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Christine Wieck
University of Bonn, Institute for Food and Resource Economics, Bonn, Germany
christine.wieck@ilr.uni-bonn.de

Simon W. Schlüter
University of Bonn, Institute for Food and Resource Economics, Bonn, Germany
simon.schlueter@ilr.uni-bonn.de

Wolfgang Britz
University of Bonn, Institute for Food and Resource Economics, Bonn, Germany
wolfgang.britz@ilr.uni-bonn.de

Editor: Thomas Heckelei
Institute for Food and Resource Economics
University of Bonn
Nußallee 21
53115 Bonn, Germany

Phone: +49-228-732332
Fax: +49-228-734693
E-mail: thomas.heckelei@ilr.uni-bonn.de

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Abstract

We use two methodological approaches to analyze avian influenza related quarantine measures. First, a Heckman type gravity model is used to estimate the trade impact and second, a spatial partial equilibrium simulation model is developed to simulate welfare changes. The simulation model considers spread and transmission risk according to the disease status of the importing country as well as parameter uncertainty of the calibrated coefficients by using a Monte Carlo approach. The econometric results show that the principle of regionalization is preferred to import trade bans for uncooked meat. The simulation results verify the negative welfare impact of currently implemented regulatory policies and indicate that significant trade diversion effects according to the disease status of countries occur. The welfare results confirm that a trade ban is not the most appropriate measure to address the infection risk resulting from the spread of the avian influenza virus.

Keywords: animal disease, quarantine measure, non-tariff measure, welfare, gravity model, simulation model.
JEL-classification: F14, F17, Q11, Q17, Q18
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1 Introduction

Sanitary and food safety measures related to animal disease outbreaks are of high relevance in meat trade (van Tongeren, 2009:5). 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 transboundary spread of avian influenza (AI). 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 its risk adequacy. These arguments are especially important for AI where most transmission of the more severe H5N1 highly pathogenic avian influenza (HPAI) occurs through the migration of wild birds into foreign territory and not via trade of commercial poultry meat products (Beato and Capua, 2011). But even for the HPAI virus strain, the human health risk mostly originate from intensive contact with infected stock in rural or periurban areas where households keep small poultry flocks in the backyard (WHO, 2011a) and not from the consumption of infected poultry products though here, the processing stage (raw versus cooked) and cultural differences in eating habits (e.g. consumption of blood pudding) determine the degree of health risk (Beato and Capua, 2011).

An analysis of the trade concerns raised in the Sanitary and Phytosanitary (SPS) Committee of the World Trade Organization (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 imposition of non-tariff measures (NTMs) which are disproportional to the associated risk and not based on World Organization for Animal Health (OIE) guidelines. An example is the concern raised by the European Union (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 EU as it was free of 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 United States (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.

But even for these bans, its risk adequacy is not fully proven when focusing on commercial poultry production as these commercially produced products are imported for human consumption and not for animal feeding. Assuming that the HPAI virus would be present in the muscle tissue of meat, this contaminated meat must still find its way into the feeding trough to potentially transmit the disease to other poultry flocks. Regarding human health, there is no scientific evidence "that avian influenza be transmitted to humans through the consumption of contaminated food, notably poultry products" (EFSA, 2012: paragraph 2) as long as it is prepared before consumption which is conventionally the case with poultry meat products. Thus, regarding the prevention of transboundary disease spread among poultry flocks, a trade ban of commercially produced poultry meat may not be the least trade distortive measure achieves this goal. Nevertheless, producers in regions affected by a ban have the possibility to shift production from uncooked to cooked meat. Further on, countries should follow the principle of regionalization allowing producers from non-affected regions within a country to maintain exports.

Cooked meat represents only a small share in global poultry meat exports (12% in quantity) (UNCTAD 2011a and market balance in Annex). This share nearly doubled from 2004 to 2006 after outbreaks of HPAI in 2003 had major negative impacts on the global poultry industry (Taha, 2007). In quantity terms, the largest exporters of uncooked poultry meat are by far the US (1.78 mill t) and Brazil (1.43 mill t) where there exports together cover about 54% of global uncooked poultry trade. For cooked meat, exports are dominated by China (0.17 mill t) and Brazil (0.14 mill t) followed closely by Japan. But overall, exports are more evenly distributed across the major trading countries as even the share for China in global cooked poultry trade does not exceed 22%. Interestingly, the Netherlands is by far the most trade dependent poultry producer as about 76% of uncooked and 86% of cooked domestically produced poultry meat is exported.

