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Assessment of the Impact of Avian Influenza–related Regulatory Policies on Poultry Meat Trade and Welfare

Christine Wieck, Simon W. Schlüter and Wolfgang Britz

Institute for Food and Resource Economics, University of Bonn, Bonn, Germany

1. INTRODUCTION

MANY countries implemented drastic import bans in poultry meat markets in recent years to reduce the risk of transboundary spread of avian influenza (AI). When the disease transmission probability is low or the food safety threat is negligible, these quarantine measures cause trade and welfare losses and may be challenged regarding their risk adequacy. For AI where transmission of the more severe H5N1 highly pathogenic avian influenza (HPAI) occurs mostly through the migration of wild birds and not via trade of commercial poultry meat products (Beato and Capua, 2011), these arguments have even more substance. Also regarding human health, for the HPAI virus, most risk originates from intensive contact with infected stock in rural or peri-urban areas where households keep small poultry flocks in the backyard (WHO, 2011a) and not from the consumption of infected poultry products although processing stage (raw versus cooked) and cultural differences in eating habits (e.g. consumption of blood pudding) contribute to the health risk determination (Beato and Capua, 2011). For the less severe low pathogenic avian influenza (LPAI), no human health risk exists as only mild infections in affected birds occur, and the risk of transboundary spread via wild birds or meat products is insignificant (Zepeda and Salman, 2007). Still, outbreaks of LPAI are monitored and confined as some LPAI strains may mutate into the more dangerous HPAI ones (OIE, 2009).

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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 per cent 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) seen as disproportional to the associated risk and not based on World Organization for Animal Health (OIE) guidelines (OIE, 2011). 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 because of 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 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 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 (FAI), although only one LPAI case was detected in one region of France. The OIE guidelines on AI also explicitly state that heat treatment deactivates the virus and that measures associated with AI should not be applied to cooked poultry meat. However, the United States had suspended for many years the importation of cooked poultry meat from China because of the presence of HPAI (WTO, 2011). To summarise, bans are according to the recommendation by the OIE only justified in the 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 through to potentially transmit the disease to other poultry flocks. Regarding human health, there is no scientific evidence 'that avian influenza can 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 to achieve 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 regionalisation 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 per cent in quantity) where this share nearly doubled from 2004 to 2006 after outbreaks of HPAI in 2003 (Taha, 2007). By far, the largest exporters of uncooked poultry meat are the United States (1.7)[1] and Brazil (1.4), covering about 54 per cent of global uncooked poultry trade. For cooked meat, exports are more evenly distributed, with China (0.2) and Brazil (0.1) being the largest exporters. The largest importers of uncooked meat are Russia (2.0) and Japan (0.8), attracting nearly 50 per cent of global imports; the largest importer of cooked meat is Japan (0.2) followed by Germany (0.1). The largest producer of uncooked and cooked poultry meat is the United States (14.6 and 2.2, respectively), followed by China (13.1) for uncooked meat and by Brazil (0.4) for cooked meat (UNCTAD, 2011a).

The objective of this case study is to analyse trade and welfare effects of changes in importers' regulatory AI policies for important poultry meat exporters (Brazil, China, France, Germany, the Netherlands and the United States) and importers (Russia, Japan). First, past AI-related policies over the period 2000–07 are evaluated in terms of their trade impact using a 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 the exporter. 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.

To account for the different AI policies, we distinguish uncooked and cooked meat. 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 paper is organised as follows: Section 2 is divided into two subparts, explains the gravity and the simulation model and describes the respective data sources; Section 3 contains the results of the two approaches; and Section 4 concludes.

2. METHODOLOGY AND DATA

a. *Trade Flow Analysis Using a Gravity Model*

(i) Model

To evaluate the impact of AI-related policy measures on trade, a Heckman-type econometric model embedded in a systems approach is estimated. The Heckman model takes advantage of the presence of non-existent trade flows by

[1] All values in million tonnes.

