatory instruments is not always negative; safe and healthy food, information transmission, increased producer efficiency, and increased consumer confidence may also imply positive trade impacts.

Gravity models at various levels of detail have been mostly used to provide evidence on the trade impact of regulatory measures. At the aggregate level of agricultural trade, an example includes Disdier et al. (2008a), whereas Otsuki et al. (2001a) analyze product-specific regulations. Another body of literature applies partial equilibrium models in the quest for an optimal set of SPS measures regarding welfare impacts and risk mitigation strategies. Peterson and Orden (2008) identify an efficient sequence of SPS measures to address pest risks from Mexican avocado imports to the US market. The mentioned studies use different methodological approaches but are similar in that they do not systematically compare the trade impacts of different regulatory instruments with equivalent risk reduction effects.

[15] This chapter is based on the two papers Schlueter et al. (2009a) and Schlueter et al. (2009b).

In analyzing the meat sector, the objective of this article is to test the hypothesis that different regulatory measures imposed to achieve a desired level of SPS health in a country have different implied trade effects. In addition, sanitary regulations are identified that most adequately conform to Articles 5.4 and 5.6 of the SPS Agreement, differentiated by classes of regulations and policy objectives. Meat products are chosen because trade in meat is exposed to a wide number of market failures. Diseases, pandemics, and meat and feed scandals in the last decade have increased consumers' and producers' awareness of external effects associated with trade in meat products. This motivates policy makers to implement regulatory instruments, which may also serve protectionist purposes.

Using a frequency approach, detailed regulation specific data on sanitary measures is manually collected and compiled for the years 1996 to 2007. The information on these regulations is further differentiated by trading partner and year for each meat product line, resulting in a unique data set of regulatory measures that distinguishes all relevant SPS instruments applied for various agri-food safety purposes in the meat sector. A non-linear panel data gravity model is estimated for the ten most important meat exporters and importers by fixed effects PPML at the level of HS 4-digit data.

The remainder of the article is organized as follows. The first section derives the applied gravity model and introduces the PPML estimator. The second section describes the explanatory and dependent variables and their data sources. The third section presents estimation results on the impact of different aggregation levels of regulatory instruments and the fourth section concludes.

3.1 Theory and methodology

A non-linear panel data gravity model with fixed effects is estimated by Poisson pseudo-maximum likelihood (cf. Silva and Tenreyro 2006). Assuming frictionless trade, perfect competition, indifference of consumers' choices between otherwise homogenous products of different origins, and specialization of countries in different products, the gravity model describes bilateral trade flows by a function of exporter and importer GDP and world GDP (Deardorff 1998). Dropping the assumption of frictionless trade generally allows assessment of the impacts of any form of tariff or non-tariff barriers, including sanitary regulatory measures, by integrating different relevant variables potentially leading to "distance" between countries.

One difficulty of estimating gravity-type trade models is the existence of heteroscedasticity, which may cause inefficient and inconsistent estimates (Silva and Tenreyro 2006). Heteroscedasticity is present when trade flows for small and remote countries may approach zero. This causes the conditional variance $Var(M \mid x)$ of the explained trade flow variable M, given a set of explanatory variables x, to tend to zero, as positive dispersions from the conditional mean cannot be offset by negative ones contrary to large trade flows where the variance can be expected to be larger as the dispersion from the conditional mean can go in either direction. For estimating gravity models, the least squares and non-linear least squares estimators cannot be efficient, as they require the conditional variance to be constant. Also, in the presence of heteroscedasticity, the error term of the log-linearized version of the simple gravity equation can only be assumed to be independent from explanatory variables under very specific conditions on proportionality of the conditional variance. Consequently, all estimators of log-linear models which ignore heteroscedasticity are generally inconsistent (Silva and Tenreyro 2006).

Pseudo-maximum likelihood estimation is able to handle inefficiencies and inconsistencies caused by heteroscedasticity. Furthermore, zero trade between particular country-pairs does not create inconsistencies, as in the case when the log-linear form of the gravity equation is used. The pseudo-likelihood function is specified appropriately as long as it is based on a probability density function that is a member of the family of linear exponential functions, such as the Poisson probability density function (Gourieroux et al. 1984). In employing a PPML estimator in their gravity application, Silva and Tenreyro (2006) start with a stochastic model explaining a vector of bilateral trade flows M, which is derived from a utility-maximizing model assuming constant elasticity of substitution preferences (cf. Anderson 1979):

$$M = \exp(x\beta) + \varepsilon, \tag{21}$$

with $M \geq 0$ and $E[\varepsilon \mid x] = 0$, where x is the vector of explanatory variables, β is the vector of coefficients of interest, and ε is the error. This functional form is a good choice in modeling gravity equations because it produces non-negative conditional expectations (the value of bilateral trade flows is by definition non-negative) without constraining the explanatory variables. When M for given x is assumed to follow a Poisson distribution, a pseudo likelihood function can be derived, whose first and second order moment conditions can be solved to obtain the vector of coefficients β (Gourieroux et al. 1984). The PPML estimator is fully robust to distributional misspecifications (Wooldridge 1999).

The multiplicative gravity model in this analysis is as follows:

$$M_{ijt} = p_{it}^{\beta_1} c_{jt}^{\beta_2} d_{ij}^{\beta_3} \exp\left(\alpha_i + \alpha_j + \beta_4 z_t + \beta_5 t_{ijt} + \sum_k \beta_k r_{ijt}^k\right) \eta_{ijt}, \tag{22}$$

where M_{ijt} is the trade flow value from exporter i to importer j at time t, p_{it} and c_{jt} present the annual meat production and meat consumption quantities of exporter i and importer j representing the country's economic size in this sectoral analysis, d_{ij} is the bilateral distance between exporter i and importer j, α_i and α_j are country-specific exporter and importer fixed effects capturing unobserved country heterogeneity, z_t is the time dummy variable, t_{ijt} is the tariff variable, $\sum_k r_{ijt}^k$ present k different regulatory measures which are included in varying aggregation levels, and η_{ijt} is a transformed error with $E\left[\eta_{ijt} \mid x\right]=1$ according to Silva and Tenreyro (2006).

Equation (22) can be written as exponential function

$$M_{ijt} = \exp\left(\beta_1 \ln p_{it} + \beta_2 \ln c_{jt} + \beta_3 \ln d_{ij} + \alpha_i + \alpha_j + \beta_4 z_t + \beta_5 t_{ijt} + \sum_k \beta_k r_{ijt}^k\right) + \varepsilon_{ijt}, \quad (23)$$

which has the functional form of equation (21) and is estimated by PPML.

3.2 Data

This section displays and describes the data used in the case study. First, the data base on sanitary regulations, which is manually constructed for this analysis, is described and main findings are discussed. Then, the remaining model data are presented.

3.2.1 The SPS data base

Data on sanitary regulations is taken from the WTO SPS Information Management System (WTO 2009) and the International Portal on Food Safety, Animal and Plant Health (IPFSAPH 2009). This manual search and gathering of information on regulatory measures in the meat sector was necessary given that the conventional data bases for non-tariff measures such as the United Nations Conference on Trade and Development (UNCTAD) Trade Analysis and Information System (TRAINS) do not provide the necessary detail for a sector-specific analysis distinguishing different types of instruments applied.

Altogether 29 specific regulatory instruments are arranged into six classes which describe different agri-food safety purposes (Table 2): (1) Disease prevention measures; (2) requirements for microbiological testing for zoonoses; (3) tolerance limits for residues and contaminants; (4) production process requirements; (5) conformity assessment and information requirements; and (6) requirements for handling meat after slaughtering. As Table 2 shows each trade flow is on average regulated by nine regulatory instruments. The 29 instruments are additionally assigned to one or more of four different policy goals that are part of the mandatory national WTO notifications: Food safety; animal health; plant protection; and protection of humans from animal/plant pests or diseases.

Regulatory measures are treated as being imposed in a given year if the date of entry into force, adoption, or notification (depending on data availability) is in the first half of the year; otherwise, it is assumed that the measures take effect in the following year. All regulatory measures within the classes (2) to (6) are assumed to be in effect permanently from the year when they were imposed. Regulations on (1) disease prevention measures are assumed to be in force from the year they were imposed through the following year allowing for the improvement of the countries' disease status.

Overview of the number of measures

Regulatory measures have to be distinguished by their scope of application.[16] Within the compilation of the data base, only measures that apply to foreign countries are considered given that no indication of the measures' relevance for domestic producers is provided in the notifications. It is distinguished between regulations that are equally applied to imports from all origins, i.e. that are uniform across all exporters, and measures that are only targeted to specific origins, i.e. that are considered to be bilateral.

[16] See e.g. Josling et al. 2004 (page 18) for a classification scheme of measures.

Table 2 Regulatory instruments and their trade policy goals

	Food safety	Animal healht	Plant protec-tion	Protect humans from animal/plant pest or disease
Disease prevention measures				
Pest/disease status	x	x		x
Quarantine		x		
Regionalization		x		
Requirements for microbiological testing				
E. coli	x			x
Listeria monocytogens	x			x
Salmonella	x			x
Tolerance limits for residues and contaminants				
Dioxin	x			
Food additives	x			x
Pesticides	x		x	x
Drugs	x	x		
Other toxins	x			
Retained water content	x			
Production process requirements				
GMO/biotechnology	x	x		
Hormones	x			
Other production processes	x			
Conformity assessment and information requirements				
Certification	x	x		
Control, inspect., approval procedures	x			
HACCP	x			
International standards/harmoniz.	x			
Labelling	x			
Traceability/registration	x	x		x
Risk assessment	x			
Sanitary requirem. in meat establishments	x			
Requirements for handling meat after slaughtering				
Irradiation	x			
Meat/bone separation	x			x
Packaging	x			
Storage	x			
TBT	x			
Transportation	x			
Number of counts	102597	17624	24193	36867

Source: Authors' compilation.

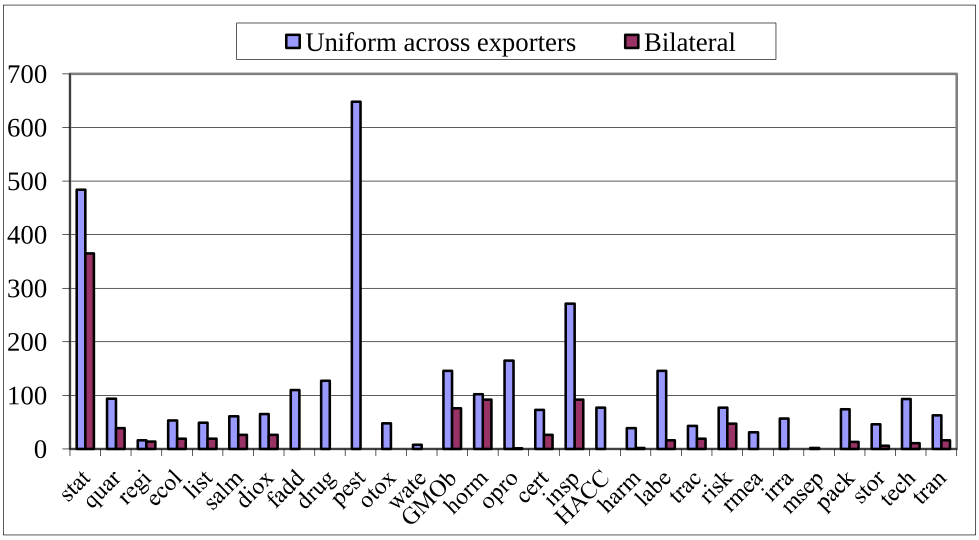
Table 3 Number of measures per regulatory class

No of measures applied	Dise	Micr	Tole	Proc	Conf	Hand
Equal across all exporters	594	163	1006	413	757	335
Bilateral measures	418	64	36	169	202	46
Total	1012	227	1042	582	959	381

Note: Dise = disease prevention measure; micr = requirements for microbiological testing; tole = tolerance limits for residues; proc = production process requirements; conf = conformity assessment; hand = handling meat after slaughtering.
Source: Authors' calculation.

In the data base, in total 4203 regulatory measures are imposed on meat trade over the observation period 1996-2007. Those ten importing (Canada, China, EU15, Hong Kong, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, and the US) and ten exporting (Argentina, Australia, Brazil, Canada, China, EU15, Hong Kong, New Zealand, Poland, and the US) countries which have the highest average aggregated meat trade flow in value terms over the sample period are included in the analysis. Out of the 4203 regulations, around 1000 measure relate to issues of disease prevention, tolerance limit requirements and conformity assessment, respectively (Table 3).

Figure 1 Number of regulatory instruments, uniform and bilateral



Note: The names of the regulatory instruments refer to the first four letters of each regulatory instrument as presented in Table 2.
Source: Authors' calculation.

The regulatory instruments used in each class are presented in Figure 1 differentiated for uniform and bilateral measures. The figure shows that most policies target pesticide residue levels in meat and pest/disease status notification. The number of uniform measures across all exporters is with around 3200 measures four times as high as the number of measures that are bilateral with around 900 (Figure 1 and Table 4). Under these bilateral regulations, the number of disease prevention measures stands out. This is reasonable given that risk of disease transmission is usually restricted to regional areas. Disaggregating the meat aggregate HS 02 into the ten subcategories as given by the HS classification, Table 4 displays that the measures are rather evenly distributed across the HS subgroups. With a slight margin, measures relevant for fresh and frozen bovine meat (HS 0201 and HS 0202) lead before measures applied to pork (HS 0203) and poultry meat (HS 0207).