The objective of this case study is to analyze trade and country 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). First, past AI-related policies over the 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 calibrated spatial simulation model which differentiates risk and infection status of imported poultry meat by origin. Finally, the results from these two approaches are brought together to provide a full picture of the effect 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 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 article is organized as follows. The second section, divided into two sub-parts, explains the gravity and the simulation model and describes the respective data sources. The third section contains the results of the two approaches and the final section concludes.

2 Methodology and data

2.1 Trade Flow Analysis Using a Gravity Model

2.1.1. 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 seemingly unrelated regression (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 or 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.

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

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

where ρ_{ijk} is the probability that country i exports poultry meat of category k to country j conditional on the vector of observed variables x_{1k}. The binary variable h_{ijk} indicates whether a trade flow is positive $\left(h_{ijk} = 1\right)$ or zero $\left(h_{ijk} = 0\right)$. The function $G(.)$ is the cumulative distribution function (cdf) of the bivariate normal distribution, and β_{1k} is the estimated vector of coefficients. The selection equation (1) is estimated separately for both poultry meat categories k. The two estimated residual vectors $\hat{\varepsilon}_k$ are then used to calculate the covariance matrix $\hat{\Omega} = E\left[\varepsilon\varepsilon'\right] = \begin{Bmatrix} \hat{\sigma}_{k_1k_1} I_T & \hat{\sigma}_{k_1k_2} I_T \\ \hat{\sigma}_{k_2k_1} I_T & \hat{\sigma}_{k_2k_2} I_T \end{Bmatrix}$, where $\hat{\sigma}_{ij}^2 = \frac{1}{df}\hat{\varepsilon}_i{}'\hat{\varepsilon}_j$, and $\left(i, j\right) \in \left\{k\right\}$, 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 used to calculate the SUR-estimates of the selection equation by including both product categories into one equation.

The second equation estimates bilateral traded quantities of poultry meat conditional on a positive trade flow:

$$E\left\{m_{ijk} \mid h_{ijk} = 1\right\} = x_{2k}\beta_{2k} + \sigma_{12k}\lambda_{ijk} + \omega_{ijk} + u_{ijk} \tag{2}$$

where m_{ijk} is the logarithmic observed trade and x_{2k} denotes a vector of variables potentially explaining trade costs. The unobserved errors u_{ijk} are assumed to be distributed bivariate normal.[1] 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 (2). Following Heckman (1979), Heckman's lambda $\lambda_{ijk} = \frac{\phi\left(x_{1k}\beta_{SUR1k}\right)}{\Phi\left(x_{1k}\beta_{SUR1k}\right)}$ controls for sample selection and can be calculated after estimating the SUR version of equation (1); the calculated estimate $\hat{\lambda}_{ijk}$ replaces λ_{ijk} in equation (2). 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 the number of exporters and 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 feasible correlation of firm level heterogeneity with the firms' export decision. .[2] 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 from selection equation (1). Technically GAUSS 9.0 is used to solve the optimization problems in conjunction with the application module "Constrained Optimization".

2.1.2. Data

Trade data in value terms for the years 2000 – 2007 originates from the United Nations Comtrade database (UNCTAD, 2011a). Trade flows from the six main poultry meat exporters (Brazil, US, Germany, France, the Netherlands, China) to Japan, Russia, and remaining countries, respectively, are considered where the

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[1] In principle, x_1 and x_2 can be identical which would lead back to the standard Tobit I model (Verbeek, 2004). However, the estimation of the trade flow equation (2) 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 and that the excluded variable should 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 (2).

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

aggregate of “remaining countries” is calculated for each exporter separately. In total, we account for $n = 288$ trade flow observations, of which 87,5% are non-zero. Mean and variance of the trade flow and explanatory variables are depicted in Table 1.