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. Like in the Heckman model, the econometric model in this study consists of two separately estimated equations (see also Schlueter, 2012): A selection equation that investigates the decision to take up a trade relation or not, and an outcome equation that estimates bilateral traded quantities of poultry meat of category k conditional on an existing positive trade flow between country i and country j:

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

where m_{ijk} is the logarithm of observed trade given the trade flow is positive $(h_{ijk}=1)$ and x_{2k} denotes a vector of variables potentially explaining trade costs. Variables u_{ijk} and σ_{12k} refer to the unobserved errors and covariance of the errors, where it is assumed that the error term is distributed bivariate normal. Heckman's lambda (Heckman, 1979), λ_{ijk}, controls for sample selection and is estimated from the 'selection' equation. Helpman et al. (2008) extend the Heckman approach by not only controlling for sample selection but also accounting for unobserved firm-level heterogeneity as they assume that firms differ in their productivity levels so that only sufficiently productive firms export who are able to overcome market entry costs, such as NTMs. Firm-level heterogeneity therefore allows accounting for the impact of NTMs and other country characteristics on the share of exporting firms. Thus, the additional parameter ω_{ijk} controls for the correlation of firm-level heterogeneity with the firms' export decision.[2]

(ii) Data

Values of trade flows for the years 2000–07 originate from the United Nations Comtrade Database (UNCTAD, 2011a). Trade flows from the six main poultry meat exporters to Japan, Russia and remaining countries, respectively, are considered where the aggregate of 'remaining countries' is calculated for each exporter separately. In total, we account for n = 288 trade flow observations, of which 126 are non-zero.

Bilateral data on the three bilateral policy measures are considered: (i) ban on both meat categories, (ii) ban on uncooked meat[3] and (iii) ban on cooked and/or uncooked meat but adhering to the principle of regionalisation based on data provided by Japanese and Russian government publications (AQS, 2010; Russian Ministry of Agriculture, 2010). It is assumed that rest of the world (ROW), as an importer, implements policy measures in line with the official OIE requirements.

[2] See Helpman et al. (2008) equations (9) and (14).
[3] Both types of bans are combined into one explanatory variable.

Data on production and consumption quantities of poultry meat come from the Food and Agricultural Organization (FAO, 2011), the United Nations (UN, 2011), the German market and price information system (ZMP, 2006, 2007, 2008). Differing from Helpman et al. (2008), we include sectoral production (for exporters) and consumption quantity data (for importers) as explanatory variables instead of the countries' GDP accounting for the sectoral approach of this case study.

Bilateral data on geographic distances and common language (ethno) originate from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII, 2011) and tariffs stem from UNCTAD (2011b). Additionally, dummy variables for the observed time period and for exporter- and importer-specific fixed effects are included. Summary statistics of all variables and further details can be found in Wieck et al. (2012).

b. *Welfare Analysis Using a Spatial Simulation Model*

Spatial partial equilibrium models analysing NTMs related to animal health have a long history in the literature (e.g. Paarlberg and Lee, 1998). Two spatial equilibrium models focus specifically on global poultry trade. The impacts of AI are analysed in Djunaidi and Djunaidi (2007) who investigate the timing of outbreaks in different HPAI world regions for the aggregate of chicken meat. The effects of tariffs, tariff rate quotas (TRQs) and binding sanitary regulations on global poultry trade flows are analysed by Peterson and Orden (2005). Focusing on uncooked meat which is classified into high- and low-value, they analyse the trade and welfare effects of the changes in trade barriers. 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.

(i) 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) allowing for a disaggregated commodity specification in conjunction with bilateral trade flows and policy measures.

(ii) Supply of Poultry Meat and Risk of Infection

On the supply side, a perfectly competitive industry within each region r (and $r1$) is assumed. Poultry meat is differentiated by its processing stage and by the disease status of the exporting country. Supply *sply* for each region and product i (and j) derived from a normalised quadratic profit function πs linear in (normalised) producer prices ps and infection risk *risk*, and parameters c, bs and br:

$$sply_{r,i} = \frac{\partial \pi_{r,i}}{\partial ps_{r,i}} = c_{r,i} + \sum_j bs_{r,i,j} ps_j + br_{r,i} risk_{r,i}. \tag{2}$$

A higher infection risk shifts the supply function by increasing marginal production costs where this risk depends on the share of infected poultry products (see Peterson and Orden, 2008) in the domestic market, either from domestic sales or imported:

$$risk_{r,i} = \frac{\sum_{r1} flows_{r,r1,i} shareInf_{r1,i}}{\sum_{r1} flows_{r,r1,i}}. \tag{3}$$

The variable flows represents a trade matrix where off-diagonal elements capture trade from region r_1 to r and diagonal ones domestic sales. The parameter *shareInf* captures for each type of meat the relative marginal costs effect (Table 1) based on the countries' AI status (WHO, 2011b). It is derived from costs and impacts listed in the literature (Swayne and Akey, 2005; Beach et al., 2007). It accounts for domestic measures such as preventive culling or establishment of protection and surveillance as domestic sales in a region are considered in the specification. For LPAI countries, the assumption about the share of infected products accounts for smaller domestic supply effects resulting from less drastic eradication and surveillance measures, but their exports are not assumed to be susceptible to disease transmission. Furthermore, we assume a constant AI status as eradication is time-consuming and difficult to achieve (Swayne and Akey, 2005).

