Regulatory Policies in Meat Trade: Is There Evidence for Least Trade-distorting Sanitary Regulations?

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Multilateral trade rules as in the Sanitary and Phytosanitary (SPS) Agreement (WTO 1994) on trade in food and agricultural goods offer guidelines to policy makers on how to make use of regulatory instruments governing agri-food trade. The provisions of the SPS Agreement require that regulations targeting specific national agri-food safety objectives are minimal with respect to their trade effects (Art. 5.4) and not more trade restrictive than required (Art. 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, Fontagné, and Mimouni (2008), whereas Otsuki, Wilson, and Sewadeh (2001) 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 U.S. 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.

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 Art. 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 are 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 nonlinear panel data gravity model is estimated for the ten most important meat exporters and importers by fixed-effects Poisson pseudo-maximum likelihood (PPML) at the level of Harmonized System (HS) four-digit data.

The remainder of the article is organized as follows. The second section derives the applied gravity model and introduces the PPML

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estimator. The third section describes the explanatory and dependent variables and their data sources. The fourth section presents estimation results on the impact of different aggregation levels of regulatory instruments, and the fifth section concludes.

Theory and Methodology

A nonlinear panel data gravity model with fixed effects is estimated by PPML (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 gross domestic product (GDP) and world GDP (Deardorff 1998). Dropping the assumption of frictionless trade generally allows assessment of the impacts of any form of tariff or nontariff 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 nonlinear 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 that ignore heteroscedasticity are generally inconsistent (Silva and Tenreyro 2006).

Pseudomaximum likelihood (PML) 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 pseudolikelihood 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, Monfort, and Trognon 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)

$$(1) \qquad m = \exp(x\beta) + \varepsilon$$

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 nonnegative conditional expectations (the value of bilateral trade flows is by definition nonnegative) without constraining the explanatory variables. When m for given x is assumed to follow a Poisson distribution, a pseudolikelihood function can be derived, whose first- and second-order moment conditions can be solved to obtain the vector of coefficients β (Gourieroux, Monfort, and Trognon 1984). The PPML estimator is fully robust to distributional misspecifications (Wooldridge 1999).

The multiplicative gravity model in this analysis is as follows:

$$(2) \qquad m_{ijt} = p_{it}^{\beta_1} c_{jt}^{\beta_2} d_{ij}^{\beta_3} \exp\left(\alpha_i + \alpha_j + \beta_4 z_t + \beta_5 t_{ijt} + \sum_k \beta_k r_{ijt}^k\right) \eta_{ijt}$$

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 that are included in varying aggregation levels; and η_{ijt} is a transformed error with $E[\eta_{ijt} \mid x] = 1$ according to Silva and Tenreyro (2006).

Equation (2) can be written as an exponential function

$$m_{ijt} = \exp\left(\beta_1 \ln p_{it} + \beta_2 \ln c_{jt} + \beta_3 \ln d_{ij} + \alpha_i + \alpha_j + \beta_4 z_t + \beta_5 t_{ijt} + \sum_k \beta_k r_{ijt}^k\right) + \varepsilon_{ijt} \quad (3)$$

which has the functional form of equation (1) and is estimated by PPML.

Data

HS four-digit data on trade in meat products originates from the United Nations Conference on Trade and Development (UNCTAD) Comtrade database (UNCTAD 2009a) for the years 1996 to 2007. Those ten importing[1] and ten exporting[2] countries, which have the highest average aggregated meat trade flow in value terms over the sample period, are included in the analysis. Zero trade flows between country pairs are included. Consumption of domestic meat is not considered. Altogether, there are $n = 11{,}400$ observations on trade flows[3], of which 51% are nonzero. Mean and variance of the trade flow and explanatory variables are depicted in table 1. Data on sanitary regulations is taken from the World Trade Organization (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 databases for nontariff measures such as the UNCTAD Trade Analysis and Information System (TRAINS) do not provide the necessary detail for a sector-specific analysis distinguishing different types of instruments applied. Twenty-nine specific regulatory instruments are arranged into six classes that describe different agri-food safety purposes (see table 1): (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 of meat after slaughtering. As table 1 shows, each trade flow is on average regulated by nine regulatory instruments. The twenty-nine 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. Meat production and consumption quantities result from the statistical webpage of the Food and Agricultural Organization (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.