Bilateral data on the bilateral policy measures (1) ban on both meat categories, (2) ban on uncooked meat,[3] 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).[4] It is assumed that ROW as importer implements policy measures in line with the official OIE requirements, i.e. bans for uncooked meat from HPAI producers according to the principle of regionalization. As Table 1 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 1: Mean and variance of model variables in the trade flow equation (eq. 3)

Variable	*Cooked meat*		*Uncooked meat*	
	Mean	*Variance*	*Mean*	*Variance*
ln trade value meat/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
Tariff	6.61	43.85	7.49	124.95
Ban	0.09	0.08	0.16	0.13
Regionalization	0.09	0.08	0.12	0.10

Source: Own calculation

Data on production and consumption quantities on the aggregate poultry meat result from the Food and Agricultural Organization (FAO, 2010) and the United Nations (UN, 2010), 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 ex-

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

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

planatory 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. This data is further used to estimate, from a regression of this disaggregated production and consumption data on per capita gross domestic product (GDP), the shares for cooked and uncooked meat for the regions where the information is missing (Zhao, 2011).

Bilateral data on geographic distances and common language (ethno)[5] originates from the Centre d'Etudes Prospectivs et d'Informations Internationales homepage (CEPII, 2011). 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 United Nations Tariff and Trade Analysis database (UNCTAD, 2010b). 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.

2.2 Welfare analysis using a spatial simulation 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, 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. Two spatial equilibrium models could be identified that focus specifically on global poultry trade. The impacts of AI are analysed in Djunaidi and Djunaidi (2007) though they focus on the timing of outbreaks in different world regions, focus on HPAI countries, and do not differentiate cooked and uncooked poultry meat.The effects of tariffs, tariff rate quotas (TRQs), and binding sanitary regulations on global poultry trade flows are analyzed by Peterson and Orden (2005). Focusing on uncooked meat which is classified into high- and low-value meat, they analyze the trade and welfare effects of the changes in trade barriers trade bans. The present model builds on this work by improving the specification of AI related policies and transmission risk. Regarding poultry meat differentiation, the criterion is the processing stage rather than the import value as this allows us to account for the different AI policy measures.

[5] 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.

2.2.1. Model Structure

Contrary to a net trade approach where a country can only be a net seller or buyer of a good, trade flows in the present model type are differentiated by source and origin and are driven by spatial arbitrage conditions derived from transport costs minimization. The model follows the design of a spatial multi-commodity model for homogenous products based on the Takayama-Judge approach (Takayama and Judge, 1971) allowing for a disaggregated commodity specification in conjunction with bilateral policy measures. 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 allow reproducing observed trade flows.

Poultry meat is not only differentiated by its processing stage but also according to the origin's country disease status. Thus, on the supply side, we distinguish six meat types (cooked/uncooked in combination with AI free, AI low pathogenic, AI high pathogenic).

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 several AI outbreaks in Asia and Europe in the years 2003-2006 was a drastic reduction of poultry meat consumption in the short run (Djunaidi and Djunaidi, 2007: 313). However, consumers returned to earlier consumption pattern relatively quickly, despite the fact that the HPAI virus was still found in waterfowl and wild birds.. 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 no change in consumption levels of cooked or uncooked poultry meat could be observed. This specification choice is further supported by the scientific evidence that there is no infection risk contained in cooked poultry products in general, nor in uncooked products originating from LPAI countries. Only raw poultry meat from HPAI may contain the virus, but this meat is banned by all countries. These observations let us chose a model specification where AI is treated as an animal disease with supply side effects, but no impact on consumption (similar to e.g. Djunaidi and Djunaidi, 2007).)

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 and $r1$. A normalized quadratic profit function (Lau, 1978) is used to measure welfare changes for the aggregate representative producer and to derive supply functions for each region and product *i* and *j*:

$$\tilde{\pi}_r = \sum_i c_{r,i}\,\widetilde{ps_{r,i}} + \tfrac{1}{2}\sum_{ij} bs_{r,i,j}\,\widetilde{ps_j}\,\widetilde{ps_i} + \sum_i br_{r,i}\,risk_{r,i}\,\widetilde{ps_{r,i}} \tag{3}$$

A general price index reflecting the price of all intermediate inputs and primary factors is assumed in the background for normalization and kept fixed at unity

in simulation experiments. Normalized producer prices ps are used in the model and drive supply via the parameters c and bs.[6] 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:

$$sply_{r,i} = \frac{\partial \pi_{r,i}}{\partial ps_{r.i}} = c_{r,i} + \sum_j bs_{r,i,j}\, ps_j + br_{r,i}\, risk_{r,i} \tag{4}$$

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 r_1 to r whereas the diagonal elements depict domestic sales) and the share of infected products $shareInf$ of the producing region r1 where this share is derived from the AI status of the country (see table 2 below):

$$risk_{r,i} = \frac{\sum_{r1} flows_{r,r1,i}\, shareInf_{r1,i}}{\sum_{r1} flows_{r,r1,i}} \tag{5}$$

According to OIE, it is assumed that only uncooked meat carries an infection risk. Thus, equation (5) 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 $shareInf$.