(iii) Demand of Poultry Meat

We assume that consumers are indifferent regarding the origin and AI status of poultry meat. That might be surprising as several AI outbreaks in Asia

TABLE 1
Avian Influenza (AI) Status of Countries and Assumption about Effect on Supply

Status	*Countries*	*Assumed Impact on Supply ('Share of Infected Products'; Per Cent)*
AI-free	Brazil, Netherlands	0
LPAI	United States, Japan, ROW	2
HPAI	Germany, France, China, Russia	5

Note:
(i) HPAI, highly pathogenic avian influenza; LPAI, low pathogenic avian influenza; ROW, rest of the world.

and Europe in the years 2003–06 induced drastic consumption reductions in the short run (Djunaidi and Djunaidi, 2007, p. 313). But consumption recovered relatively quickly despite continuing reports about HPAI in wild birds, which may be explained by public confidence that the implemented bans safely contain all risk that potentially may arise from meat from HPAI origins.

Demand is based on a generalised Leontief expenditure system (Ryan and Wales, 1999) following the implementation in the Common Agricultural Policy Regional Impact (CAPRI) global multi-commodity model (Britz and Witzke, 2008, p. 92). Welfare changes for consumers are calculated as equivalent variation at current prices (Varian, 1992).

(iv) Market Equilibrium

Besides the behavioural equations for supply and demand, equations for each market ensure that supply cannot exceed exports plus domestic sales and that import flows plus domestic sales dot not fall below demand. Spatial arbitrage conditions ensure zero trade flows if the demand price falls below the producer price at the origin plus import tariffs and (per unit) transport costs. It is assumed that transport costs are non-constant and increase linearly with transported quantities.

(v) Data, Model Parameters and Parameter Uncertainty

The model shares as far as possible the data with the gravity estimation using 2000–07 averages as baseline data. Parameter uncertainty is addressed using Monte Carlo techniques drawing 1,000 random sets of parameters around assumed means. Further details of this procedure can be found in Wieck et al. (2012).

(vi) Avian Influenza Policy Scenario

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

1 'Drastic scenario': FAI countries ban imports for cooked and uncooked meat from HPAI and LPAI countries; LPAI countries ban imports for both meat types from HPAI countries.
2 'Realistic scenario': FAI and LPAI countries ban imports only for uncooked meat from HPAI countries.

Missing data at the subnational level (production, consumption, trade, AI status) preclude modelling the principle of regionalisation.

3. RESULTS

a. Trade Flow Analysis Using a Gravity Approach

Findings of the 'outcome' equation are presented in Table 2 estimated by non-linear least squares (NLS). Common language is used as excluded variable. Results from the first stage 'selection' equation can be found in Wieck et al. (2012).

The cooked meat equation estimates yield the expected signs for production, consumption and distance. The import ban is positive, but the regionalisation variable has a negative insignificant result. Interpreting the ban variable in terms of marginal effects, a situation with a ban increases trade of cooked meat more than five times in comparison with a situation without a ban. Substantial shift effects in trade from uncooked to cooked meat after establishing a ban may play a role in understanding this result. Firm-level heterogeneity shows a positive trade impact, whereas the sample selection estimate is significantly negative.

The outcome for uncooked meat mirrors our expectations for the regulatory policy variables. Production, consumption and distance variables show the expected signs, although only distance is statistically significant. A situation with a ban reduces trade in uncooked meat by nearly 100 per cent in comparison with a situation without a ban. Implementing instead the regionalisation principle augments trade more than 22 times compared to the mean trade flows indicating that the international approach to allow imports from AI-free zones within a country is very successful. Estimates for the tariff and firm-level heterogeneity variables are not significant, whereas sample selection is present in the data.