Table 4 Number of measures per HS 02 subcategory

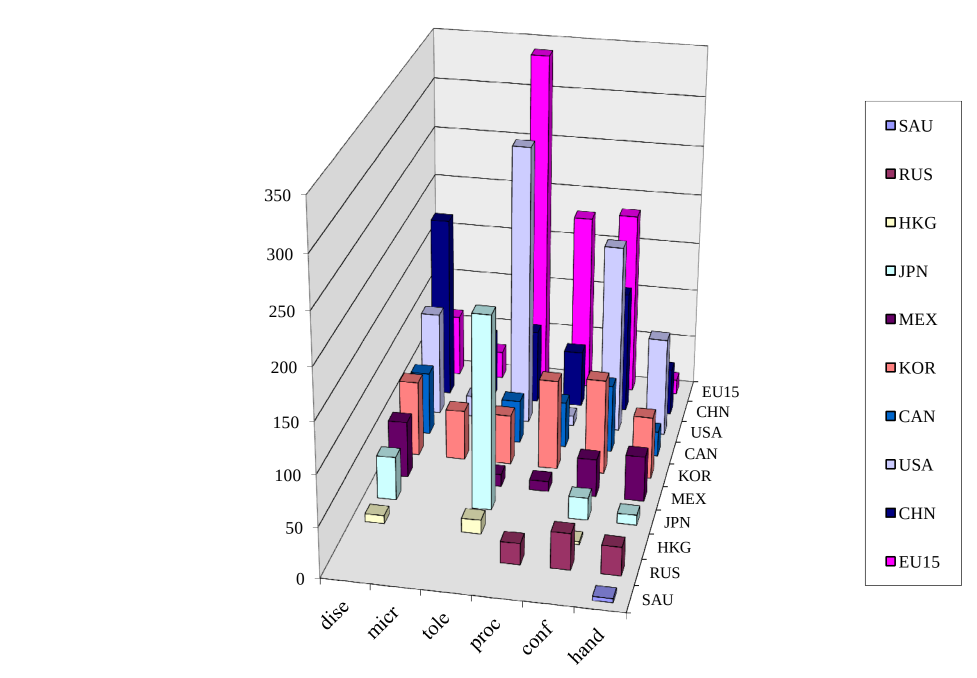
HS code	0201	0202	0203	0204	0205	0206	0207	0208	0209	0210
Eq. across exp.	455	432	362	358	306	325	345	201	237	247
Bilat. measures	169	148	103	98	66	80	99	40	69	63
Total	624	580	465	456	372	405	444	241	306	310

Note: 0201 = meat of bovine animals, fresh or chilled; 0201 = meat of bovine animals, frozen; 0203 = meat of swine, fresh, chilled or frozen; 0204 = meat of sheep or goats, fresh, chilled or frozen; 0205 = meat of horse, ass, etc., fresh, chilled or frozen; 0206 = edible offal of domestic animals; 0207 = meat and edible offal of poultry, fresh, chilled or frozen; 0208 = meat and edible offal nes., fresh, chilled or frozen; 0209 = pig and poultry fat, unrendered; 0210 = salted, dried or smoked meat or offal.
Source: Authors' calculation.

Measures which are uniform across all exporting countries

The EU and the US, followed by China and Korea, apply the upmost number of uniform sanitary regulations to the importation of meat (Figure 2 and Table 5). A disaggregation of the classes into single regulatory instruments is shown in Table 5

Figure 2 Number of uniform measures in each class per importer



Note: Dise = disease prevention measures; micr = requirements for microbiological testing; tole = tolerance limits for residues; proc = production process requirements; conf = conformity assessment; hand = handling meat after slaughtering.
Source: Authors' calculation.

for each country. For the EU and to a lower extent also for the US, it is noticeable that most of the regulations are applied in the area of tolerance limits. Within the class of tolerance limits, basically all measures relate to residue limits of pesticides in meat. In contrast to the highly regulated US and EU import markets, Hong Kong (25) and Saudi Arabia (4) meat imports face the fewest SPS regulation (Table 6).

Table 5 Number of uniform regulatory instruments per importer

Class	Regulatory instrument	USA	CAN	CHN	EU15	HKG	JPN	KOR	RUS	SAU	MEX
dise	stat	97	61	115	62	8	41	57			43
	quar			66			2	16			10
	regi	7	2	2				2			3
micr	ecol	5		19	9			20			
	list	11		19	9			10			
	salm	5		26	10			20			
tole	diox	2		10	35	14		4			
	fadd	33		23	10		4	40			
	drug	10		10			101	6			
	pest	229	43		289		87				
	otox			31	5						12
	wate	7			1						
prod	GMO			50	76			10	10		
	horm				102						
	opro	10	46	7	1			80	11		10
conf	cert	2	3	16	20				32		
	insp	53	46	63	83		2	10	4		10
	HACCP	48	1	1	17						10
	harm	7			20		10				2
	labe	49	5	10	3	3	10	66			
	trac	14	10					19			
	risk		3	32	42						
	rmea	16									15
hand	irra	42		1				10		4	
	msep	2									
	pack		15	21				10	13		15
	stor	17	1	7				6			15
	tech	31	7		15		10	30			
	tran	7	2	18				6	15		15
	SUM	704	245	547	809	25	267	422	85	4	160

Note:The name of the regulatory instruments refers to the first four letters of each regulatory instrument as presented in Table 2.
Source: Authors' calculation.

Table 6 Number of uniform measures per importer

Countries	USA	CAN	CHN	EU15	HKG	JPN	KOR	RUS	SAU	MEX
No of measures	704	245	547	809	25	267	422	85	4	160

Source: Authors' calculation.

Finally, in Table 7 and Figure 3 the number of measures in each class is presented differentiated by the date of initiation. Two observations can be made: Starting with the year 2001, the number of newly initiated measures nearly doubled compared to the first years after the SPS Agreement entered into force in 1995. Second, in the years 2001 and 2002 an increased number of notifications related to the class of disease prevention measures (131 and 203, respectively) can be noted.

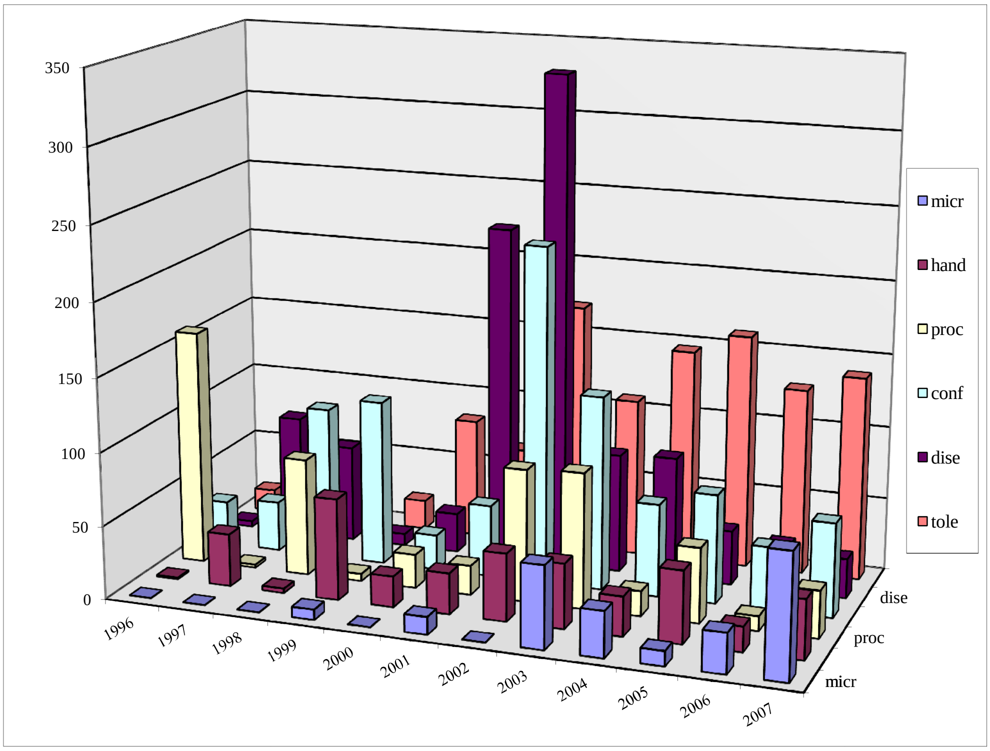
Table 7 Development of number of uniform measures, 1996-2007

Years	96	97	98	99	00	01	02	03	04	05	06	07
No of measures	122	113	145	174	139	294	652	384	322	361	243	319

Source: Authors' calculation.

In 2001, most of these notifications result from the US (28), Canada (19), Korea (29), and Mexico (30), whereas in the year 2002, 165 out of 203 notifications result exclusively from China. This huge number can be explained by China's WTO accession. Also conformity assessment and information requirement regulations have a peak in 2002. Again, China implements the most new measures (105).

Figure 3 Number of uniform measures in each class applied by importing countries differentiated by year of initiation



Note: Dise = disease prevention measures; micr = requirements for microbiological testing; tole = tolerance limits for residues; proc = production process requirements; conf = conformity assessment; hand = handling meat after slaughtering.
Source: Authors' calculation.

Bilateral measures

China and the EU, followed by the US, have implemented by far the most bilateral measures across the sample (Table 8). For China and the US, disease and pest prevention regulations rank first. For the EU, the highest number of bilateral measures is located in the areas of production processing requirements and conformity assessment regulations. Focusing on the bilateral trade partnerships, Table 9 depicts that most of the US measures are targeted towards the EU. China targets US and EU imports nearly to the same extent.

Table 8 Number of bilateral measures implemented by importing countries

	USA	**CAN**	**CHN**	**EU15**	**HKG**	**JPN**	**KOR**	**RUS**	**MEX**
dise	99	50	123	24	8	26	44		44
micr			64						
tole	2		20		14				
proc				169					
conf	16	5	34	102		2	35	6	2
hand			23	1		10	12		
SUM	**117**	**55**	**264**	**296**	**22**	**38**	**91**	**6**	**46**

Note: Dise = disease prevention measures; micr = requirements for microbiological testing; tole = tolerance limits for residues; proc = production process requirements; conf = conformity assessment; hand = handling meat after slaughtering.
Source: Authors' calculation.

Countries exporting to the EU seem to be rather uniformly affected by European bilateral import regulation, at which Australia, Canada, and the US still face the highest number of regulations. Here, most of the bilateral measures focus on regulations related to the use of genetically modified organisms (GMOs), biotechnology, and hormones.

Table 9 Number of bilateral SPS measures per country-pair

	USA	**CAN**	**CHN**	**EU15**	**HKG**	**JPN**	**KOR**	**RUS**	**MEX**
USA	n.p.	14	112	73		3	20		3
ARG	16	7	8	42		10	2		10
AUS			10	59			13		
BRA		2	10	13			4		
CAN	4	n.p.	8	63	2	1	20		3
CHN				23		7		6	
EU15	97	30	99	n.p.	20	17	21		20
HKG			15	3	n.p.				
NZL			1	20			9		
POL		2	1				2		10

Note: Rows = exporters; columns = importers; n.p. = not provided.
Source: Authors' calculation.

3.2.2 Other model data

HS 4-digit data on trade in meat products originates from the UNCTAD Comtrade database (UNCTAD 2009a) for the years 1996 to 2007.

Table 10 Mean and variance of model variables

Variable	Mean	Variance
Trade value/10,000,000	2.08	86.07
ln production exporter	22.54	2.72
ln consumption importer	22.54	2.03
ln distance	9.01	0.45
Tariff	4.20	251.82
Aggregate of regulations	9.10	186.69
Disease prevention measures	0.36	1.16
Pest/disease status	0.26	0.62
Quarantine	0.10	0.21
Regionalization	0.01	0.01
Requirements for microbiological testing	0.36	1.30
E. coli	0.10	0.15
Listeria monocytogens	0.12	0.14
Salmonella	0.14	0.21
Tolerance limits for residues and contaminants	3.42	52.10
Dioxin	0.17	0.46
Food additives	0.39	0.81
Pesticides	0.22	0.67
Drugs	0.48	2.24
Other toxins	2.12	35.33
Retained water content	0.03	0.03
Production process requirements	1.06	3.67
GMO/biotechnology	0.32	1.20
Hormones	0.59	1.92
Other production processes	0.14	0.34
Conformity assessment and information requirements	2.62	15.80
Certification	0.30	0.43
Inspection and approval procedure	0.83	1.90
HACCP	0.45	1.86
Harmonization	0.19	0.20
Labeling	0.37	0.77
Traceability	0.09	0.12
Risk assessment	0.17	0.40
Sanitary requirements for meat establishments	0.22	0.42
Requirements for handling meat after slaughtering	1.29	4.90
Irradiation	0.31	0.76
Meat/bone separation	0.01	0.02
Packaging	0.21	0.27
Storage	0.19	0.22
Technical barriers to trade	0.32	0.58
Transportation	0.26	0.30
Food safety	9.00	184.48
Animal health	1.55	6.38
Plant health	2.12	35.33
Protect humans from animal/plant pests or diseases	3.23	51.77

Source: Authors' calculation.

Zero trade flows between country-pairs are included. Consumption of domestic meat is not considered. Altogether, there are n=11400 observations on trade flows[17] of which 51 percent are non-zero. Mean and variance of the trade flow and explanatory variables are depicted in Table 10.

Meat production and consumption quantities result from the Food and Agricultural Organization (FAO) statistical webpage (FAO 2009) and from the webpage of Indexmundi (2009). Bilateral data on the explanatory variable geographic distance originates from the Centre d'Etudes Prospectives et d'Informations Internationales homepage (CEPII 2009). Weighted distance is chosen as the distance variable, where the EU15 is centered on Germany. A time dummy variable is included. Tariff data stems from UNCTAD TRAINS database (UNCTAD 2009b). If available, the bilateral effectively applied tariff is chosen; otherwise, the most-favored-nations tariff is incorporated.

3.3 Results and specification tests

Table 11 presents outcomes of four different models estimated by PPML.[18] The common base of the four models is the exponential regression function (23). The models differ with respect to the differentiation of regulatory measures $\sum_k \beta_k r_{ijt}^k$.

The model named ‘aggregate’ in the first column of Table 11 includes one overall measure of regulatory instruments being the sum of all counts for a particular country-pair and HS-line within one year. The model ‘classes’ in the second column of Table 11 includes the six pre-defined classes of regulatory measures. The third column presents parameter estimates for the ‘instruments’ model, which captures the individual 29 specific regulatory measures. The parameter estimates of the ‘goals’ model are presented in the fourth column, which

[17] (95 country-pairs) * (12 years) * (10 HS 4-digit codes).

[18] Technically, GAUSS 9.0 is used to solve the optimization problem in conjunction with the application module Constrained Optimization. The code is available upon request.

considers regulatory measures aggregated by the four safety objectives listed above. All models are tested on independence of the conditional mean from the explanatory variables (Wald-test) and on the correct specification of the functional form of the conditional mean expectation (Ramsey's regression equation specification error test (RESET)). The tests are carried out using standard errors that are robust to distributional misspecifications imposed by restrictions of the Poisson assumption (Wooldridge 1999).

