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Avian influenza, non-tariff measures and the poultry exports of China*

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This paper focuses on the direct impact of avian influenza outbreaks and the impact of the consequent non-tariff measures (NTMs) on the international poultry trade. Using monthly export data from China and its 122 poultry importing countries, a random-effect gravity model has been adopted. Emphasising the agri-food trade in a global value chain context, the research analysis distinguishes between 'agri-food goods' (mostly uncooked poultry products) and 'processed goods' (mostly cooked poultry products). The results show that domestic avian influenza outbreaks have a significant negative impact on a country's poultry imports compared with such outbreaks in exporting countries. Moreover, NTMs induced by avian influenza reduce the uncooked poultry trade but temporarily increase the cooked poultry trade. However, with a time-lag, the cooked poultry trade may soon face increasing NTMs. The results also imply that developing countries that attempt to export agri-food products to developed countries should increase and enhance processed food production.

Key words: avian influenza, non-tariff measures, poultry trade.

1. Introduction

The occurrence of avian influenza (AI) outbreaks has resulted in significant impacts not only on human and animal health, but also on economic activities, such as the international poultry trade. AI, commonly known as bird flu, is a highly contagious viral disease that affects several species of birds, including food-producing birds such as chickens. Sometimes, human infections caused by the AI virus may also occur (CDC 2016; OIE 2016). The World Organisation for Animal Health (OIE) has been recording AI outbreaks since 2005. From January 2005 to December 2015, 6,463 cases of highly pathogenic avian influenza (HPAI) outbreaks occurred in 73 countries (OIE 2016). The impact of AI outbreaks on the poultry trade is obvious. Global AI outbreaks during the last quarter of 2003 led to a 23% drop of global poultry meat exports by the end of March 2004, which

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represents an immediate decrease in exports within two quarters. For example, in 2004, Thailand, one of the world's top poultry exporters, experienced an outbreak of H5N1, an influenza A virus subtype. Subsequently, the country's frozen chicken products were banned by its top three importers: Japan; Germany; and Korea. The ban resulted in a 93% decrease in exports compared with 2003 (Puthavathana 2006).

In addition to the impact on direct trade demand, AI outbreaks also influence trading countries' policymaking for related products. Because of concerns regarding animal and human health, many governments impose non-tariff measures (NTMs), such as sanitary and phytosanitary (SPS) measures and technical barriers (TB) on poultry imports from AI-infected countries when the outbreaks occur. According to SPS notification information from the World Trade Organization (WTO), approximately 40% of NTMs for the world poultry trade have been raised directly because of AI outbreaks from January 2005 to December 2013. Another example is the suspension by the United States of the import of Chinese cooked poultry meat for 5 years (from 2006 to 2010) because of the presence of HPAI in China (WTO 2011).

The literature on the impact of AI and related NTMs on the poultry trade can be grouped into two types: (i) simulations of the effects of AI outbreaks on trade and welfare in major countries and regions (Peterson and Orden 2005; Djunaidi and Djunaidi 2007; Wieck *et al.* 2012); and (ii) empirical trade flow analysis on the impacts of AI outbreaks on NTMs, focused mainly on developed countries (Paarlberg *et al.* 2007; Taha 2007; Disdier *et al.* 2008). Such research has shown the importance of AI outbreaks on the poultry trade from different perspectives, such as rising global export prices (Djunaidi and Djunaidi 2007), the confirmation of large country effects (Djunaidi and Djunaidi 2007) and regionalisation and producer welfare (Paarlberg *et al.* 2007). The impact of AI-related NTMs on the poultry trade has also been captured from different perspectives, such as the trade diversion effects from NTMs (Wieck *et al.* 2012) and developing countries facing NTMs imposed by developed countries (Disdier *et al.* 2008; Jongwanich 2009).

With recent globalisation and tariff reduction trends, it is unclear if previous responses will continue into the future, hence, we address this uncertainty through the following steps: (i) we use monthly poultry trade data to accurately capture the impact of AI outbreaks; (ii) we differentiate uncooked and cooked poultry products to address processing food trade in the value chain; (iii) we group trading countries into developed countries and developing countries to deliver trade policy implications. For agricultural and food trade, developed countries and developing countries have differences in consumer preferences, market capacities to react, production capacities to comply, magnitude of the imposing NTMs and trade negotiation mechanisms. Contributions (i) and (ii) will be further elaborated in detail in the Section 2.1. Contribution (iii) will be addressed in the Sections 3 and 4.