TABLE 2
Results of the Gravity Model

Control Variable	*Cooked Meat*		*Uncooked Meat*	
	NLS	*SE*	*NLS*	*SE*
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
Regionalisation	−0.551	0.532	3.109*	1.736
Tariff	0.393	0.720	−1.439	0.906
Omega (Firm-level heterogeneity)	1.127***	0.396	0.872	0.656
Lambda (Sample selection)	−3.988***	0.910	−7.652***	2.030
n = 126				

Notes:
(i) NLS, non-linear least squares.
(ii) *,** and *** denote significance at 10, 5 and 1% levels.

TABLE 3
Mean Absolute Welfare Changes Compared to Baseline (Million Euro)

	AI status	*Sum*	*Money metric*	*Transport costs*	*Profits*
Realistic scenario					
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					
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

Note:
(i) AI, avian influenza; FAI, AI-free; HPAI, highly pathogenic avian influenza; LPAI, low pathogenic avian influenza; ROW, rest of the world.

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 per cent of total traded meat quantities (in value) in our sample. Calculating the net marginal effect, overall meat trade is reduced by about 23 per cent in the case of an import ban, whereas an implementation of the principle of regionalisation increases overall trade flows significantly. In the case of the ban, the positive marginal effect for cooked meat offsets a large amount of the trade reductions estimated for uncooked meat.

b. Welfare Analysis Using a Spatial Simulation Model

Import bans are globally welfare-decreasing in both scenarios as shown in Table 3.[4] In both scenarios, production is slightly shifted from uncooked to

[4] 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).

TABLE 4
Mean Supply and Demand Quantities and Mean Prices

Country	*AI Status*	*Type of Meat*	*Realistic Scenario*				*Drastic Scenario*			
			Supply [1,000 t]	*Demand [1,000 t]*	*Price*		*Supply [1,000 t]*	*Demand [1,000 t]*	*Price*	
					Producer [€/kg]	*Consumer [€/kg]*			*Producer [€/kg]*	*Consumer [€/kg]*
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	1011.9	1.0	1.1	675.9	1004.6	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	1,2947.1	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	1585.2	1.0	1.1	993.7	1,586.5	1.0	1.1
			2.5	*−0.1*	*1.0*	*0.3*	*2.4*		*1.1*	*0.3*
		Cooked	307.5	397.0	1.9	2.2	310.1	395.4	1.9	2.3
			−0.2		*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*		*0.6*	*0.9*

Notes:
(i) AI, avian influenza; FAI, AI-free; HPAI, highly pathogenic avian influenza; LPAI, low pathogenic avian influenza; ROW, rest of the world. (ii) Percentage change to baseline is shown in italic below each value; *inf* characterises positive changes (greater than 1,000 per cent); blank cells represent zero values.

cooked meat with associated changes in demand and prices (see Table 4). On world level, quantity-weighted average producer prices for uncooked meat decrease from cost savings in countries with reduced infection risk, whereas consumer prices increase as trade diversion effects drive up per unit trade costs. Globally, exports of uncooked meat are reduced, whereas trade in cooked meat increase. Largest absolute welfare losses are recorded in the aggregate of the ROW countries which represents, with about 43 per cent of world consumption, the largest market for poultry meat.

In the realistic scenario where FAI/LPAI countries ban uncooked HPAI imports, HPAI and FAI countries face welfare losses, whereas LPAI countries, besides ROW, show welfare gains. Welfare reductions in FAI and HPAI countries mostly result from lower profits caused by trade diversion effects in uncooked (see Table 5) and cooked meat (see Table 6). HPAI countries, losing export markets for uncooked meat, 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) crowding out FAI countries (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 increase in these countries, whereas demand goes down as prices increase.

Export-oriented FAI countries cannot benefit from lower AI risk after the ban as they hardly import uncooked meat from infected countries, 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 exports so that they have to export to new destinations (ROW) at lower prices. Similarly, for Brazil, larger exports to Japan and ROW cannot compensate for reduced ones to Germany, France and Russia. Overall, in both countries, lower profit due to decreased production of uncooked meat cannot be offset by positive but low 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 United States 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.

Classified as an LPAI country, ROW bans 80 per cent of its uncooked baseline imports. These imports from Russia, China and Germany are partially replaced by HPAI-free imports and domestic sales as marginal production costs increase both domestically and in the HPAI-free countries. ROW is a net importer for both types of meat; consumer welfare losses in ROW outweigh profit gains. An opposite effect occurs in Japan (profit gains larger than consumer losses).