The Wald-test rejects the hypothesis that the conditional mean is independent of the explanatory variables for all four models. The heteroscedasticity-robust RESET tests the null hypothesis that the additional regressors $\left(x\hat{\beta}\right)^2$ and $\left(x\hat{\beta}\right)^3$ do not help to explain the dependent variable by using the auxiliary regression

$$M = \exp\left(x\beta + \delta_1\left(x\hat{\beta}\right)^2 + \delta_2\left(x\hat{\beta}\right)^3\right); \tag{24}$$

thus δ_1 and δ_2 are not significantly different from zero (Silva and Tenreyro 2006, Wooldridge 1999). The test suggests a correct specification of the three models 'aggregate', 'classes', and 'goals', but fails for the 'instruments' model. The parameter estimates of the four traditional gravity explanatory variables are rather similar in the four models with the exception that the estimates of economic size of exporter and importer diverge in the 'instruments' model. The outcomes are all significant at the 1% significance level. The signs of the covariates' economic size and geographic distance are as expected: Distance negatively affects trade, while the economic size fosters trade flows. The slightly positive tariff coefficient's estimate of $\exp(0.01) \approx 1.01$ suggests a minor influence of tariffs on today's meat trade.

Table 11 Parameter estimates of model variants

Variable	Aggregate	Classes	Instruments	Goals
ln production exporter	1.526***	1.736***	3.425***	1.653***
ln consumption importer	1.678***	1.986***	4.156***	1.804***
ln distance	-0.931***	-0.964***	-1.063***	-0.967***
Tariff	0.010***	0.009***	0.010***	0.009***
Aggregate of regulatory measures	0.015***			
Disease prevention measures		0.122***		
Pest/disease status			0.096	
Quarantine			0.200	
Regionalization			-0.153	
Requ. for microbiological testing		0.087		
E.coli			-0.092	
Listeria monocytogens			-0.573	
Salmonella			0.760***	
Tolerance limits for residues		0.015**		
Dioxin			0.416***	
Food additives			-0.102	
Pesticides			-0.067***	
Drugs			0.200***	
Other toxins			-0.456***	
Retained water content			0.597	
Production process requirements		-0.091***		
GMO/biotechnology			0.030	
Hormones			-0.447**	
Other production processes			-0.146**	
Conformity assessment		0.050**		
Certification			0.018	
Inspection/approval proced.			0.449***	
HACCP			0.360***	
Harmonization			0.267	
Labeling			0.007	
Traceability			0.161	
Risk assessment			-0.639	
Requ. for meat establishm.			-0.869***	
Handling meat after slaught.		-0.128**		
Irradiation			-0.662***	
Meat/bone separation			-0.412	
Packaging			0.117	
Storage			-0.060	
Technical barriers to trade			0.192	
Transportation			0.879***	
Food safety				0.012
Animal health				0.080***
Plant protection				0.016
Protect humans				-0.010
Wald test	r.***	r.***	r.***	r.***
RESET	n.r.***	n.r.***	r.***	n.r.***

Note: (**) and (***) denote significance at 5% and 1% level; r. = rejected; n.r. = not rejected.
Source: Authors' calculation.

However, this result has to be read with caution since no distinction between imports under preferential tariff rate quotas and imports under tariffs has been made. The first column of Table 11 additionally reports the estimate for the aggregate regulatory instruments variable. The estimate's value of $\exp(0.015) \approx 1.015$ affirms the ambiguous impact of regulatory measures on trade: Regulations may be trade-restricting or trade-facilitating or may have no trade impact at all – a strong tendency cannot be determined from the result of the aggregate variable. The more disaggregated classes model gives first evidence on the differing implied trade effects of regulatory measures. Five of the six estimates are significant. Whereas the classes (1) disease prevention measures, (3) tolerance limits for residues and contaminants, and (5) conformity assessment and information requirements are trade-promoting, the trade impact of the classes (4) production process requirements and (6) requirements for handling meat after slaughtering is negative.

The third column of Table 11 goes further into the analysis and presents the specific regulatory instruments' influence on trade. For example the negative impact of the class (4) production process requirements is caused by measures regulating the application of hormones and by other production processes, while the impact of regulations on GMOs and biotechnology is not significant. The fourth column of Table 11 shows that only animal health is significant among the policy objectives potentially underlying the regulations. The corresponding parameter estimate of $\exp(0.080)$ confirms the necessity of measures providing a good animal health status for an active global trade in meat.

3.4 Conclusion of the chapter

Using a non-linear panel data gravity model, this article analyzes the trade effects of different regulatory measures that are imposed in the meat sector in order to achieve a desired national level of SPS health. The dataset used is specifically compiled for this study and is new and unique with respect to the detail of information on the applied sector specific national regulatory instruments and with respect to the applied classification of measures into SPS areas and political objectives they serve.

The disaggregated analysis of the trade effects of regulatory instruments reveals the theoretically well-known ambiguous trade impact of many of these measures. At the class level we find that regulations imposed to achieve a desired level of SPS health differ in their implied trade impact. The even further disaggregated estimation at the level of the single regulation shows that there are specific measures which have a substantial positive impact and others with a significant negative one. These effects can offset each other within a class. When grouping the regulations according to underlying policy goals, policy measures ensuring animal health are identified as being significantly trade-enhancing. These results add more detail to the findings of recent research by Disdier et al. (2008a), who estimate an overall negative impact of SPS and TBT measures on meat trade using a log-linear fixed effects gravity model with HS 2-digit data.

Limitations that apply to this chapter result from the fact that a frequency count is used to characterize the importance of the measures. This does not allow a comparison of the SPS safety level achieved by a specific measure to the trade restriction that it imposes. For this, more theoretical work on how to compare and quantify the potential SPS safety levels that are achievable with single measures or sets of measures is necessary.

4 Determining the welfare impact of regulatory measures

Simulation models have routinely been used in the applied trade analysis of regulatory measures in the last decade. They are firmly rooted in microeconomic theory and thus are appropriate tools for a systematic and economically sound analysis. They are able to show the trade-off between negative and positive effects of regulatory measures. Employing common welfare indicators, simulation analysis sheds light on the measures' welfare and distributional implications, thus going beyond results of econometric trade models concentrating on pure trade effects.

For quantitatively determining the welfare impact of regulatory measures in a trade context most often spatial partial equilibrium models are applied in the literature. They are partial as not the whole economy is represented, but only a specific sector or product chain. A partial equilibrium approach allows for the representation of a sector or even a single product in question at considerable detail, but comes at the cost of insight of the effect of shocks on the overall economy and its feedback. If the sector or the single product represents only a small fraction of the overall economy, the effects on the overall economy and thus the feedback effects on the sector or the product chain can be neglected. This thesis focuses on the analysis of regulatory measures in the meat sector, and the second case study being discussed in chapter five just zooms in on poultry meat, analyzing avian influenza-related regulatory policies on poultry meat trade and welfare. Thus, only a small sector of the overall economy is considered favoring the use of a partial instead of a general equilibrium model.

Simulation models allow analyzing changes of regulatory measures, whereby scenarios often refer to the removal of possible trade barriers. Functional equations describing costs and benefits of regulations are introduced into the model, and the simulation exercise subsequently models the producer and consumer behavior in response to changing regulatory requirements. Sensitivity analysis helps to check the robustness of the models' results. As governments are generally not able to generate tariffs or other revenues from regulatory measures, and thus modifications in regulations typically do not affect government revenues, a change in government welfare is not considered.

The way regulatory measures are depicted in simulation models crucially determines the simulation results. Rau (2010) elaborates on the methods commonly applied to incorporating regulatory measures in simulation models and discusses the practicability and challenges of their application. On the supply side, simulation models usually depict regulatory measures as additional cost parameter that producers incur when complying with the respective requirements. The costs are modeled as iceberg tariffs (Samuelson 1952, Krugman 1991). Starting with Paarlberg and Lee (1998), papers following the risk-based approach additionally capture producers' benefits associated with regulatory measures. These papers take into account the risk-reducing character of some regulatory measures, for instance regulations minimizing the probability of introducing diseases or invasive species that may threaten domestic production. On the demand side, regulations are reflected by consumers' willingness to pay for certain product characteristics which are provided by regulatory measures and by consumers' perceptions of the product attribute. Beghin et al. (2009) provide an extensive overview on recent methods to determine the consumers' willingness to pay and how to appropriately depict the consumers' behavior in face of regulatory measures.

This chapter sets up the methodological approach being used in the second part of the case study presented in chapter five which analyzes trade and welfare effects of avian influenza-related policy measures. The chapter first discusses the economic specification of simulation models appropriate for simulating the distributional and welfare effects of regulatory measures. Then it summarizes the different options of incorporating costs and benefits of regulatory measures into the simulation model's supply and demand functions. The last section concludes.

4.1 Economic specification: Takayama-Judge versus Armington

In general there are two economic frameworks for modeling bilateral trade in simulation models: (1) The Armington approach and (2) the Takayama-Judge approach.

The Armington approach is based on a theory of demand distinguishing products by their origin (Armington 1969). Consumers show a different willingness to pay for the same commodity depending on its place of origin, thus prices do not necessarily equalize across countries. The Armington approach can be used with a variety of functional forms for aggregating the utility of goods from different origins. The most common functional form is the CES utility function. Its main advantage is its limited data requirement, only asking for an estimate of (or an assumption on) one single substitution elasticity in addition to trade flow and price data. The Armington approach, however, comes along with some weaknesses in regard to applied agricultural trade modeling. Changes induced through shocks such as policy changes will always take place only in relation to the existing market share. That means a country with a small share in an import market cannot significantly expand its exports unless the elasticity of substitution is arbitrarily set to high values. Another problem is that (near) zero trade flows remain (near) zero even after strong price changes. This so-called small shares problem arises because producer and consumer incentive prices are calculated as volume weighted shares of prices for domestic and imported goods. If trade volumes in the base period are (close to) zero, e.g. due to (nearly) prohibitive trade barriers, such trade-weighted averages of prices will not fully reflect the size of the impact of reduced trade barriers. That means CES-based Armington models tend to understate the trade creation effect following significant reductions of trade barriers if initial trade flows are small or zero.[19]

The Takayama-Judge model goes back to Enke (1951), Samuelson (1952) and Takayama and Judge (1964). Trade flows are driven by transport cost minimization. The behavioral equations for supply and demand are formulated and calibrated to recover observed quantities at given prices. The model assumes homogenous goods and is able to display the products' origins and destinations. It is appropriate to display a competitive economic environment which contains some regions and some discrete time periods. Bilateral trade is possible between all pairs of countries and time periods, where trade causes certain per unit transportation costs. Trade flows and quantities produced and demanded are rendered which satisfy the equilibrium condition of equalizing prices (including transport costs which may include expenses associated with import requirements) in the importing countries with those in the exporting countries. The poultry meat case study in chapter five applies a Takayama-Judge model. It is a good choice as for a product like poultry meat which is widely traded globally the product's origin is not a major determinant for consumers' purchase decisions.[20] The model follows the design of a spatial multi-commodity model for homogenous products and allows for a highly disaggregated commodity specification in conjunction with bilateral trade policy measures. This is necessary as poultry meat is not only differentiated by its processing stage but also according to the exporter's disease status and the resulting different policy responses. Additionally, drawbacks associated with the weaknesses of the Armington approach can be circumvented without extensive data and functional adjustments.

[19] Structural solutions dealing with the small shares problem incorporate first the adjustment of the functional form (Kuiper and van Tongeren 2006, Witzke et al. 2005, Tchamourliyski 2002), and second the change of the whole utility function (Yue and Beghin 2009, Phaneuf et al. 2000, Wales and Woodland 1983). In both cases the distinction of goods by origin is maintained.

[20] The argument of assuming poultry meat to be homogenous is amplified through the increasing share of consumption of convenience products on total poultry meat consumption.

4.2 Economic application: Including costs and benefits of regulations

This section specifies demand and supply systems which can generally be used under a Takayama-Judge framework. Furthermore, the section discusses the inclusion of costs and benefits of regulatory measures, especially those being related to the protection of domestic agri-food production from biohazards.

4.2.1 Supply side: Modeling costs and benefits of regulations

Tariff equivalents (Yue and Beghin 2009, Yue et al. 2006) or iceberg tariffs (Krugman 1991, Samuelson 1952) are commonly used to model the costs of compliance with NTMs on the supply side of simulation models. When analyzing NTMs related to the protection of agri-food production from biohazards the risk-based approach has a long history in literature. Pioneering research by Paarlberg and Lee (1998) was amplified through spatial coverage (Jansson et al. 2005), linkages to dynamic herd-size models (Niemi and Lehtonen 2011, Nogueira et al. 2011, Mangen and Burrell 2003), and richness in model and disease parameter specification (Peterson and Orden 2008, Wilson and Antón 2006, Yue et al. 2006).

Peterson and Orden (2008), for instance, employ a constant elasticity of transformation frontier and linear supply function which allows producers to shift sales between seasons as relative prices change. Their domestic revenue function is dependent on the producer prices in two consecutive time periods, the level of factors employed, the expected per-unit cost of measures to control the specific product attributes, and the expected disease-related domestic productivity loss $\left(N_j \cdot shareInf_j \cdot pl_j\right)$, where N_j is the frequency of a disease outbreak in importing country j, $shareInf_j$ is the share of affected domestic production by the disease, and pl_j is the disease-related proportion reduction in productivity. The frequency of disease outbreaks N_j is a function of the level of imports. The foreign revenue function additionally depends on compliance costs for possible exporters to meet the importing country's regulations; compliance costs are a function of sanitation and disease survey costs, which were obtained through field research.