We follow the World Health Organization (WHO, 2011b) in the classification of a country's disease status (AI free, LPAI, HPAI). The assumption about the supply effect (share of infected products) for a specific disease status is derived from costs and impacts listed in the literature (Swayne and Akey, 2005; Beach et al., 2007)[7]. This "share of infected products"-assumption also captures supply effects resulting from preventive culling, establishment of protection and surveillance zones, and other domestic measures as also domestic sales are considered in the specification. As stated earlier, only uncooked meat imports from HPAI countries may transmit an infection risk to a domestic market. Thus, supply quantities in other countries are not adversely affected when importing meat from LPAI countries. For LPAI countries, the assumption about the share of infected prod-

[6] Normalization is no longer explicitly shown in the following equations.

[7] Djunaidi and Djunaidi for example assume a 25 per cent production loss when a HPAI outbreak occurs.

ucts accounts for smaller domestic supply effects resulting from less drastic eradication and surveillance measures. Furthermore, we assume that the AI status remains constant over time as eradication is time-consuming and difficult to achieve (Swayne and Akey, 2005).

Table 2: AI status of countries and assumed share of infected products

Status	*Countries*	*Assumed share of infected uncooked meat*
AI free	Brazil, The Netherland	0 %
LPAI	US, Japan, ROW	2 %
HPAI	Germany, France, China, Russia	5%

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:

$$\begin{aligned} dem_i &= comm_{r,i} + \frac{Gi_{r,i}}{G_r}\left[Y - F_r\right] \\ with\ \ F_r &= \sum_i comm_{r,i}\, pd_i \\ G_r &= \sum_{i,j} bd_{ij}\sqrt{pd_i\, pd_j} \\ Gi_{r,i} &= \partial G_r / \partial pd_{r,i} = \sum_j bd_{ij}\sqrt{pd_i / pd_j} \end{aligned} \qquad (6)$$

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 $(Y-F)$ is then distributed to the products according the term G and its first derivative with respect to prices Gi as shown above. 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 (Varian, 1992), which is calculated for the GL demand systems as:

$$monMetr_r = \frac{G_r^{sim}}{G_r^{cal}}\left[Y_r - F_r^{sim}\right] - \left[Y_r - F_r^{cal}\right] \qquad (7)$$

Terms for the welfare change calculation must be measured in the calibrated baseline 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 dot not fall below demand:

$$\begin{aligned} sply_{r,i} &\geq \sum_{r} flows_{r,r1,i} \perp ps_{r,i} \\ \sum_{r} flows_{r,r1,i} &\geq dem_{r,i} \perp pd_{r,i} \end{aligned} \tag{8}$$

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

$$ps_{r1,i} * (1 + t_{r1,i}) + tc_{r,r1,i} \geq pd_{r,i} \perp flows_{r,r1,i} \tag{9}$$

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

$$tc_{r,r1,i} = atc_{r,r1,i} + btc_{r,r1,i} flows_{r,r1,i} \tag{10}$$

Non-constant per unit transport costs were 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 the 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 degenerate dual solutions. It is derived by assuming that per unit transport costs increase a certain percentage if all imports plus domestic flows double. The slope term is hence uniform for all flows into a market so that trade diversion between existing flows respectively domestic sales alone does not change total transport cost into the market.

2.2.2. 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 (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.

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 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 that is based on the available raw data information.

2.2.3. 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. The choice of functional form and code for parameter calibration were based on the experiences gained with the CAPRI global multi-commodity model. Further details on the parameter calibration can be found in the CAPRI documentation (Britz and Witzke 2008, pp. 92-93).