TABLE 5
Mean Trade Flows of Domestic Sales (1,000 Tonnes) for Uncooked Meat

	Exporter	*Netherlands*	*Brazil*	*Germany*	*France*	*China*	*Russia*	*USA*	*Japan*	*ROW*
Importer	*AI status*	*FAI*	*FAI*	*HPAI*	*HPAI*	*HPAI*	*HPAI*	*LPAI*	*LPAI*	*LPAI*
Realistic scenario										
Netherlands	FAI	141.5	74.3					2.6		1.5
		−2.5	*−0.1*					*inf*		*inf*
Brazil	FAI	6.5	5,599.6					0.9		1.4
		inf						*inf*		*inf*
Germany	HPAI	233.1	27.8	480.7	106.6	15.1	148.5	0.2		
		−29.9	*−70.2*	*1.7*	*−1.0*	*inf*	*inf*	*−78.0*		
France	HPAI	1.2	0.0	3.0	1,259.7	7.4	92.1			
		−96.6	*−99.7*	*inf*	*−3.8*	*inf*	*inf*	*−100.0*		*−100.0*
China	HPAI	1.0	61.4	38.6	22.9	12857.6	178.8	402.8		
		−88.5	*−53.6*	*inf*	*366.8*	*0.2*	*inf*	*−24.1*		
Russia	HPAI	20.4	360.8	143.1	172.6	66.9	638.8	1,027.3		
		−73.7	*−22.0*	*37.7*	*7.0*	*724.9*	*47.5*	*−12.5*		
USA	LPAI	30.2	31.0					12,823.8	0.1	502.6
		inf	*inf*					*−0.1*		*−6.9*
Japan	LPAI	40.1	738.0					116.2	682.0	8.8
		inf	*11.7*	*−100.0*	*−100.0*	*−100.0*		*47.9*	*−9.5*	*inf*
ROW	LPAI	123.7	121.9					249.5	313.0	21,819.8
		inf	*inf*	*−100.0*		*−100.0*	*−100.0*	*inf*	*44.5*	*1.0*
Drastic scenario										
Netherlands	FAI	143.1	76.8							
		−1.4	*3.2*					*−100.0*		*−100.0*
Brazil	FAI	7.4	5,601.0							
		inf								*−100.0*
Germany	HPAI	222.3	24.2	482.1	110.2	16.6	148.9	0.2		
		−33.1	*−74.0*	*2.0*	*2.4*	*inf*	*inf*	*−75.6*		
France	HPAI	0.8		3.0	1258.1	7.1	88.8			
		−97.9	*−99.8*	*inf*	*−3.9*	*inf*	*inf*	*−100.0*		*−100.0*
China	HPAI	0.9	56.3	42.1	26.4	12,859.6	180.5	393.7		
		−89.7	*−57.4*	*inf*	*436.2*	*0.3*	*inf*	*−25.8*		
Russia	HPAI	18.0	352.0	148.6	179.2	71.5	640.9	1,018.1		
		−76.8	*−23.9*	*43.0*	*11.1*	*781.2*	*47.9*	*−13.3*		
USA	LPAI	32.9	34.7					12,826.7	0.1	497.0
		inf	*inf*					*−0.1*		*−7.9*
Japan	LPAI	41.8	740.0					117.5	679.3	8.0
		inf	*12.0*	*−100.0*	*−100.0*	*−100.0*		*49.6*	*−9.9*	*0.0*
ROW	LPAI	130.2	129.2					256.2	314.3	21,818.5
		inf	*inf*	*−100.0*		*−100.0*	*−100.0*	*inf*	*45.1*	*1.0*

Notes:
(i) AI, avian influenza; FAI, AI-free; HPAI, highly pathogenic avian influenza; LPAI, low pathogenic avian influenza; ROW, rest of the world. (ii) Percentage change to baseline is shown in italic below each value; *inf* characterises positive changes (greater than 1,000 per cent); blank cells represent zero values.

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.[5]

[5] 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.