In the analysis of regulatory measures their benefits need also be accounted for when modeling the supply side. The benefits relating to productivity gains and reduced transaction and information costs are ideally considered in the approximation of the compliance costs such that the net cost increase for exporters is used in the simulation model. Additionally, producers in the importing country clearly benefit from import regulations that reduce risks related to biohazards. For example, in the case of the implementation of an import requirement downsizing the probability of the transmission of a disease through trade, the welfare loss due to restricted trade can be offset by avoiding domestic production losses that would prevail elsewise. In this case $\left(N_{j0} \cdot shareInf_j \cdot pl_j\right)$ is the expected domestic disease-related productivity loss when safety regulations are absent, where N_{j0} is the frequency of a disease outbreak in period 0. Instead, $\left(N_{j1} \cdot shareInf_j \cdot pl_j\right)$ is the expected domestic producers' productivity loss when safety measures are implemented, where N_{j1} is the frequency of a disease outbreak in period 1 when safety measures are implemented. By intuition, $N_{j1} < N_{j0}$, and it can clearly be seen that

$$\left(N_{j1} \cdot shareInf_j \cdot pl_j\right) < \left(N_{j0} \cdot shareInf_j \cdot pl_j\right), \qquad (25)$$

proving that domestic producers benefit from implementing measures preventing the dispersion of the disease. In the evaluation of the whole welfare effect of such a policy measure, the benefits are faced with foreign producer or exporter costs which are caused by the regulatory measures possibly restricting trade. Thus, such risk-based analysis can be used to investigate the optimal policy response that maximizes overall welfare. Peterson and Orden (2008), for example, calculate the optimal level of food safety regulation for US imports of Mexican avocados accounting for the probabilities of pest infestation (fruit fly) and the costs for US producers (costs to prevent production losses) as well as for Mexican exporters (compliance costs).

The risk-based analysis of regulations crucially relies on scientific information on the probability of an outbreak and the spread of diseases or pests. This combination of natural sciences and economic modeling is promising, but also poses major challenges given the considerable uncertainty about the risks and their economic consequences. In the literature, several case studies applying partial equilibrium models conduct risk-based analyses of import regulations; important recent contributions to this topic are Disdier and Marette (2010), Yue and Beghin (2009), Peterson and Orden (2008), Wilson and Antón (2006), and Yue et al. (2006).

4.2.2 Demand side: Modeling costs and benefits of regulations

Whether the demand side is directly affected by a regulatory measure depends on the consumers' awareness relative to a specific product characteristic regulated by the NTM and their preferences regarding this charcteristic. If consumers are aware of a specific product characteristic which reduces their utility, they will negatively internalize the expected damage linked to the characteristic in their consumption. Polinsky and Rogerson (1983) call this condition the rule of "no liability", meaning consumers take over their own losses causing the demand curve to shift down by the consumers' perceived expected losses. If a product characteristic is considered to affect consumers' utility positively, consumers incur their own profits and demand is shifted up by their perceived profits.

To distinguish consumers with preferences for a specific product characteristic from those who do not have a preference, Paarlberg et al. (2008) include a vector of parameters $0 \leq \beta_j \leq 1$ into the demand function indicating the share of the population having preferences with respect to certain product attributes: $m_{ij} = f(x, \beta)$, where m_{ij} is country j's demand for the product of country i, x is a vector of explanatory variables explaining preferences for attributes of each m_{ij}, and $f(.)$ is any functional form describing this trade relationship. If $\beta = 1$, demand is not affected by the product attribute, whereas if $\beta = 0$, consumers' preferences are prohibitive, meaning consumption falls to zero. Beghin et al. (2009) extend this train of thought. They employ a non-homothetic quasi-linear utility function that includes quadratic preferences for the market good of interest:

$$\max U(m, z) = m^*_{ij} - \vartheta_j r_{ij} m_{ij} + z, \tag{26}$$

where $m^*_{ij} = m_{ij} - \frac{m_{ij}^2}{2}$ is the immediate satisfaction of consumers in country j from consuming a quantity of good m_{ij}, and z is the numeraire good. Parameter ϑ_j represents the knowledge regarding a product characteristic. If consumers are not aware of the specific characteristic, $\vartheta_j = 0$. If $\vartheta_j = 1$, consumers are aware of the product attribute and they reduce their consumption. The perceived expected losses associated with the consumption of the good with a specific characteristic is denoted $r_{ij} m_{ij}$, where r_{ij} is the per-unit damage. Aggregate demand for good m_{ij} is obtained by summing individual demand functions over all N consumers. Including Paarlberg's et al. (2003) concept of share of consumers having preferences with regard to specific product attributes, demand functions for two subgroups of consumers can be formulated and aggregated. Parameter β_j is then the share of consumers completely indifferent with regard to a specific characteristic, with $r_{ij} = 0$, and the remaining share $(1 - \beta_j)$ is reluctant to consume the specific product attribute and associates a damage per unit consumed, thus $r_{ij} > 0$. The partition of consumers into the respective group (1) having a preference with regard to a specific characteristic and (2) not having this preference is done by willingness-to-pay analysis, or assumptions are made based on reasonable argumentation.[21]

4.3 Conclusion of the chapter

Spatial partial equilibrium models are an appropriate tool to analyze welfare effects of regulatory measures. They allow including functional equations describing costs and benefits into the model, and the simulation exercise models the producer and consumer behavior in response to changing requirements.

The Takayama-Judge approach is appropriate to model a competitive economic environment containing different regions and discrete time periods. The model follows the design of a spatial multi-commodity model for homogenous products. It allows for a highly disaggregated commodity specification. This is a necessary condition as the case study in chapter 5 analyzes meat trade flows differentiated by processing stage and according to the exporters' disease status.

When formulating demand and supply equations, in both cases the effects of costs and benefits associated with regulatory measures have to be taken into account. On the supply side, the introduction of policy measures regulating the threat associated with biohazards impacts the supply function considerably. Parameters that have to be considered in such analyses are for instance the frequency of disease outbreaks with and without a policy measure in place, the expected annual pest-related domestic productivity loss, or the expected per-unit cost of a measure to control the specific product attribute. Exporters are additionally faced with compliance costs to meet the importing countries'

[21] Pearce et al. (2006) provide a detailed overview on methods assessing consumers' choice behaviour.

regulations. Looking at benefits of regulatory measures, those that are related to productivity gains and reduced transaction and information costs are ideally considered in the approximation of the compliance costs such that the net cost increase for producers is used in the equilibrium model. Those measures that are related to reduce the prevention of a disease outbreak in the importing country are taken into account in the risk-based approach, combining scientific or epidemiologic information about probabilities of disease outbreaks and their spread, and economic modeling. On the demand side, product characteristics may affect consumers' utility or not. If a product characteristic is considered to affect consumers' utility positively (negatively), demand is shifted up (down) by consumers' perceived benefits (losses). Though, if they are not aware of the specific product attribute, the perceived damage or profit disappears from the consumers' utility function, and the demand side is not directly affected.

5 Impact of avian influenza-related policy measures on poultry meat trade and welfare

Sanitary and food safety measures related to animal disease outbreaks are of high relevance in meat trade.[22] The measures' costs are considerable, but without these regulations international trade flows may be significantly lower due to lack of trust and information between international trading partners. However, these induced costs reduce competitiveness of imports compared to domestic products. That is especially true in poultry meat markets where many countries implemented drastic quarantine measures in recent years in order to reduce the perceived or actual risk of AI transmission across territories. When the possibility of disease transmission is very low or the threat to food safety is negligible, these trade impediments cause trade and welfare losses for exporting and importing countries and the measures may be questioned regarding their risk adequacy. These arguments are especially important for AI where most transmission occurs through the migration of wild birds into foreign territory (Fouchier et al. 2007). Equally, the human health risk seems to be very low and mostly related to intensive contact with infected stock (WHO 2011a).

An analysis of the trade concerns raised in the SPS Committee of the WTO shows that import measures related to the prevention of the spread of AI were by far the most controversial ones in recent years (1995-2010). About 57% of all trade concerns focus on AI where most often the exporting country complains about the importing country's NTMs to be disproportional to the associated risk and not based on World Organisation for Animal Health (OIE) guidelines. An example is the concern raised by the EU about India's import ban on European live birds, fresh poultry meat and meat products due to AI. The EU argued that these measures were disproportionate to the health risks associated with imports from the

[22] This chapter is based on the paper Wieck et al. (2012). The econometric analysis was realized by the second author, development of the concept of the simulation analysis as well as data work was done by all three authors, and the simulation model was implemented by the first and the third author.

EU as it was free of high pathogenic avian influenza (HPAI) at that time. Within these discussions the OIE clarified that findings of AI in wild birds and of low pathogenic avian influenza (LPAI) should not lead to import bans (WTO 2011). Nevertheless, China still imposed import restrictions on poultry imported from LPAI infected areas in the US and the EU. Brazil imposed an import restriction on French poultry meat as to protect its own poultry population and to maintain its status as AI free, although only one LPAI case was detected in one region of France. The OIE guidelines on AI also explicitly state that heat treatment de-activates the virus and that measures associated with AI should not be applied to cooked poultry meat. However, the US had suspended for many years the importation of cooked poultry meat from China because of the presence of HPAI (WTO 2011). As recommended by the OIE, bans are only justified in case of uncooked meat originating from sources with HPAI. Producers in affected regions then have the possibility to shift fresh meat into cooked meat production as both meat categories are substitutes in the processing step.[23] Further on, countries should follow the principle of regionalization allowing producers from non-affected regions within a country to maintain exports.

The objective of this case study is to analyze trade and welfare effects of changes in importers' regulatory AI policies for important poultry meat exporters (Brazil, China, France, Germany, the Netherlands, and the US) and importers (Russia, Japan, ROW aggregate). First, past AI-related policies over the time period 2000 – 2007 are evaluated in terms of their trade impact using a sample selection gravity model approach. Second, welfare effects arising from the different quarantine measures imposed in the last years are calculated using a spatial partial simulation model which differentiates risk and infection status of imported poultry meat by origin. Finally, the results from these two approaches are brought together

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[23] The share of cooked poultry meat exports on total global poultry meat exports nearly doubled from 2004 to 2006 after outbreaks of HPAI in 2003 had major negative impacts on the global poultry industry (Taha 2007). Overall, the share of global cooked poultry meat exports on global total poultry meat exports was just 12% in quantity terms and 23% in value terms in the year 2005 (UNCTAD 2011a).

to provide a full picture of the effects of these quarantine measures on trade and welfare.

In order to account for the different AI policies that are relevant for uncooked and heat-treated poultry meat, we distinguish these two meat categories. Uncooked poultry meat is defined as to include fresh, chilled or frozen broilers, chickens, turkeys, ducks, geese and guinea flows sold in cuts, parts or whole birds (HS 0207) and cooked poultry meat covers all processed poultry products sold in preserved, smoked, prepared or cooked form (HS 160231, 160232, 160239).

The remainder of the case study is organized as follows. The first section, divided into two sub-parts, explains the gravity and the simulation model and describes the respective data sources. The second section contains the results of the two approaches and the final section concludes.

5.1 Methodology and data

This section derives methodology and presents data used in the case study. The first part concentrates on the gravity model of poultry meat trade, and the second part presents the spatial partial simulation model to assess welfare changes of different AI-related regulatory policies.

5.1.1 Trade flow analysis using a gravity model

In order to evaluate the impact of AI-related policy measures on trade, a Heckman-type econometric model based on Helpman et al. (2008) extended to a SUR systems approach is estimated. This allows for the desired disaggregated commodity specification. Generally, the more disaggregated the product classification of the observed trade flows, the more frequently zeros are found in the datasets. The sample selection (or Heckman or Tobit II) model takes advantage of the presence of non-existent trade flows by making a selection of country-pairs into the ones that are trading and that are not trading with each other. Helpman et al. (2008) extend that basic sample selection model by accounting for firm level heterogeneity. Given that poultry meat is split into two different product categories which are linked (e.g. via prices) to each other, the inclusion of a SUR system corrects for potential correlation between errors that may be present when using the basic sample selection approach.

Model structure

Like in the Heckman model, the econometric model in this paper consists of two separately estimated equations. First, the selection equation investigates the decision whether to trade or not:

$$\rho_{ijk} = \Pr\left(h_{ijk} = 1 \mid x_{1k}\right) = G\left(x_{1k}, \beta_{1k}\right), \tag{27}$$

where ρ_{ijk} is the probability that country i exports poultry meat of category $k \in \left[cookedmeat\left(1\right), uncookedmeat\left(2\right)\right]$ to country j conditional on the vector of observed variables x_{1k} potentially explaining trade costs which might vary between the two meat categories k. The binary variable h_{ijk} indicates whether a trade flow from country i to country j is positive $\left(h_{ijk} = 1\right)$ or zero $\left(h_{ijk} = 0\right)$ for the respective meat category k. The function $G\left(.\right)$ is designed as the cdf of the bivariate normal distribution and is therefore in the interval $\left[0,1\right]$, and β_{1k} is the vector of coefficients in the domain k. The selection equation (27) is estimated separately for both poultry meat categories k. Following Verbeek (2004), the two estimated residual vectors $\hat{\varepsilon}_k$ originating from the Probit selection equation (27) are both normal and identically distributed $NID(0,1)$ and are used to calculate the covariance matrix

$$\hat{\Omega} = E\left[\varepsilon\varepsilon'\right] = \begin{Bmatrix} \hat{\sigma}^2_{k=1,k=1} I_T & \hat{\sigma}^2_{k=1,k=2} I_T \\ \hat{\sigma}^2_{k=2,k=1} I_T & \hat{\sigma}^2_{k=2,k=2} I_T \end{Bmatrix}, \qquad (28)$$

where $\hat{\sigma}^2_{m,n} = \frac{1}{df}\hat{\varepsilon}_m{}'\hat{\varepsilon}_n$, $(m,n) \in \{1,2\}$, with df being degrees of freedom, and I is the TxT identity matrix with T being the number of explanatory variables in x_{1k}. The estimated covariance matrix $\hat{\Omega}$ is then used to calculate the SUR-estimates

$$\hat{\beta}_{1SUR} = \left(X_1{}'\hat{\Omega}^{-1}X_1\right)^{-1} X_1{}'\hat{\Omega}^{-1} y \qquad (29)$$

by stacking both product categories into one equation, where $X_1 = \begin{Bmatrix} x_{1k=1} & 0 \\ 0 & x_{1k=2} \end{Bmatrix}$ and the vector $y = \begin{Bmatrix} y_{k=1} \\ y_{k=2} \end{Bmatrix}$ is the stacked latent variable originating from the Probit selection equation (27).