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 Abler et al. (1999) and Gilbert (2003). 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. Given that we treat the exogenous parameters as random, all model results subsequently are also random. The resulting changes in quantities, prices, and resulting welfare measures for each draw are stored. Each outcome is an independent observation from which we estimate the expected outcome (mean value), sensitivity of that outcome (standard deviation) and significance (t-value) of each outcome variable.

For the demand elasticities, we draw own price elasticities from a uniform distribution of -0.5*u[0,2] and cross price elasticities from +0.25*u[0,2]. Similar, on the supply side, we draw from +1*u[0,2] for own and -0.5*u[0,2] for cross-price elasticities. The risk shift parameter is drawn from “20% of the production quantities" *u[0,2] divided by share of infected stock for HPAI producers. That means that the worst case modeled would be a 40% loss of the production if any marketed quantities have the AI high status. The increase in per unit transport costs are also randomly drawn assuming a "0.1% increase for the double of the lowest transport costs" * u[0,20]. The means for the parameters are hence: -0.5 for own and +0.25 for cross price demand elasticities, +1 for own and -0.5 for cross price supply elasticities, and 0.1% in increase in per unit transport cost if the trade flow doubles.

2.2.4. Avian influenza policy scenario definitions

Whereas the gravity approach evaluates ex-post the trade impact of import bans and 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 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 import ban for *uncooked meat from HPAI countries only* by FAI and LPAI countries.

Missing data at the sub-national level (production, consumption, trade, AI status) do not allow modeling the principle of regionalization.

3 Results

3.1 Trade flow analysis using a gravity approach

The following three tables present outcomes of the Heckman-type gravity model. Table 3 provides the results of the selection equation (1). In addition to the variables presented in Table 3, a time dummy variable and exporter and importer-specific fixed effects are included in equation (1). 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 size of their poultry meat markets does not have a clear positive impact on the probability of bilateral trade, contrary to the prediction of gravity theory. The common language variable has unexpectedly a negative impact for both product groups.

Table 3: Results of the selection equation for cooked and uncooked meat

	Cooked meat		*Uncooked meat*	
Control variable	*Coefficient*	*Std. Error*	*Coefficient*	*Std. Error*
Prod_ex	-6.042	9.140	-307.437***	8.958
Cons_im	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: Own calculation

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. 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 principle of 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.

Findings of the "outcome" equation are presented in Table 3. Due to the non-linearity introduced by the term ω_{ijk} the model is estimated by non-linear least squares (NLS). Following Helpman et al. (2008), common language is used as excluded variable.

Table 4: Results of the selection equation for cooked and uncooked meat

Control variable	*Cooked meat*		*Uncooked meat*	
	NLS	*Std. errors*	*NLS*	*Std. errors*
ln prod_ex	14.060***	4.440	4.420	6.541
ln cons_im	27.912***	8.889	11.909	7.530
ln 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 per cent, 5 per cent, and 1 per cent level.
Source: Gravity model.

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 outcome of the import ban variable is positive, but the regionalization variable has a negative but not significant result. Interpreting the ban variable in terms of marginal effects, a situation with a ban increases trade of uncooked meat more than five times in comparison to a situation without a ban. This result remains robust across various specifications. Substantial shift effects in trade from uncooked meat to cooked meat after establishing a ban may play a role in understanding this result. 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 mirrors our expectations for the regulatory policy variables. Production, consumption, and distance variables show the expected signs, though only the distance variable is statistically significant. The ban shows a negative sign whereas the regionalization variable is positive; both variables statistically significant. Interpreting the two policy variables, a situation with a ban reduces trade in uncooked meat by nearly 100 per cent in comparison to a situation without a ban. Installing instead the regionalization principle augments trade more than 22 times compared to a ban indicating that the international approach to allow imports from AI free zones within a country is very successful. Results of the variables tariff and firm level heterogeneity are not significant, whereas sample selection again shows a significant negative trade impact.

Marginal net effects for the sum of cooked and uncooked meat are driven by the results for uncooked meat as trade of cooked meat represents only about 5% of total traded meat quantities (in value) in our sample. Calculating the net marginal effect, overall meat trade is reduced by about 22 per cent in case of an import ban whereas an implementation of the principle of regionalization increases overall trade flows significantly. In case of the ban, the positive marginal effect for cooked meat offsets a large amount of the trade reductions estimated for uncooked meat.