TABLE 6
Mean Trade Flows of Domestic Sales (1,000 Tonnes) for Cooked Meat

	Exporter	*Netherlands*	*Brazil*	*Germany*	*France*	*China*	*Russia*	*USA*	*Japan*	*ROW*
Importer	*AI status*	*FAI*	*FAI*	*HPAI*	*HPAI*	*HPAI*	*HPAI*	*LPAI*	*LPAI*	*LPAI*
Realistic scenario										
Netherlands	FAI	9.2	33.9		5.5	0.3		0.9		
		−16.6	*1.4*		*2.4*	*inf*		*inf*		
Brazil	FAI		254.1							0.2
			−0.2			*840.6*		*888.7*		*inf*
Germany	HPAI	31.9	69.5	127.6	20.8	0.5		1.1		
		−8.4	*1.5*	*−1.0*	*4.2*	*inf*		*inf*		
France	HPAI		1.5		196.3					0.3
			−48.5		*0.1*					*inf*
China	HPAI				0.5	188.0		4.1		79.8
					172.7	*0.7*		*−12.4*		*−2.3*
Russia	HPAI		6.8		7.9	0.3	59.4	3.9		
		−91.4	*9.5*	*−92.2*	*6.0*	*inf*	*−2.5*	*13.1*		
USA	LPAI				12.1			inf		13.1
					−10.6			*0.1*		*−15.4*
Japan	LPAI		34.7		1.3	166.9		10.6	183.5	
			3.0	*−76.3*	*249.3*		*−13.6*	*8.0*	*−1.5*	
ROW	LPAI	36.9		95.1			7.5		124.0	8,935.8
		17.0		*3.4*			*44.3*		*1.7*	*0.2*
Drastic scenario										
Netherlands	FAI	7.0	42.7							
		−36.2	*27.6*		*−100.0*	*−100.0*		*−100.0*		
Brazil	FAI		254.0							
			−0.3			*−100.0*		*−100.0*		*−100.0*
Germany	HPAI			115.5	42.7	89.5	12.1			
		−100.0	*−100.0*	*−10.4*	*114.2*	*inf*	*inf*	*−100.0*		
France	HPAI			34.4	152.0		18.4			
			−100.0		*−22.5*		*inf*			*−100.0*
China	HPAI			35.4	29.5	201.3	15.1			
					inf	*7.9*	*inf*	*−100.0*		*−100.0*
Russia	HPAI			20.9	3.9	39.8	16.5			
		−100.0	*−100.0*	*13,159.8*	*−47.6*	*inf*	*−72.9*	*−100.0*		
USA	LPAI	0.2						inf		25.8
					−100.0			*−0.2*		*66.4*
Japan	LPAI	4.3	105.1					40.7	202.6	42.6
		0.0	*212.1*	*−100.0*	*−100.0*	*−100.0*	*−100.0*	*315.7*	*8.8*	
ROW	LPAI	66.9							107.4	8,995.6
		112.1		*−100.0*			*−100.0*		*−11.9*	*0.8*

Note:
(i) AI, avian influenza; FAI, AI-free; HPAI, highly pathogenic avian influenza; LPAI, low pathogenic avian influenza; ROW, rest of the world. (ii) Percentage change to baseline is shown in italic below each value; *inf* characterises positive changes (greater than 1,000 per cent); blank cells represent zero values.

The drastic scenario provokes somewhat stronger welfare changes with directions and disaggregated effects comparable to the realistic scenario. Now, FAI countries also ban uncooked meat from LPAI producers, and FAI and LPAI countries ban cooked meat from HPAI producers. The cooked meat ban provokes losses for HPAI producers also in the production of cooked meat which they now trade more intensively among each other. Given the described effect of increased domestic supply under a ban, the additional ban of uncooked LPAI meat hurts FAI countries, as their exports are now also displaced from LPAI markets. Thus, in the drastic scenario, the FAI countries (Brazil and the Netherlands) decrease exports further instead of capturing new export markets as AI risk-free producers.

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

4. CONCLUSIONS

Using two complementary approaches, this case study analyses the impact of AI-related regulatory measures on worldwide trade of cooked and uncooked poultry meat. Results of the econometric model for uncooked meat show that a ban has a nearly prohibitive trade impact, whereas the principle of regionalisation is trade-enhancing. The simulation model highlights important trade diversion effects among countries conditional on the infection status. A major effect was that banned exporting countries redirect much of their original exports towards their own market and that banned countries start to trade among each other, crowding out imports from countries that were not directly targeted by the ban.

In this study, disease transmission across territories was modelled via the import of infected uncooked poultry meat from HPAI countries. This is in line with the guidelines made by the OIE, but 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 virus into poultry flocks or because of the preventive slaughtering of neighbouring poultry herds. Thus, the assumed risk-related supply side effects in the simulation model might 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 regarding the disease transmission potential of commercially produced poultry meat and the trade results of the welfare analysis of the simulation model, it is clear that a trade ban on meat is not the least trade- and welfare-distorting measure to address the infection risk resulting from the spread of the AI virus.

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