The second equation estimates bilateral trade quantities of poultry meat conditional on a positive trade flow (Helpman et al. 2008):

$$E\left\{m_{ijk} \mid h_{ijk} = 1\right\} = x_{2k}\beta_{2k} + \sigma_{12k}\lambda_{ijk} + \omega_{ijk} + u_{ijk}, \qquad (30)$$

where m_{ijk} is the logarithmic observed trade flow from country i to country j given that the observed trade flow h_{ijk} is positive, and x_{2k} denotes a vector of variables potentially explaining trade costs. As in the selection equation (27), the estimation is done separately for both meat categories k and the unobserved errors

u_{ijk} are assumed to be distributed bivariate normal. The covariance σ_{12k} of the unobserved errors (or unobserved trade costs) of the selection and the trade flow equation is estimated as a coefficient in equation (30). Following Heckman (1979), Heckman's lambda $\lambda_{ijk} = \frac{\phi(x_{1k}\beta_{1k})}{\Phi(x_{1k}\beta_{1k})}$ controls for sample selection and can be calculated after estimating the SUR equation (29); the calculated estimate $\hat{\lambda}_{ijk}$ replaces λ_{ijk} in equation (30). Helpman et al. (2008) extend the Heckman approach by not only controlling for sample selection through variable λ, but also accounting for unobserved firm level heterogeneity.

The underlying idea is that firms differ in their productivity levels so that only sufficiently productive firms who are able to overcome market entry costs such as NTMs export. Firm level heterogeneity therefore allows accounting for the impact of NTMs and other country characteristics on the share of exporting firms. In this respect the impact of trade frictions is decomposed into its effect on the number of exporters and its effect on the trade volume per exporter. Thus, the additional parameter $\omega_{ijk} = \ln\left\{\exp\left[\delta\left(\hat{z}_{ijk} + \hat{\lambda}_{ijk}\right)\right] - 1\right\}$ controls for the correlation of firm level heterogeneity with the firms' export decision.[24] The estimate $\hat{z}_{ijk}$ is the inverse of the cdf of the estimated probability that country i exports to country j $\left(\hat{\rho}_{ijk}\right)$ and is obtained after estimation of the SUR-equation (29).[25]

Data

Trade data in value terms for the years 2000 – 2007 originates from the United Nations (UN) Comtrade database (UNCTAD 2011a). Each of the exporters covered in the analysis potentially exports in each year both types of poultry meat

[24] See Helpman et al. (2008) equation (9) and (14).

[25] Technically, GAUSS 9.0 is used to solve the optimization problem in conjunction with the application module Constrained Optimization. The code is available upon request.

products to the covered importers, accounting for $n = 288$ trade flow observations, of which 87.5% are nonzero. Mean and variance of the trade flow and explanatory variables are depicted in Table 12.

Bilateral data on the bilateral policy measures (1) ban on both meat categories, (2) ban on uncooked meat,[26] and (3) ban on cooked and/or uncooked meat but adhering to the principle of regionalization result from the Japanese Animal Quarantine Service homepage (AQS 2010) and from the Russian Ministry of Agriculture (2010).[27] It is assumed that ROW as importer implements policy measures in line with the official OIE requirements, i.e. just bans for uncooked meat from HPAI producers according to the principle of regionalization. As Table 12 shows, 9% of the bilateral cooked poultry meat trade relationships are faced with a ban and in 9% of the trade flows the principle of regionalization is applied. In comparison with cooked meat, trade flows of uncooked poultry meat are affected more often by AI-related policy measures: 16% are constrained by a ban, and 12% operate under the principle of regionalization.

Table 12 Mean and variance of model variables

	Cooked meat		Uncooked meat	
Variable	**Mean**	**Variance**	**Mean**	**Variance**
ln trade value/1000 [$]	9.01	10.25	11.78	4.90
ln production exporter [t]	14.05	1.57	14.93	1.56
ln consumption importer [t]	13.61	4.56	15.58	2.71
ln distance [km]	8.82	0.35	8.81	0.35
Ban	0.09	0.08	0.16	0.13
Principle of regionalization	0.09	0.08	0.12	0.10
Tariff	6.61	43.85	7.49	124.95

Source: Authors' calculation.

[26] By way of construction, policy measures (1) and (2) are combined into one explanatory variable "ban" in the econometric analysis.

[27] The three policy options are chosen as they are addressed in the Terrestrial animal health code (OIE 2011). Additionally, they are a matter of trade concerns raised in the SPS Committee (WTO 2011). Bans may be imposed for time periods less than a year. In case such a short time ban is imposed, nonetheless the ban dummy changes from zero to one in that year. As result, trade flows may be present in a particular year even though a ban is imposed.

Data on production and consumption quantities on the aggregate poultry meat result from the FAO (2011) and the UN (2011), as well as from the German market and price information system (ZMP 2006-2008). Differing from Tinbergen (1962) we include sectoral production (for exporters) and consumption quantity data (for importers) as explanatory variables instead of the countries' GDP, accounting for the sectoral analysis within this case study. An inquiry carried out by the Business Analytical Center (BAC 2010) delivered disaggregated production and consumption data for European countries differentiated by cooked and uncooked poultry meat. It is further used to estimate the shares for cooked and uncooked meat for the regions where the information is missing. This is done by a regression of the disaggregated production and consumption data on per capita GDP (Zhao 2011).

Bilateral data on geographic distance and common language (ethno)[28] originates from the Centre d'Etudes Prospectivs et d'Informations Internationales homepage (CEPII 2010). The distance to the respective ROW import destination is calculated as the mean over all countries where the two explicit importers Russia and Japan are excluded. Tariff data stems from the UN Tariff and Trade Analysis database (UNCTAD 2011b). If available, the bilateral effectively applied weighted tariff is chosen; otherwise, the most-favored-nations tariff is included. Additionally, dummy variables for the observed time period and for exporter and importer-specific fixed effects are included.

5.1.2 Welfare analysis using a spatial partial equilibrium model

Spatial partial equilibrium models analyzing NTMs related to animal health have a long history in the literature. Since early research as found in Paarlberg and Lee (1998), the spatial coverage (e.g. Jansson et al. 2005), richness in model and disease parameter specification (e.g. Disdier and Marette 2010, Peterson and Orden

[28] The trade partners within the sample do not share a common language. However, we assume that the trade partners US-ROW, EU-ROW, and France-ROW use a common language, expressing the worldwide dispersion of the languages English and French.

2008), and linkage to dynamic herd-size models (e.g. Niemi and Lehtonen 2011, Nogueira et al. 2011, Mangen and Burrell 2003), or other information related to the impact of specific measures has considerably amplified. A specific focus on the impacts of AI is found in Djunaidi and Djunaidi (2007) though they focus on the timing of outbreaks in different world regions, concentrate just on HPAI countries, and do not differentiate between cooked and uncooked poultry meat.

Model structure

The model follows the design of a spatial multi-commodity model for homogenous products based on the Takayama-Judge approach (Takayama and Judge 1971) which allows for a highly disaggregated commodity specification in conjunction with bilateral trade policy measures. It is able to display the products' origins and destinations. Trade flows are driven by transport cost minimization. The behavioral equations for supply and demand are calibrated as to recover observed quantities at given prices, and non-linear per unit transport cost are introduced to reproduce observed trade flows.

Poultry meat is not only differentiated by its processing stage (cooked/uncooked) but also according to the origin's country disease status (AI free, AI low pathogenic, AI high pathogenic) in order to model the various AI policy measures on a disaggregated level. According to OIE (2011) guidelines, only for uncooked meat from high pathogenic origins a ban is an appropriate measure for preventing the dispersion of AI.

For the demand side, we assume that consumers are indifferent regarding the origin of poultry meat and thus, implicitly, also regarding the meat's AI status. The latter assumption might be astonishing as one effect of the global avian influenza outbreak a few years back was a drastic reduction of poultry meat consumption in the short run. However, consumers returned to earlier consumption pattern relatively quickly, despite the fact that herds still carried the disease. In spring 2011, a poultry herd in Germany was culled due to an AI outbreak in wild birds in the neighborhood. This was widely made known via the media but a change in consumption levels of cooked or uncooked poultry meat could not be observed. These observations let us chose a model specification where AI is treated as an animal disease with supply side effects, but no impact on consumer behavior (as e.g. in Nogueira 2011, Djunaidi and Djunaidi 2007, and Paarlberg and Lee 1998).

Supply of poultry meat and risk of infection

On the supply side, a perfectly competitive industry within each region is assumed where regions are indexed by r. A normalized quadratic (NQ) profit function (cf. Lau 1978) is used to measure welfare changes for the aggregate representative producer and to derive supply functions for each region and poultry meat category i and j:

$$\pi^*{}_r = \sum_i c_{r,i} ps^*_{r,i} + \tfrac{1}{2} \sum_{ij} bs_{r,i,j} ps^*_j ps^*_i + \sum_i br_{r,i} risk_{r,i} ps^*_{r,i}, . \quad (31)$$

where π_r is the profit in region r. A general price index reflecting the price of all intermediate inputs and primary factors is implicitly assumed in the background for normalization and kept fixed at unity in simulation experiments.[29] Normalized producer prices $ps_{r,i}$ for each region and meat category are used in the model and drive supply via the parameters c and bs. The second summation in equation (31) reflects cross price effects. Additionally, supply is influenced by infection risk $risk$. A higher infection risk shifts the supply function to the left depending on the parameter br, equivalent to the assumption of marginal production costs increasing with the infection risk.

The derived supply functions $sply$ are linear in (normalized) producer prices and risk:

[29] ‘Star’ stands for normalized values. Normalization is no longer explicitly shown in the following equations.

$$sply_{r,i} = \frac{\partial \pi_{r,i}}{\partial ps_{r,i}} = c_{r,i} + \sum_j bs_{r,i,j}\, ps_j + br_{r,i} risk_{r,i} \,. \tag{32}$$

Similar to Peterson and Orden (2008), the infection risk for a product and market is determined by the share of infected uncooked poultry products in the domestic market, either imported or from domestic sales. The variable $risk$ is hence calculated from the variable flows (the off-diagonal elements represent the trade from region $r1$ to region $r,$ whereas the diagonal elements depict domestic sales) and the share of infected products $shareInf$ of the producing region $r1.$ The share is derived from the AI status of the country (see Table 13 below):

$$risk_{r,i} = \frac{\sum_{r1} flows_{r,r1,i} shareInf_{r1,i}}{\sum_{r1} flows_{r,r1,i}}. \tag{33}$$

According to OIE (2011), it is assumed that only uncooked meat carries an infection risk. Thus, equation (33) above together with the supply formulation implies that higher shares of infected uncooked meat in imports lead to higher infection rates of domestic livestock. A distinction between LPAI and HPAI importers is hence solely expressed by the parameter $shareInf$.

The disease status for each country results from the AI country classification of the WHO (2011b) based on AI outbreaks during the years 2000-2007 and is depicted in Table 13.[30] We assume that the AI status of each region does not change over time as experience has shown that once AI is present in a region it is extensive and time-consuming to eradicate it (Swayne and Akey 2005).

[30] Djunaidi and Djunaidi (2007) for example do not distinguish between LPAI and HPAI status and assume a flat 25% production loss when an outbreak occurs.

Table 13 AI status of countries and assumption about the effect on supply

Status	Countries	Assumed impact on supply ("share of infected products")
AI free	Brazil, The Netherlands	0 %
LPAI	US, Japan, ROW	2 %
HPAI	Germany, France, China, Russia	5%

Source: Country classification based on WHO (2011b).

Demand of poultry meat

On the demand side, a Generalized Leontief (GL) expenditure system (Ryan and Wales 1999) drives demand quantities dem of the aggregate representative consumer depending on endogenous consumer prices pd and fixed and given regional income Y :

$$dem_i = comm_{r,i} + \frac{Gi_{r,i}}{G_r}\left[Y_r - F_r\right], \tag{34}$$

with $F_r = \sum_i comm_{r,i}\, pd_i$, $G_r = \sum_{i,j} bd_{ij}\sqrt{pd_i\, pd_j}$, and

$Gi_{r,i} = \partial G_r \big/ \partial pd_{r,i} = \sum_j bd_{ij}\sqrt{pd_i \big/ pd_j}$.

The parameters $comm$ can be interpreted as commitments, i.e. quantities consumed independent of prices and income, the term F being the value of the commitments at given demand prices pd . The non-committed income $\left(Y - F\right)$ is then distributed to the products according to the term G and its first derivative with respect to prices Gi as shown above. Parameter bd represents the matrix of coefficients to be calibrated. Symmetry is guaranteed by a symmetric bd matrix describing the price dependent terms. Correct curvature is assured by non-negativity of the off-diagonal elements of bd , and adding up is automatically given.

Welfare changes for consumers are based on the money metric concept (cf. Varian 1992), which is calculated for the GL demand systems as:

$$monMetr_r = \frac{G_r^{sim}}{G_r^{cal}}\left[Y_r - F_r^{sim}\right] - \left[Y_r - F_r^{cal}\right]. \qquad (35)$$

Terms for the welfare change calculation must be measured in the calibrated benchmark point of the model cal and in the simulation run sim.

Market equilibrium

Besides the behavioral equations for supply and demand, the model further comprises for each market two equations which ensure first, that supply cannot exceed exports plus domestic sales and second, that import flows plus domestic sales do not fall below demand.[31]

$$sply_{r,i} \geq \sum_r flows_{r,r1,i} \perp p\text{s}_{r,i}, \qquad (36)$$

where $\sum_r flows_{r,r1,i} \geq dem_{r,i} \perp pd_{r,i}$.

These trade flow equations are paired with the respective producer and consumer prices. Thus, the complementary slackness condition ensures that excess supply requires zero producer prices where excess sales let consumer prices drop to zero.