3.2 Welfare analysis using a spatial simulation model

As explained before, all results presented here are the mean value of 1000 simulation runs of one specific scenario. The introduction of import bans is globally welfare[8] decreasing in both scenarios (Table 4). Equally, in both scenarios, production is slightly shifted from uncooked to cooked meat with associated changes in demand and prices (Table 5). 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 meat are reduced whereas exports of cooked meat increase. Largest absolute welfare losses are recorded in the aggregate of the rest of the world (ROW) countries which also represent the largest market with about 43 per cent of world consumption.

Overall, in the realistic scenario, welfare losses due to the imposed trade ban for uncooked meat occur in all HPAI and FAI countries whereas LPAI countries show welfare gains with the exception of ROW. These welfare reductions in FAI and HPAI countries mostly result from losses in producer profits provoked by trade diversion effects in uncooked (Table 6) and cooked meat (Table 7). As HPAI countries can no longer sell uncooked meat abroad, they increase domestic sales (e.g. Germany +1.7 per cent) 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 per cent). 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.

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

Export oriented FAI countries cannot benefit from 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 Dutch r exports 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 import 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, uncooked meat being the more important type in the market. Due to the assumption that ROW is a LPAI country, it loses all imports of uncooked meat from Russia, China, and Germany, representing 80 per cent of the baseline imports. The imports are partially replaced by increased imports from HPAI free countries and domestic sales while marginal production costs increase both domestically and in the non-HPAI countries. The resulting increase in profits cannot offset the loss of consumer welfare due to 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.[9]

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. 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 cooked 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 hurt FAI countries, as their exports are again dis-

[9] 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.

placed 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 because of their AI risk free status.

Overall, the results show that AI risk transmission reduction via trade bans of commercially produced products comes at the costs of significant reorganization of trade flows between exporting and importing countries. Not only countries directly targeted by the ban record changes in the trade structure, but also countries free of AI are affected through competition with ban-displaced products.

Table 5: Mean absolute welfare changes compared to baseline situation (Million 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: Simulation model.

Table 6: 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: Simulation model.

Table 7: Mean trade flows (1000 tons) and changes in per cent 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 (>1,000 per cent) starting from a mean value close or equal to zero.
Source: Simulation model.

Table 8: Mean trade flows (1000 tons) and changes in per cent compared to base-line 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 (>1,000 per cent) starting from a mean value close or equal to zero.
Source: Simulation model.

4 Conclusions

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 SUR gravity model based on Helpman et al. (2008) is estimated to analyze the trade impact of three AIpolicies: (1) ban on both meat categories, (2) ban on uncooked meat, and (3) principle of regionalization. Second, a spatial multi-commodity simulation model is specified to account for the welfare effect of these trade measures. 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 principle of regionalization is trade enhancing. For cooked meat, the results are inconclusive. The simulation model shows that important trade diversion effects among countries take place which depend very much on the infection status of the involved countries. A major effect, found in other studies as well but perhaps still astonishing was that banned exporting countries redirect much of their original exports towards their own market and that the banned countries start to trade among each other, crowding out imports from countries which were not directly targeted by the ban. Due to the missing additional disaggregation of countries into several regions because of lack of more disaggregated country data, the principle of regionalization could not be analyzed with the simulation model. But it is likely, that a similar reorganization of trade flows among regions with similar infection status and related welfare effects would have taken place.

In this study, disease transmission was modeled via the import of infected poultry meat. This is in line with the guidelines and assumptions made by the OIE, but there exists scientific evidence that indicates that the risk potentially resulting from imports of uncooked meat may be negligible (Pharo, 2003; Zepeda and Salman, 2007). In addition, one has to remember that most transmission occurs through the migration of wild birds into foreign territory. Subsequent damage then happens through the infiltration of the viruses into poultry flocks or because of the preventive slaughtering of neighboring poultry herds. Thus, the risk related supply side effects assumed in this study are likely to be overestimated and may eventually be better represented 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.

5 APPENDIX

Table A1: Market balance for uncooked and cooked poultry meat

Poultry meat		*Supply* [1000 t]	*Domestic sales* [1000 t]	*Imports* [1000 t]	*Demand* [1000 t]	*Export* [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

Source: Simulation model baseline (based on UNCTAD, 2011a).

References

Abler, D.G., Rodriguez, A.G., and J.S. Shortle (1999): Parameter uncertainty in CGE modeling of the environmental impacts of economic policies. *Environmental and Resource Economics*, 14: 75-94.