Results and Specification Tests

Table 2 presents outcomes of four different models estimated by PPML. The common base of the four models is the exponential regression function equation (3). The models differ with respect to the differentiation of regulatory measures $\sum_k \beta_k r_{ijt}^k$. The model Aggregate in the first column of table 2 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 2 includes the six predefined classes of regulatory

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[1] Observed importers: Canada, China, EU15, Hong Kong, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, and the United States.

[2] Observed exporters: Argentina, Australia, Brazil, Canada, China, EU15, Hong Kong, New Zealand, Poland, and the United States.

[3] (95 country pairs) (12 years) × (10 HS four-digit codes).

Table 1. Mean and Variance of Model Variables

Variable	Mean	Variance
Trade value/10,000,000	2.078	86.066
ln production exporter	22.542	2.718
ln consumption importer	22.538	2.027
ln distance	9.005	0.450
Tariff	4.204	251.820
Aggregate of regulations	9.102	186.687
Disease prevention measures	0.358	1.164
Pest/disease status	0.256	0.623
Quarantine	0.097	0.205
Regionalization	0.005	0.005
Requirements for microbiological testing	0.360	1.295
E. coli	0.100	0.154
Listeria monocytogens	0.118	0.139
Salmonella	0.142	0.213
Tolerance limits for residues and contaminants	3.418	52.102
Dioxin	0.174	0.457
Food additives	0.393	0.810
Pesticides	0.217	0.672
Drugs	0.478	2.239
Other toxins	2.122	35.329
Retained water content	0.034	0.033
Production process requirements	1.057	3.672
GMO/biotechnology	0.323	1.198
Hormones	0.594	1.915
Other production processes	0.140	0.338
Conformity assessment and information requirements	2.617	15.795
Certification	0.296	0.434
Inspection and approval procedure	0.826	1.901
HACCP	0.452	1.860
Harmonization	0.185	0.198
Labeling	0.373	0.768
Traceability	0.091	0.121
Risk assessment	0.172	0.398
Sanitary requirements for meat establishments	0.222	0.417
Requirements for handling of meat after slaughtering	1.290	4.900
Irradiation	0.313	0.755
Meat/bone separation	0.011	0.017
Packaging	0.207	0.267
Storage	0.185	0.223
Technical barriers to trade	0.318	0.578
Transportation	0.256	0.296
Food safety	9.000	184.484
Animal health	1.546	6.379
Plant health	2.122	35.329
Protect humans from animal/plant pests or diseases	3.234	51.766

Source: Authors' calculations.

measures. The third column presents parameter estimates for the Instruments model, which captures the individual twenty-nine specific regulatory measures. The parameter estimates of the Goals model are presented in the fourth column, which considers regulatory measures aggregated by the four safety objectives listed above. All models are tested on the 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).

Table 2. 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	–
Requirements 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 procedures	–	–	0.449***	–
HACCP	–	–	0.360***	–
Harmonization	–	–	0.267	–
Labeling	–	–	0.007	–
Traceability	–	–	0.161	–
Risk assessment	–	–	−0.639	–
Requirement for meat establishment	–	–	−0.869***	–
Handling of meat after slaughtering	–	−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: Double asterisks (**), and triple asterisks (***) denote significance at 5% and 1% levels. r. = rejected; n.r. = not rejected.
Source: Authors' calculations.

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 $(x\hat{\beta})^2$ and $(x\hat{\beta})^3$ do not help to explain the dependent variable by using the auxiliary regression $m = \exp(x\beta + \delta_1(x\hat{\beta})^2 + \delta_2(x\hat{\beta})^3)$; 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 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. 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 2 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 of meat after slaughtering is negative.

The third column of table 2 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 genetically modified organisms (GMO) and biotechnology is not significant. The fourth column of table 2 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.

Conclusion

Using a nonlinear 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 data set 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 that have a substantial positive impact and others with 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 are identified as being significantly trade enhancing. These results add more detail to the findings of recent research by Disdier, Fontagné, and Mimouni (2008), who estimate an overall negative impact of SPS and technical barriers to trade measures on meat trade using a log-linear fixed effects gravity model with HS two-digit data.

Limitations that apply to this article 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.

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