Finally, the spatial arbitrage condition from transport cost minimization is added for each market. It is paired according to complementary slackness conditions with the transport flows implying that when a trade flow is positive,

[31] Market balances for cooked and uncooked poultry meat are displayed in Table A1 in the Appendix.

producer price multiplied with import tariff t plus transport costs tc must be (larger or) equal to demand price:

$$ps_{r1,i}\left(1+t_{r1,i}\right)+tc_{r,r1,i} \geq pd_{r,i} \perp flows_{r,r1,i}. \tag{37}$$

Per unit transport costs are a linear function of transported quantities where the function is specified using the parameters atc and btc:

$$tc_{r,r1,i} = atc_{r,r1,i} + btc_{r,r1,i}\, flows_{r,r1,i}. \tag{38}$$

Non-constant per unit transport costs are introduced in order to smooth the overall behavior of the model but with the disadvantage that the additional slope parameter introduces a rather unknown element in the model. The parameters are derived from the dual solution of a model forced to replicate the observed trade flows at given prices (cf. Paris et al. 2009). However, in here we introduce additionally a slope term to avoid a degenerate dual solution. It is derived by assuming that per unit transport costs increase a certain percentage if the trade flow doubles.[32]

Data

The simulation model shares as far as possible the data with the gravity estimation. As the reference point, averages of trade quantities, values, supply and consumption of the years 2000-2007 are taken. Transport costs are derived from the maritime transport costs data base of OECD (2011). Port-to-port shipping distance between trading partners is collected from the website SeaRates.com where the "Nearest Rule" is applied when more than one port in a country exists (SeaRates 2011). In order to come up with average transport costs from country to country, several steps need to be performed as outlined in Zhao (2011). Import

[32] Technically, GAMS 23.6 in conjunction with PATH 4.6 is used to solve the optimization problem. The code is available upon request.

tariffs for poultry meat result from the Common Agricultural Policy Regional Impact (CAPRI) global multi-commodity model (Britz and Witzke 2008).
For the data to be used in an economic simulation model, the first order conditions from welfare maximization must hold at the calibration point. Accordingly, similar to the construction of data sets for global computable general equilibrium models (Narayanan and Walsmley 2008), we first calculated a closed, complete and consistent set of quantity and price data for our products and regions in the simulation model based on the available raw data information.

Model parameters and parameter uncertainty

Parameters for both the supply and demand system are chosen such as to recover given point elasticities of quantities and prices at the calibration point. However, given standard constraints from microeconomic theory, even flexible functional forms as the ones chosen in the model cannot recover any set of given point elasticities from the data. Accordingly, parameter calibration is based on constraint optimization which chooses the set of parameters minimizing the differences between point elasticities calculated from current parameters and given point elasticities, while calibrating the behavioral functions to given prices and quantities and theory consistent microeconomic constraints. Further details on the parameter calibration can be found in the CAPRI documentation (Britz and Witzke 2008 pp. 92-93). The intercept of the transport cost equation is derived from the dual solution of the model forced to replicate the observed trade flows at given prices (cf. Paris et al. 2009). The slope term, introduced additionally to avoid degenerate dual solutions, is drawn from a uniform distribution as described below.

For all countries, the following parameters are unknown or proxies from other studies: Supply and demand elasticities differentiated for cooked and uncooked poultry meat, impact of increased infection risk on supply, and slope parameter of the transport costs. We address this parameter uncertainty using Monte Carlo techniques following Gilbert (2003) and Abler et al. (1999). This is done by drawing 1000 random sets of parameter values from a uniform distribution assuming that the parameters vary simultaneously and independently. Next, for each draw, the behavioral functions are re-calibrated against the drawn parameters and the model is solved. The resulting changes in quantities, prices and resulting welfare measures for each draw and scenario are stored and their mean values are calculated and reported in the end. The parameter means are assumed to be: -0.5 for own and +0.25 for cross price demand elasticities; +1 for own and -0.5 for cross price supply elasticities; 0.1% increase in per unit transport costs if the trade flow doubles as starting point for the slope of the transport cost equation (38); and a 20% drop of production if all imports and domestic sales would be HPAI infected, as relevant for the risk parameter in the supply equation (32).

5.1.3 Avian influenza policy scenario definitions

Whereas the gravity approach evaluates ex-post the trade impact of import bans and the principle of regionalization, the spatial simulation model quantifies the welfare effects related to the introduction of import bans. Given the policy discussion about the justification of import bans, two scenarios are implemented:

1. "Drastic scenario": Introduction of an import ban by avian influenza free (FAI) countries for cooked and uncooked meat from HPAI and LPAI countries and by LPAI countries for imports from HPAI countries.
2. "Realistic scenario": Introduction of an import ban for uncooked meat from HPAI countries only by FAI and LPAI countries.

The bans prevent any imports of uncooked poultry meat, as results of the econometric estimation (see column 3 of Table 15) indicate that past import bans on uncooked poultry meat were effective. Missing data at the sub-national level (production, consumption, trade, AI status) do not allow modeling the principle of regionalization.

5.2 Results

First, results of the trade flow analysis are described, before the findings of the welfare analysis including the different chosen policy scenarios are presented.

5.2.1 Trade impact results using the gravity model

The following two tables present outcomes of the econometric model consisting of the selection equation (27) and the outcome equation (30). The SUR-estimates of equation (29) are not presented but are available upon request.

Selection equation

Table 14 provides the results of the selection equation (27) which present an intermediate output of the chosen econometric specification. Thus, results have to be interpreted with caution. In addition to the variables presented in Table 14, a time dummy variable and exporter and importer-specific fixed effects are included in equation (27). The signs for ‘distance’ are highly negative for both meat categories suggesting a strong impact of transport costs or a preference of consumers towards domestic or nearby produced meat. The trade partners’ economic sizes of their poultry meat markets do not have a clear positive impact on the probability of bilateral trade, contrary to the prediction of gravity theory. The ‘language’ variable has unexpectedly a negative impact for both product groups which may be determined by the fact that only few trade partners within the sample share a common language (cf. footnote 28). The sign of the policy variable ‘import ban’ is negative, but significant only in case of uncooked meat. The difference in magnitude and significance can be explained through the combination of ‘ban on both meat categories’ and ‘ban on uncooked meat’ into one explanatory variable ‘ban’. That means, $n_{cu} \geq n_u$, where n_{cu} is the number of observed bans imposed on cooked and uncooked meat, and n_u is the number of observed bans just on uncooked meat.

Table 14 Results of the selection equation for cooked and uncooked meat estimated by Probit ML

	Cooked meat		Uncooked meat	
Control variable	**Coefficient**	**Std. error**	**Coefficient**	**Std. error**
Production exporter	-6.042	9.140	-307.437***	8.958
Consumption importer	32.314	22.599	-642.566***	16.685
Distance	-61.265***	5.234	-25.514***	9.307
Ban	-1.185	1.091	-5.698***	0.353
Regionalization	-4.775*	2.585	2.744***	0.311
Tariff	-14.437***	4.9780	60.423***	5.697
ComLang	-17.535***	1.177	-47.629***	0.789
n = 144			n = 144	

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% level.
Source: Authors' calculation.

The marginal effects of the 'ban' evaluated at the sample means (cf. Greene 2008 p.775) are -0.383 for cooked and -0.490 for uncooked meat, meaning the 'ban' downsizes the probability of trade for a typical country pair by 38% and 49%, respectively. The policy variable 'regionalization' has an unexpected negative and significant trade impact in case of cooked meat (marginal effect: -0.415), whereas it is, as expected, significantly positive in case of uncooked meat (marginal effect: 0.500). The result for the 'tariff' variable is negative in case of cooked poultry meat, but unexpectedly positive in case of uncooked meat.

Outcome equation

Findings of the final outcome equation (30) which is estimated by NLS due to its non-linear term ω are presented in Table 15. Following Helpman et al. (2008), 'language' is used as excluded variable. Estimates deviate from the findings of the selection equation, becoming more theory consistent. In case of cooked poultry meat, the outcome equation yields the expected estimates for the 'production', 'consumption' and 'distance' variables as can be seen in column 1. The cooked meat coefficients' standard errors are presented in column 2.

Table 15 Results of the outcome equation for cooked and uncooked meat estimated by NLS

	Cooked meat		Uncooked meat	
Control variable	**Coefficient**	**Std. error**	**Coefficient**	**Std. error**
Production exporter	14.060***	4.440	4.420	6.541
Consumption importer	27.912***	8.889	11.909	7.530
Distance	-4.139***	0.856	-2.625**	1.286
Ban	1.692***	0.623	-6.046***	1.710
Regionalization	-0.551	0.532	3.109*	1.736
Tariff	0.393	0.720	-1.439	0.906
Omega (Firm heterogeneity)	1.127***	0.396	0.872	0.656
Lambda (Sample selection)	-3.988***	0.910	-7.652***	2.030
n = 126				

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% level.
Source: Authors' calculation.

The trade impact of the 'tariff' is not significant. The outcome of the 'ban' variable is positive, but the 'regionalization' variable has a negative estimation result, though not significant. Interpreting both variables in terms of marginal effects, a situation with a ban increases trade more than 5 times $\left[\left(\exp\left(m+1.692\right)\right)=M\cdot 5.430\right]$ in comparison to a situation without a ban, where m is the natural logarithm of the actual trade flow observation M. Obviously, shift effects from raw meat to preserved meat after establishing a ban play its role. Instead, implementing the 'regionalization' variable reduces trade by more than 40% in the cooked meat case. As in Helpman et al. (2008), firm level heterogeneity shows a positive trade impact, whereas the sample selection estimate is significantly negative.

The outcome for uncooked meat presented in column 3 of Table 15 mirrors our expectations for the regulatory policy variables. Column 4 contains the uncooked meat coefficients' standard errors. 'Production', 'consumption' and 'distance' variables show the expected signs, though only the 'distance' variable outcome is statistically significant. The 'ban' shows a negative sign whereas the 'regionalization' variable is positive, both statistically significant. Interpreting the two policy variables, a situation with a ban reduces trade in uncooked meat by nearly 100% $\left[\left(\exp\left(m-6.046\right)\right)=M\cdot 0.002\right]$ in comparison to a situation without a ban. Installing the policy option 'regionalization' instead augments trade more than 22 times. Results of the variables 'tariff' and 'firm level heterogeneity' are not significant, whereas 'sample selection' again shows a significant negative trade impact.

Summarizing, the policy variable 'ban' has a nearly prohibitive trade impact for uncooked meat whereas the 'regionalization' variable is trade enhancing. For cooked meat estimation results are inconclusive: The estimates are either insignificant, or have unexpected signs. This outcome might be linked to substantial shift effects from uncooked meat to cooked meat.

5.2.2 Welfare results using the spatial partial equilibrium model

The introduction of import bans is globally welfare decreasing in both scenarios (Table 16).[33] In both scenarios, production is slightly shifted from uncooked to cooked meat with associated changes in demand and prices (Table 17). On world level, quantity weighted average producer prices for uncooked meat decrease, also due to cost savings in countries with reduced infection risk, whereas consumer prices increase as a result of increasing average per unit trade costs due to trade diversion effects. Globally, exports of uncooked poultry meat are reduced whereas exports of cooked meat increase. Largest absolute welfare losses are recorded in the ROW countries which also represent the largest market with about 43% of world consumption.

[33] The supply side is split up into production of meat and the transport and marketing sector. The sum of their marginal costs determines consumer prices and consumption effects. The welfare calculation accounts for the effects of the three representative agents (producers, traders, consumers).

Table 16 Mean absolute welfare changes compared to baseline (M. Euro)

		Realistic scenario			
	AI status	**Sum**	**Money Metric**	**Transport costs**	**Profits**
World		-224.87	-296.18	78.60	-7.29
Netherlands	FAI	-1.67	0.46	-0.81	-1.32
Brazil	FAI	-3.11	15.08	-0.11	-18.08
Germany	HPAI	-15.08	8.94	5.90	-29.92
France	HPAI	-8.91	17.35	-1.46	-24.79
China	HPAI	-59.06	122.25	8.58	-189.90
Russia	HPAI	-4.44	21.37	25.84	-51.66
USA	LPAI	18.54	4.41	-1.95	16.08
Japan	LPAI	15.22	-6.90	-7.10	29.22
ROW	LPAI	-166.36	-479.14	49.70	263.08
		Drastic scenario			
	AI status	**Sum**	**Money Metric**	**Transport costs**	**Profits**
World		-282.16	-356.79	85.90	-11.27
Netherlands	FAI	-1.46	0.04	-1.42	-0.08
Brazil	FAI	-1.65	12.82	-0.06	-14.40
Germany	HPAI	-30.88	43.61	-0.01	-74.48
France	HPAI	-30.50	45.30	-5.44	-70.36
China	HPAI	-86.25	167.36	16.94	-270.55
Russia	HPAI	-17.33	33.82	15.18	-66.34
USA	LPAI	29.71	-23.84	-2.68	56.22
Japan	LPAI	28.65	-13.84	5.83	36.66
ROW	LPAI	-172.45	-622.06	57.56	39.04

Source: Authors' calculation.