AQS (2010): Countries (regions) on temporary import suspensions due to outbreaks of Avian Influenza. http://www.maff.go.jp/aqs/english/news/hpai.html, (accessed December 21, 2010).

Armington, P.S. (1969): A theory of demand for products distinguihed by place of production. *IMF Staff Papers* 16: 159–178, Washington, D.C.

BAC (2010): Prepared and preserved poultry meat: European Union market outlook 2011 and forecast till 2015.

Beato, M.S. and I. Capua (2011): Transboundary spread of highly pathogenic avian influenza through poultry commodities and wild birds: a review. *Scientific and Technical Review OIE* 30(1): 51-61.

Britz W. and H.-P. Witzke (2008): CAPRI model documentation. University of Bonn, http://www.capri-model.org/docs/capri_documentation.pdf, (accessed June 17, 2011).

CEPII (2011): Distances. http://www.cepii.fr/anglaisgraph/bdd/distances.htm. (accessed March 31, 2011).

Chiang, A.C. (1984): Fundamental Methods of Mathematical Economics (3rd. edition), McGraw Hill, New York.

Disdier, A.-C. and S. Marette (2010): The combination of gravity and welfare approaches for evaluating non-tariff measures. *American Journal of Agricultural Economics* 92(3): 713-726.

Djunaidi, H. and Djunaidi, A. C. M. (2007): The Economic Impacts of Avian Influenza on World Poultry Trade and the U.S. Poultry Industry: A Spatial Equilibrium Analysis. *Journal of Agricultural and Applied Economics* 39(2): 313-323

FAO (2011): FAOSTAT, http://faostat.fao.org/site/339/default.aspx, (accessed March 31, 2011).

Gilbert, J. (2003): Trade liberalization and employment in developing economies of the Americas. *Economie Internationale* 94-95: 155-174.

Greene, W.H. (2008): Econometric analysis. Prentice Hall, Upper Saddle River.

Harrison, G.W., Jones, R., Kimbell, L.J., and R. Wigle (1993): How robust is applied general equilibrium analysis? *Journal of Policy Modeling* 15(1): 99-115.

Heckman, J.J. (1979): Sample selection bias as a specification error. *Econometrica* 47(1): 153-161.

Helpman, E., Melitz, M., and Y. Rubinstein (2008): Estimating trade flows: Trading partners and trading volumes. *Quarterly Journal of Economics* 123(2): 441-487.

Jansson, T., Norell, B., and E. Rabinowicz (2005): Modelling the impact of compulsory foot and mouth disease insurance. Poster paper presented at the 2005 EAAE Congress, August 24-27, 2005, Copenhagen.

Lau, L.J. (1978): Testing and imposing monoticity, convexity and quasi-convexity constraints. In: Fuss, M. and D. McFadden, eds.: Production economics: A dual approach to theory and applications. pp. 409-453, vol. I. North Holland, Amsterdam.

Mangen, M.-J.J. and A. Burrell (2003): Who gains, who loses? Welfare effects of classical swine fever epidemics in the Netherlands. *European Review of Agricultural Economics* 30(2): 125-154.

Narayanan, G.B. and T.L. Walsmley (2008): Global trade, assistance, and production: The GTAP 7 Data Base. Purdue University's Center for Global Trade Analysis, Purdue.

Niemi, J.K. and H. Lehtonen (2011): Modelling pig sector dynamic adjustment to livestock epidemics with stochastic-duration trade disruptions. *European Review of Agricultural Economics* 38(4): 529-551

Nogueira, L, Marsh, T.L., Tozer, P.R., and D. Peel (2011): Foot-and-mouth disease and the Mexican cattle industry. *Agricultural Economics* 42(Issue supplement s1): 33-44.

OECD (2011): OECD StatExtracts Theme “Goods transport: National sea transport”. http://stats.oecd.org/Index.aspx, (accessed June 30, 2011).

OIE (2011): Terrestrial animal health code 2010. http://web.oie.int/eng/normes/mcode/en_chapitre_1.10.4.htm, (accessed March 31, 2011).

Paarlberg, P.L. and J.G. Lee (1998): Import restrictions in the presence of a health risk: An Illustration using FMD. *American Journal of Agricultural Economics*, 80(1): 175-183.

Paris, Q., Drogué, S. and G. Anania (2009): Calibrating Mathematical Programming Spatial Models. Working Paper 2009-10 of the AGFOODTRADE (New Issues in Agricultural, Food and Bioenergy Trade) project presented at the IATRC meeting 13-15 December 2009, Fort Myers, USA.

Peterson, E. and D. Orden (2005): Effects of tariffs and sanitary barriers on high- and low-value poultry trade. *Journal of Agricultural and Resource Economics*, 30(1): 109-127.

Peterson, E. and D. Orden (2008): Avocado pests and avocado trade. *American Journal of Agricultural Economics* 90(2): 321-335.

Pharo, H.J. (2003): The impact of new epidemiological information on a risk analysis for the introduction of avian influenza viruses in imported poultry meat. *Avian Diseases* 47(3): 988-995.

Russian Ministry of Agriculture (2010): Russian import restrictions due to AI. Table communicated by Galina Kamichova, Saratov State Agrarian University.

Ryan, D.L. and T.J. Wales (1999): Flexible and semiflexible consumer demands with quadratic Engel curves. *Review of Economics and Statistics*, 81(2): 277-287.

Swayne D.E and B.L. Akey (2005): Avian influenza control strategies in the United States of America, Avian influenza: Prevention and control. Editor: K. G. Schrijver RS: p.113-130.
Taha, F.A. (2007): How highly pathogenic influenza (H5N1) has affected world poultry-meat trade. Report from the Economic Research Service/USDA, LDP-M-159-02, Washington, D.C.
Takayama, T. and Judge, G.G. (1971): Spatial and temporal price and allocation models, North-Holland, Amsterdam (1971).
Tinbergen, J. (1962): Shaping the world economy. The Twentieth Century Fund, New York.
UN (2011): Estimates of mid-year population: 1997-2006. United Nations Statistics Division, http://unstats.un.org/unsd/demographic/products/dyb/dyb2006/Table05.pdf, (accessed March 31, 2011).
UNCTAD (2011a): UNCTAD Comtrade Database. http://wits.worldbank.org/WITS/wits/AdvanceQuery/RawTradeData/QueryDefinition.aspx?Page=RawTradeData, (accessed December 28, 2011).
UNCTAD (2011b): UNCTAD TRAINS Database. http://wits.worldbank.org/WITS/wits/AdvanceQuery/TariffAndTradeAnalysis/AdvancedQueryDefinition.aspx?Page=TariffandTradeAnalysis, (accessed March 21, 2011).
Van Tongeren, F. (2009): Measuring Costs and Benefits of Non-Tariff Measures in Agri-Food. Invited paper prepared for the IATRC meeting 13-15 December 2009, Fort Myers, USA.
Varian, H.R. (1992): Microeconomic Analysis. Norton & Company Inc, New York.
Verbeek, M. (2004): A guide to modern econometrics. Wiley and Sons Ltd., West Sussex.
WHO (2011a): Avian influenza: food safety issues. http://www.who.int/foodsafety/micro/avian/en/index1.html, (accessed December 29, 2011).
WHO (2011b): H5N1 avian influenza: Timeline of major events. http://www.who.int/csr/disease /avian_influenza/H5N1_avian_influenza_update.pdf, (accessed March 21, 2011).
WTO (2011): SPS information management system. http://spsims.wto.org/, (accessed March 31, 2011).
Zepeda, C. and M.D. Salman (2007): Assessing the probability of the presence of low pathogenic avian influenza virus in exported chicken meat. *Avian Diseases* 51(2):344-351.
Zhao, Na (2011): Evaluating the welfare Impact of avian influenza related regulatory policies on poultry meat trade. Master thesis, Institute for Food and Resource Economics, University of Bonn.
ZMP (2006): ZMP-Marktbilanz Eier und Geflügel 2006. ZMP Zentrale Markt- und Preisberichtstelle GmbH. Bonn.

ZMP (2007): ZMP-Marktbilanz Eier und Geflügel 2007. ZMP Zentrale Markt- und Preisberichtstelle GmbH. Bonn.
ZMP (2008): ZMP-Marktbilanz Eier und Geflügel 2008. ZMP Zentrale Markt- und Preisberichtstelle GmbH. Bonn.