Table 17 Mean supply and demand quantities and mean prices

			Realistic scenario				Drastic scenario			
Country	**AI status**	**Type of meat**	**Supply**	**Demand**	**Price [€/kg]**		**Supply**	**Demand**	**Price [€/kg]**	
			[1000 t]	*[1000 t]*	*Producer*	*Consumer*	*[1000 t]*	*[1000 t]*	*Producer*	*Consumer*
World		Uncooked	61,797.6	61,797.6	1.0	1.1	61,804.9	61,804.9	1.0	1.1
			-0.2	*-0.2*	*-0.3*	*0.4*	*-0.1*	*-0.1*	*-0.3*	*0.4*
		Cooked	12,963.3	12,963.3	2.0	2.1	12,953.1	12,953.1	2.0	2.1
			0.2	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*	*0.2*	*0.4*
Netherlands	FAI	Uncooked	597.7	219.8	1.0	1.1	597.4	219.9	1.0	1.1
			-0.3	*0.2*	*-0.3*	*-0.3*	*-0.4*	*0.2*	*-0.3*	*-0.2*
		Cooked	78.0	49.8	1.9	2.2	78.5	49.7	1.9	2.3
			0.4	*-0.2*	*0.2*	*0.2*	*0.9*	*-0.3*	*0.7*	*0.5*
Brazil	FAI	Uncooked	7,014.9	5,608.5	1.0	1.1	7,014.1	5,608.4	1.0	1.1
			-0.3	*0.1*	*-0.3*	*-0.3*	*-0.3*	*0.1*	*-0.3*	*-0.2*
		Cooked	400.5	254.3	2.0	2.2	401.8	254.0	2.0	2.2
			0.3	*-0.1*	*0.2*	*0.1*	*0.6*	*-0.3*	*0.5*	*0.4*
Germany	HPAI	Uncooked	665.4	1,011.9	1.0	1.1	675.9	1,004.6	1.0	1.1
			-4.5	*0.5*	*-1.1*	*-0.9*	*-3.0*	*-0.2*	*-1.2*	*-0.9*
		Cooked	222.7	251.3	1.9	2.2	206.2	259.7	1.8	2.1
			0.7	*-0.3*	*0.2*	*0.2*	*-6.8*	*3.0*	*-6.6*	*-5.8*
France	HPAI	Uncooked	1,561.8	1,363.4	1.0	1.1	1,573.9	1,357.8	1.0	1.1
			-1.6	*0.7*	*-0.9*	*-1.2*	*-0.8*	*0.2*	*-1.0*	*-1.3*
		Cooked	244.4	198.1	2.0	2.2	228.1	204.8	1.9	2.1
			0.6	*-0.4*	*0.2*	*0.2*	*-6.1*	*3.0*	*-6.0*	*-5.8*
China	HPAI	Uncooked	12,947.1	13,563.1	1.0	1.1	12,954.7	13,559.4	1.0	1.1
			-1.4	*0.4*	*-1.2*	*-0.8*	*-1.4*	*0.4*	*-1.3*	*-0.9*
		Cooked	356.0	272.3	2.0	2.2	330.7	281.4	1.9	2.1
			0.7	*-0.3*	*0.2*	*0.2*	*-6.5*	*3.0*	*-6.4*	*-5.7*
Russia	HPAI	Uncooked	1,058.1	2,430.1	0.9	1.1	1,059.2	2,428.4	0.9	1.1
			-4.9	*0.4*	*-2.3*	*-0.8*	*-4.8*	*0.3*	*-2.4*	*-0.8*
		Cooked	66.9	78.4	1.9	2.2	62.1	81.2	1.8	2.1
			1.2	*-0.3*	*0.2*	*0.2*	*-6.1*	*3.3*	*-6.5*	*-6.1*
USA	LPAI	Uncooked	14,623.3	13,387.7	1.0	1.1	14,612.4	13,391.4	1.0	1.1
			0.0	*0.1*	*0.0*	*-0.1*	*-0.1*	*0.1*	*0.0*	*-0.1*
		Cooked	2,257.9	2,262.6	2.0	2.2	2,271.7	2,257.0	2.0	2.2
			0.2	*-0.1*	*0.2*	*0.2*	*0.8*	*-0.4*	*0.7*	*0.6*
Japan	LPAI	Uncooked	995.0	1,585.2	1.0	1.1	993.7	1,586.5	1.0	1.1
			2.5	*-0.1*	*1.0*	*0.3*	*2.4*	*0.0*	*1.1*	*0.3*
		Cooked	307.5	397.0	1.9	2.2	310.1	395.4	1.9	2.3
			-0.2	*0.0*	*0.2*	*0.2*	*0.6*	*-0.4*	*1.0*	*0.9*
ROW	LPAI	Uncooked	22,334.2	22,627.9	1.0	1.1	22,323.5	22,648.4	1.0	1.1
			0.9	*-0.8*	*0.2*	*1.8*	*0.8*	*-0.7*	*0.3*	*1.9*
		Cooked	9,029.3	9,199.4	2.0	2.1	9,064.1	9,169.9	2.0	2.1
			0.1	*0.3*	*0.2*	*0.2*	*0.5*	*0.0*	*0.6*	*0.9*

Note: Per cent change to baseline in italic below each value.
Source: Authors' calculation.

Overall, in the realistic scenario, welfare losses due to the imposed trade ban for uncooked meat are recorded for all HPAI and FAI countries. LPAI countries show welfare gains with the exception of the aggregate of remaining countries (ROW). The welfare reductions in FAI and HPAI countries mostly result from losses in producer profits provoked by trade diversion effects in uncooked (Table 18) and cooked meat (Table 19). As HPAI countries can no longer sell uncooked meat abroad, they increase domestic sales (e.g. Germany +1.7%) and trade more among each other (e.g. Germany to China, or China to Russia) so that FAI countries lose important export destinations (e.g. Brazil to Germany -70%). In HPAI countries, the increased pressure on domestic markets leads to lower producer and consumer prices for uncooked meat which induce some production reductions. At the same time, production and exports of cooked meat slightly increases in these countries whereas demand goes down as prices decrease.

Table 18 Mean trade flows (1000 t) and per centage changes compared to baseline for uncooked meat

		Realistic scenario								
		Exporter								
		Netherlands	Brazil	Germany	France	China	Russia	USA	Japan	ROW
Importer	AI status	FAI	FAI	HPAI	HPAI	HPAI	HPAI	LPAI	LPAI	LPAI
Netherlands	FAI	141.5	74.3	0.0	0.0	0.0	0.0	2.6	0.0	1.5
		-2.5	*-0.1*	*0.0*	*0.0*	*0.0*	*0.0*	*inf*	*0.0*	*inf*
Brazil	FAI	6.5	5,599.6	0.0	0.0	0.0	0.0	0.9	0.0	1.4
		inf	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*inf*	*0.0*	*inf*
Germany	HPAI	233.1	27.8	480.7	106.6	15.1	148.5	0.2	0.0	0.0
		-29.9	*-70.2*	*1.7*	*-1.0*	*inf*	*inf*	*-78.0*	*0.0*	*0.0*
France	HPAI	1.2	0.0	3.0	1,259.7	7.4	92.1	0.0	0.0	0.0
		-96.6	*-99.7*	*inf*	*-3.8*	*inf*	*inf*	*-100.0*	*0.0*	*-100.0*
China	HPAI	1.0	61.4	38.6	22.9	12,857.6	178.8	402.8	0.0	0.0
		-88.5	*-53.6*	*inf*	*366.8*	*0.2*	*inf*	*-24.1*	*0.0*	*0.0*
Russia	HPAI	20.4	360.8	143.1	172.6	66.9	638.8	1,027.3	0.0	0.0
		-73.7	*-22.0*	*37.7*	*7.0*	*724.9*	*47.5*	*-12.5*	*0.0*	*0.0*
USA	LPAI	30.2	31.0	0.0	0.0	0.0	0.0	12,823.8	0.1	502.6
		inf	*inf*	*0.0*	*0.0*	*0.0*	*0.0*	*-0.1*	*0.0*	*-6.9*
Japan	LPAI	40.1	738.0	0.0	0.0	0.0	0.0	116.2	682.0	8.8
		inf	*11.7*	*-100.0*	*-100.0*	*-100.0*	*0.0*	*47.9*	*-9.5*	*inf*
ROW	LPAI	123.7	121.9	0.0	0.0	0.0	0.0	249.5	313.0	21,819.8
		inf	*inf*	*-100.0*	*0.0*	*-100.0*	*-100.0*	*inf*	*44.5*	*1.0*

		Drastic scenario								
		Exporter								
		Netherlands	Brazil	Germany	France	China	Russia	USA	Japan	ROW
Importer	AI status	FAI	FAI	HPAI	HPAI	HPAI	HPAI	LPAI	LPAI	LPAI
Netherlands	FAI	143.1	76.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		-1.4	*3.2*	*0.0*	*0.0*	*0.0*	*0.0*	*-100.0*	*0.0*	*-100.0*
Brazil	FAI	7.4	5,601.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		inf	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*-100.0*
Germany	HPAI	222.3	24.2	482.1	110.2	16.6	148.9	0.2	0.0	0.0
		-33.1	*-74.0*	*2.0*	*2.4*	*inf*	*inf*	*-75.6*	*0.0*	*0.0*
France	HPAI	0.8	0.0	3.0	1,258.1	7.1	88.8	0.0	0.0	0.0
		-97.9	*-99.8*	*inf*	*-3.9*	*inf*	*inf*	*-100.0*	*0.0*	*-100.0*
China	HPAI	0.9	56.3	42.1	26.4	12,859.6	180.5	393.7	0.0	0.0
		-89.7	*-57.4*	*inf*	*436.2*	*0.3*	*inf*	*-25.8*	*0.0*	*0.0*
Russia	HPAI	18.0	352.0	148.6	179.2	71.5	640.9	1,018.1	0.0	0.0
		-76.8	*-23.9*	*43.0*	*11.1*	*781.2*	*47.9*	*-13.3*	*0.0*	*0.0*
USA	LPAI	32.9	34.7	0.0	0.0	0.0	0.0	12,826.7	0.1	497.0
		inf	*inf*	*0.0*	*0.0*	*0.0*	*0.0*	*-0.1*	*0.0*	*-7.9*
Japan	LPAI	41.8	740.0	0.0	0.0	0.0	0.0	117.5	679.3	8.0
		inf	*12.0*	*-100.0*	*-100.0*	*-100.0*	*0.0*	*49.6*	*-9.9*	*0.0*
ROW	LPAI	130.2	129.2	0.0	0.0	0.0	0.0	256.2	314.3	21,818.5
		inf	*inf*	*-100.0*	*0.0*	*-100.0*	*-100.0*	*inf*	*45.1*	*1.0*

Note: Per cent change to baseline in italic below each mean trade value. inf characterizes positive changes (>1000%) starting from a mean value close or equal to zero.
Source: Authors' calculation.

Table 19 Mean trade flows (1000 t) and changes in per cent compared to baseline situation for cooked meat

		Realistic scenario								
		Exporter								
		Netherlands	Brazil	Germany	France	China	Russia	USA	Japan	ROW
Importer	AI status	FAI	FAI	HPAI	HPAI	HPAI	HPAI	LPAI	LPAI	LPAI
Netherlands	FAI	9.2	33.9	0.0	5.5	0.3	0.0	0.9	0.0	0.0
		-16.6	*1.4*	*0.0*	*2.4*	*inf*	*0.0*	*inf*	*0.0*	*0.0*
Brazil	FAI	0.0	254.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2
		0.0	*-0.2*	*0.0*	*0.0*	*840.6*	*0.0*	*888.7*	*0.0*	*inf*
Germany	HPAI	31.9	69.5	127.6	20.8	0.5	0.0	1.1	0.0	0.0
		-8.4	*1.5*	*-1.0*	*4.2*	*inf*	*0.0*	*inf*	*0.0*	*0.0*
France	HPAI	0.0	1.5	0.0	196.3	0.0	0.0	0.0	0.0	0.3
		0.0	*-48.5*	*0.0*	*0.1*	*0.0*	*0.0*	*0.0*	*0.0*	*inf*
China	HPAI	0.0	0.0	0.0	0.5	188.0	0.0	4.1	0.0	79.8
		0.0	*0.0*	*0.0*	*172.7*	*0.7*	*0.0*	*-12.4*	*0.0*	*-2.3*
Russia	HPAI	0.0	6.8	0.0	7.9	0.3	59.4	3.9	0.0	0.0
		-91.4	*9.5*	*-92.2*	*6.0*	*inf*	*-2.5*	*13.1*	*0.0*	*0.0*
USA	LPAI	0.0	0.0	0.0	12.1	0.0	0.0	inf	0.0	13.1
		0.0	*0.0*	*0.0*	*-10.6*	*0.0*	*0.0*	*0.1*	*0.0*	*-15.4*
Japan	LPAI	0.0	34.7	0.0	1.3	166.9	0.0	10.6	183.5	0.0
		0.0	*3.0*	*-76.3*	*249.3*	*0.0*	*-13.6*	*8.0*	*-1.5*	*0.0*
ROW	LPAI	36.9	0.0	95.1	0.0	0.0	7.5	0.0	124.0	8,935.8
		17.0	*0.0*	*3.4*	*0.0*	*0.0*	*44.3*	*0.0*	*1.7*	*0.2*

		Drastic scenario								
		Exporter								
		Netherlands	Brazil	Germany	France	China	Russia	USA	Japan	ROW
Importer	AI status	FAI	FAI	HPAI	HPAI	HPAI	HPAI	LPAI	LPAI	LPAI
Netherlands	FAI	7.0	42.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		-36.2	*27.6*	*0.0*	*-100.0*	*-100.0*	*0.0*	*-100.0*	*0.0*	*0.0*
Brazil	FAI	0.0	254.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	*-0.3*	*0.0*	*0.0*	*-100.0*	*0.0*	*-100.0*	*0.0*	*-100.0*
Germany	HPAI	0.0	0.0	115.5	42.7	89.5	12.1	0.0	0.0	0.0
		-100.0	*-100.0*	*-10.4*	*114.2*	*inf*	*inf*	*-100.0*	*0.0*	*0.0*
France	HPAI	0.0	0.0	34.4	152.0	0.0	18.4	0.0	0.0	0.0
		0.0	*-100.0*	*0.0*	*-22.5*	*0.0*	*inf*	*0.0*	*0.0*	*-100.0*
China	HPAI	0.0	0.0	35.4	29.5	201.3	15.1	0.0	0.0	0.0
		0.0	*0.0*	*0.0*	*inf*	*7.9*	*inf*	*-100.0*	*0.0*	*-100.0*
Russia	HPAI	0.0	0.0	20.9	3.9	39.8	16.5	0.0	0.0	0.0
		-100.0	*-100.0*	*13,159.8*	*-47.6*	*inf*	*-72.9*	*-100.0*	*0.0*	*0.0*
USA	LPAI	0.2	0.0	0.0	0.0	0.0	0.0	inf	0.0	25.8
		0.0	*0.0*	*0.0*	*-100.0*	*0.0*	*0.0*	*-0.2*	*0.0*	*66.4*
Japan	LPAI	4.3	105.1	0.0	0.0	0.0	0.0	40.7	202.6	42.6
		0.0	*212.1*	*-100.0*	*-100.0*	*-100.0*	*-100.0*	*315.7*	*8.8*	*0.0*
ROW	LPAI	66.9	0.0	0.0	0.0	0.0	0.0	0.0	107.4	8,995.6
		112.1	*0.0*	*-100.0*	*0.0*	*0.0*	*-100.0*	*0.0*	*-11.9*	*0.8*

Note: Per cent change to baseline in italic below each mean trade value. inf characterizes positive changes (>1000%) starting from a mean value close or equal to zero.
Source: Authors' calculation.

Export-oriented FAI countries cannot benefit from the AI risk reduction due to an import ban as their imports of uncooked meat from infected countries are negligible whereas their exports into LPAI and HPAI markets now compete with ban-displaced products. The Netherlands suffer losses as increased domestic sales in Germany and Russia at lower marginal production costs replace their imports so that they have to export to new destinations (ROW) at lower prices. A similar situation occurs for Brazil, where larger exports to Japan and ROW cannot compensate for the losses in the German, French, and Russian export market. Overall, in both countries, production of uncooked meat decreases and cannot be offset by low, but, positive developments in the production and export of cooked meat.

Contrary to producers in FAI countries, producers in LPAI countries benefit in this scenario (except for ROW). These gains mostly result from changes in producer rent. The export-oriented US can slightly increase its overall exports of uncooked meat (mainly to Japan and ROW) whereas for the more importer-oriented Japan (and ROW) this increase in agricultural profits results mostly from a slight increase in production in conjunction with higher domestic prices.

ROW is a net importer for both types of meat where uncooked meat is more important. Due to the assumption that ROW is a LPAI country, it loses all imports of uncooked meat from Russia, China and Germany, representing 80% of its baseline imports and 4.5% of its baseline demand. The imports are partially replaced by increased imports from HPAI free countries and domestic sales as marginal production costs increase both domestically and in the non-HPAI countries. The increase in profits cannot offset the loss of consumer welfare due to the higher prices.

The higher domestic prices for both types of meat in Japan and ROW lead to a negative effect on consumer welfare which subsequently explains the overall negative welfare effect for ROW. Consumers in all other countries benefit from lower domestic prices for the more important commodity of uncooked meat as the bans together with the trade diversion effects imply higher supply on domestic markets and thus decreased domestic prices.[34]

In the drastic scenario we observe somewhat stronger welfare changes where the direction and disaggregated effects for agricultural producers and consumers are comparable to the realistic scenario. The difference is that FAI countries also ban uncooked meat originating from LPAI countries and that cooked meat produced in HPAI countries is globally banned by countries with a lower risk status. In the results the effect of cooked meat is reflected in the fact that now HPAI countries also record losses in the production of this type of meat and that they start to trade this type of meat more intensively among each other. Given the already described effect of increased domestic supply when a ban is introduced, also this additional ban of uncooked LPAI meat hurts FAI countries, as their exports are again displaced from these markets. Thus, in the drastic scenario, overall, the FAI countries Brazil and the Netherlands decrease exports instead of being able to capture new export markets.

[34] The reader is however reminded that our findings are based on the assumption that consumers' utility is not affected directly by the perceived protection delivered by a ban.

5.3 Conclusion of the chapter

Using two approaches, this case study analyzes the impact of avian influenza-related regulatory measures on worldwide trade of cooked and uncooked poultry meat. A Heckman-type gravity model is estimated to analyze the trade impact of three AI-related policies. Second, a spatial multi-commodity simulation model is specified to account for the welfare effects of two of these policies. Results of the econometric model show differences in the trade impact of the policy measures for uncooked and cooked meat. For uncooked meat a ban has a nearly prohibitive trade impact whereas the regionalization variable is trade enhancing. For cooked meat, the results are inconclusive, which might be related to substantial shift effects from uncooked to cooked meat when bans are imposed. The simulation model highlights that important trade diversion effects among countries take place which depend very much on the infection status of the involved countries. The outcomes of the realistic and the drastic scenario differ in the intensity of their implication: The drastic scenario generally leads to higher welfare losses. A major effect, found in other studies as well but perhaps still astonishing is that banned exporting countries redirect much of their original exports towards their own market. The banned countries start to trade among each other, crowding out imports from countries which are not directly targeted by the ban.

In this study, disease transmission is modeled via the import of infected poultry meat. This is in line with the guidelines and assumptions made by the OIE, but there is scientific evidence that the risk potentially resulting from imports of uncooked meat might be negligible (Zepeda and Salman 2007, Pharo 2003). In addition, it has to be remembered that most transmission into foreign territory occurs through the migration of wild birds. Subsequent damage then happens through the infiltration of the virus into poultry flocks or because of the preventive slaughtering of neighboring poultry herds. Thus, the infection risk-related supply side effects assumed in this study are likely to be smaller and may eventually be replaced by fixed costs that are dependent on the number of outbreaks assumed to occur within a territory.

Given the scientific evidence and the country results of the welfare analysis of the simulation model, it is even more questionable than at the starting point of this study if a trade ban is the most appropriate measure to address the infection risk resulting from the spread of the avian influenza virus.

6 Conclusions of the thesis

The doctoral thesis ‘Impact of regulatory measures on international trade in meat products’ discussed the effects of various regulatory measures on international meat trade and on welfare. It surely clarified that different regulatory measures, and especially those related to the protection of agri-food production from biohazards, impact trade and welfare of countries and involved stakeholders in considerably differing levels. The analysis was carried out in two case studies, developing two different gravity models and a spatial partial equilibrium model. The most important findings shall be summarized in the following.

6.1 Summary of results

The thesis started with setting regulatory measures into the legal context of the multilateral trade regime and into the economic context of associated benefits and costs. The WTO as well as the multilateral SPS and TBT Agreements were identified to set the boundaries for a justifiable and reasonable implementation of regulatory measures within the multilateral trade regime. This system of rules aims at ensuring that regulations are not misused as disguised protectionist measures. It demands that national regulations are based on international rules developed by international standard setting organizations. However, the mulilateral trade regime foresees the possibility of divergent rules for imported food products if they impact human, animal and/or plant health and life in the importing country negatively. These divergent rules apply only to regulations which are directly product-related, or which govern production processes that are directly product-related, i.e. the choice of the production method physically impacts the final product. In order to impose different and possibly tighter regulatory measures on imported products, importing countries are required to provide a scientific risk assessment procedure, substantiating the threat associated with the product, and thereby justifying the necessity of the respective divergent requirements. Additionally, regulations have to be commensurate with regard to their objective and have to be least trade restrictive in terms of achieving their objective. Analyzing the economic context of regulatory measures, it was elaborated that they cause costs as well as benefits and therefore can shift supply and demand curves. Thus, they may impact trade flows between countries as well as domestic and foreign countries' producers' and consumers' welfare negatively or positively. Assessing the trade and welfare impact is first and foremost an empirical issue.

Chapter 2 discussed theory and quantitative methods available to determine the impact of regulatory measures on trade and gave first reasons for the choice of the econometric approaches used in the two case studies. It was elaborated that different trade theories can be used to justify the appearance and the results of the gravity equation theoretically. The gravity model can be derived from Heckscher-Ohlin and Ricardian trade theories, as well as from monopolistic competition models and Armington-like specifications. Additionally, various econometric approaches for estimating impacts of border barriers were presented in chapter 2, and their merits and disadvantages were discussed. Traditionally, gravity models are specified in a straightforward log-normal equation that is estimated by ordinary least squares (OLS). However, there are considerable problems associated with this specification and its estimation, as depending on the structure of the data the estimates might be biased and inefficient. First, trade is determined by relative trade barriers like multilateral resistance; omitting these may cause country-pair heterogeneity and biased estimates. Second, sample selection bias may result from the need to drop missing trade relationships which are quite common on a disaggregated product level. Third, the intensive and extensive margin of the trade impact of trade frictions has to be taken into account. And fourth, the questionable assumption of homoscedasticity underlying the log-linear model is a matter of concern. Possible solutions to overcome some or all of these challenges are non-linear regression models, fixed or random effects models, Tobit models, sample selection models, and different Poisson-type models. Overall, there is no unifying econometric method and the different approaches presented to overcome the discussed econometric challenges have all their advantages and disadvantages in terms of practicability, coverage and ability to capture certain features of regulatory measures.

Chapter 3 presented the first case study of this thesis. It analyzed the impact of different regulatory policy measures on meat trade with the aim to identify least trade-distorting sanitary regulations. Meat products were chosen because trade in meat is exposed to a wide number of market failures which motivates policy makers to implement regulatory instruments that may also serve protectionist purposes. A data base was developed which comprises manually collected regulations which were available in existing data bases of the WTO and the International Portal on Food Safety, Animal and Plant Health. The dataset used was specifically compiled for this study. It is new and unique with respect to the detail of information on the applied sector specific national regulatory instruments and with respect to the applied classification of measures into SPS areas and political objectives these measures serve. Altogether, over 4000 regulatory measures could be identified in the sample that were imposed on meat trade. These measures were grouped according to different classes, instruments and policy objectives. A non-linear panel data gravity model with fixed effects was estimated by Poisson pseudo-maximum likelihood to identify the measures' or rather the aggregation groups' trade impact. The outcome displayed the already mentioned ambiguous effect of many of these measures: At the class level, regulations differed in their implied trade impact. The even further disaggregated estimation at the level of the single regulation showed that there are specific measures which have a substantial positive and others which have a significant negative impact. These effects can offset each other within a class. When grouping the regulations according to underlying policy goals, policy measures ensuring animal health were identified as being significantly trade-enhancing.

Chapter 4 summarized the literature relevant for analyzing the welfare impact of sanitary regulations and set up the methodological approaches being used in the simulation part of the second case study. The chapter justified the application of a

Takayama-Judge-type model instead of an Armington-type model. Furthermore, the chapter discussed how to incorporate benefits and costs of regulatory measures into the demand and supply functions of a partial equilibrium model. It was elaborated that the introduction of policy measures regulating the threat associated with biohazards into the simulation model may impact the supply and demand functions considerably.

In chapter 5 the second case study of this thesis was presented. It analyzed the impact of AI-related policy measures on poultry meat trade and welfare. Avian influenza was identified as an important area of political concern when analyzing the trade concerns on poultry raised in the SPS Committee of the WTO. Within the case study, in a first step past AI-related policies were evaluated in terms of their trade impact using a Heckman-type sample selection gravity approach being extended according to Helpman et al. (2008) and additionally modified by introducing a SUR system. On the basis of a sample of six major poultry meat exporters and two importers as well an ROW aggregate, the policy option ban was identified to restrict trade considerably at least for uncooked meat, whereas a ban which is modified by complying with the principle of regionalization had a positive trade impact. In a second step, a spatial Takayama-Judge-type partial equilibrium model was used to simulate welfare changes due to the implementation of different AI-related policy options. Disease transmission was modeled via the import of infected poultry meat, following a so-called risk-based approach. The results of the simulation model show that important trade diversion effects among countries take place which depend very much on the infection status of the involved countries. Given scientific evidence and the results of the analysis in this second case study, it is even more questionable than at the starting point of this study whether a trade ban is the most appropriate measure to address the infection risk resulting from the spread and transmission of avian influenza.

6.2 Limitations and suggestions for further research

This thesis has provided insights into the impact of regulatory policy measures on meat trade and welfare and results can be used by policy makers and regulators. Though considerable effort has been made to capture the complexity of the research questions, the chosen methods still go along with some limitations. These are pointed out in the following, and suggestions for further research are made.

As possibly any empirical work, this thesis is subject to limitations in the existence and quality of data. This is especially the case for data on regulatory measures. Existing data bases containing information of various types of NTMs are not comprehensive enough to execute a case study on a detailed product-specific level, as it was done in both case studies in this thesis. The manual search of regulations in the first case study improved the data situation considerably, but cannot claim to be all-embracing. Furthermore, it is not always clear, whether a regulation, once implemented, is not phased out after some time. Therefore, an assumption had to be made about the average duration of effectiveness of the disease-related measures in the first case study. In the second case study this was not a concern as time-specific data was available, i.e. starting as well as ending points were given. Improving the quality of data availability was one big aim of the Framework Programme 7 NTM-Impact project sponsored by the European Commission, which supported the development of the second case study financially. However, even in a project with relatively many resources it proved to be difficult to encompass the different types, the scope, and the way of implementation of existing regulatory measures for more than a few products. Further research should measure the stringency of regulations instead just count the number of existing ones. In this regard the concept of policy heterogeneity which generates an index comparing regulations across countries on an identical scale seems to be a promising tool. This concept is pursued in an aggregate analysis as one part of the NTM-Impact project (cf. Rau et al. 2010).

The availability of data on production, consumption and on domestic as well as foreign prices for a highly disaggregated product level was also limited. The data calibration process partly changed the original values considerably as a compromise had to be made between given values, consistency with the assumed economic behaviour and achieving a technical solution. Moreover, empirically estimated elasticities were not available for the same level of product disaggregation. Additionally, scientific data on infected stocks and disease transmission rates were partly missing making it necessary to assume values based on reasonable arguments. Improving the data quality, and estimating the full set of elasticities econometrically would possibly augment the quality of the simulation model's outcome.

An improvement of the partial equilibrium model could be to also let the demand function react to a disease outbreak. Though it is reasonable that in case of avian influenza medium term changes in consumer response are negligible, in other cases this is not the case as it could be seen in demand of beef after the outbreak of bovine spongiform encephalopathy that shrunk considerably even in the long run.

6.3 Concluding remarks

The thesis has advanced existing literature in quantitatively and systematically comparing the trade and welfare impacts of a multitude of relevant regulatory measures shaping the global meat trade system. So far research just focused on one or few regulations or on an index of an overall regulatory measure. Identifying the best regulatory measure in each regulatory situation is still comprehensive and depends on the precise economic and regulatory or sanitary environment. Further improvements of data quality on regulatory measures exceeding the advancements realized by the NTM-Impact project and a multitude of different case studies along with an intensified interaction between natural sciences and economic modeling will surely help to achieve the final aim to derive rules making it easier to identify the best regulatory measure in each regulatory situation.

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Appendix

Table A1 Market balances for uncooked and cooked poultry meat

Poultry meat		Supply [1000 t]	Domestic sales [1000 t]	Imports [1000 t]	Demand [1000 t]	Exports [1000 t]
Uncooked	Germany	696.62	472.77	534.21	1,006.98	223.85
	Netherlands	599.59	145.08	74.42	219.50	454.51
	France	1,587.36	1,309.04	45.58	1,354.62	278.32
	USA	14,623.27	12,839.34	540.86	13,380.20	1,783.93
	Brazil	7,035.28	5,601.23	0.01	5,601.25	1,434.05
	Japan	970.34	753.70	833.60	1,587.30	216.64
	China	13,132.26	12,827.40	678.45	13,505.85	304.86
	Russia	1,112.89	433.21	1,987.12	2,420.33	679.68
	Rest of the World	22,137.82	21,598.07	1,221.34	22,819.41	539.75
Cooked	Germany	221.17	128.94	123.19	252.13	92.23
	Netherlands	77.73	11.04	38.84	49.87	66.70
	France	242.92	196.06	2.82	198.88	46.86
	USA	2,253.87	2,236.01	29.06	2,265.06	17.86
	Brazil	399.33	254.68	0.00	254.68	144.65
	Japan	308.16	186.19	210.89	397.08	121.97
	China	353.59	186.66	86.43	273.09	166.94
	Russia	66.17	60.95	17.66	78.61	5.22
	Rest of the World	9,019.29	8,922.12	250.70	9,172.82	97.17

Note: Simulation model baseline (based on UNCTAD 2011a).
Source: Authors' calculation.