We have chosen the Chinese poultry export case for the following five reasons. (i) China has been the second largest poultry producer in the world for the past two decades. It accounted for approximately 15% of global poultry production from 2005 to 2013, second only to the United States at 25%. (ii) China has been a major exporter of poultry products. From 2005 to 2013, China was the seventh largest poultry product exporter in the world. Moreover, China is the third largest exporter of cooked poultry products, accounting for approximately 13.8% of global cooked poultry exports. (iii) China exports both uncooked and cooked poultry products. AI outbreaks may affect both types of product in different ways. (iv) A large number of countries import poultry products from China. Among the 122 importing countries, there are countries with high incidences of AI outbreaks (e.g. Bangladesh, Cambodia, India, Indonesia, Laos and Vietnam), and also countries free from AI (e.g. Bahrain, Singapore, Armenia, the United Arab Emirates and the Philippines). In addition, China itself has suffered from occasional AI outbreaks. From 2005 to 2013, 34 cases of HPAI and 23 of low pathogenic avian influenza (LPAI) were reported by China to the World Organisation for Animal Health (OIE). Avian influenza is defined by the OIE as an infection of poultry and other birds that is caused by any influenza, a virus with high pathogenicity (HPAI), and by H5 and H7 subtypes with low pathogenicity. In accordance with the severity of the disease in poultry, AI virus strains are usually classified into two categories: HPAI; and LPAI. HPAI can cause severe clinical signs and potentially high mortality rates among poultry. LPAI strains cause few or no clinical signs in poultry; however, they are likely to become highly pathogenic through mutation. In addition, among the 122 importing countries, the developed countries tend to import cooked poultry products, while the less developed countries tend to import uncooked poultry products. Approximately 76% of China's uncooked product exports are to middle-income countries, and 99% of cooked product exports are to high-income countries. (v) As one of the largest and most active economic bodies, China has been participating in a number of free trade agreements and economic zones (WTO 2011). Based on the above reasons, China's poultry trade is a good representative case for discussing the direct impact of AI outbreaks on the poultry trade and the indirect impact through NTMs. The conclusion and policy implication may be generalised to other countries participating in the poultry trade.

This paper is divided into the following sections. Section 2 introduces the model and the data used in the paper. Section 3 discusses the regression results, and Section 4 concludes the paper.

2. Theory and methodology

2.1 Data

To study Chinese poultry exports, we used data from several sources. For trade data, we used monthly poultry export data obtained from the

Administration of China's Customs agency. Previous studies usually use quarterly or annual data on bilateral trade (Djunaidi and Djunaidi 2007). However, poultry production, from inception to slaughterhouse, takes approximately 34 days on average (González-García *et al.* 2014). The AI outbreak cycle depends on the detection and time control of individual cases. The cycle varies from five to ten months; for example, during the HPAI outbreaks in 2004 and 2007 (Sugiura *et al.* 2009). Thus, the monthly data are able to capture the AI outbreak impact promptly and accurately, as market responses and government mandated regulations (such as SPS and TB) take place within a one-month period. Monthly data also gives us flexibility to study the short-term and long-term AI outbreak impacts on trade. Therefore, in this paper, we use monthly trade data in accordance with the Harmonized System of Classification (hereafter HS) eight-digit level. The monthly trade data extends from 2005 to 2013. During this period, 122 countries imported poultry products from China. European Union member countries are considered individually. Trade flows between China and Hong Kong and between China and Macau are excluded from our sample because of the close political ties.

We differentiate between cooked and uncooked products. The HS code of specific uncooked products we included in the data is available in the Appendix S1 Table A33. All poultry products from chicken, ducks, and geese are included. From China, 11 uncooked poultry products and eight cooked poultry products at the HS eight-digit level were imported by 122 countries. Uncooked poultry products include fresh, chilled, and frozen ones that can be used as ingredients (intermediate good) to produce other food commodities (final goods); cooked poultry products include preserved and canned products that are generally consumed directly as final products. As heating can inactivate the AI virus, uncooked and cooked poultry products have different responses to AI outbreaks. Distinguishing between them allows us to better identify and analyse the trade impacts of AI outbreaks.

In the past decade, global exports of cooked poultry products have increased from approximately 2.61 million tons in 2005 to more than 4 million tons in 2015. Global exports of uncooked poultry products have also increased from nearly 19 million tons to approximately 30 million tons in the same period. Uncooked poultry exports account for approximately 88% of global poultry export volumes. Cooked poultry exports account for approximately 12% of global poultry export volume. These percentages have been stable throughout the 10-year period.

Poultry trade-related NTMs also affect uncooked and cooked products in different ways. The World Trade Organization's (WTO's) Integrated Trade Intelligence Portal (I-TIP) Goods service provides comprehensive information on NTMs applied by WTO members in the merchandise trade. A typical NTMs is import suspension (applied with zoning by importing countries sometimes to only avoid poultry from AI-affected areas in the exporting country) which is usually lifted 90 days after contamination clearing. In the long-run after the AI outbreak, SPS standards are also imposed. From 2005 to 2015, most of the 393 records of NTMs induced by AI are SPS measures. Among the 393 SPS records, there are three relating to uncooked and cooked poultry products simultaneously, 317 relating to uncooked poultry products only, and 73 relating to live poultry and poultry eggs (see Figure 1). No records relate to cooked poultry products only. All 393 SPS records aim to stop the import of specific poultry products from countries affected by HPAI outbreaks.

In addition to important suspension and other NTMs, such as SPS, there are also trade barriers (TBs) imposed by some countries to restrict poultry imports in a relatively indirect way. These TBs are mainly targeted at cooked poultry products, to 'eliminate' any poultry trade. For example, an Australian quarantine regulation requires that chicken meat imported from Thailand must be heated at 70°C for 143 min to avoid the possibility of carrying HPAI virus (Jongwanich 2009). This mandated heating changes the texture and taste of the imported Thai chicken meat. Therefore, it has effectively stopped the Australian market for Thai chicken exports.

Information on AI outbreaks in China and the 122 trading partners was obtained from the OIE. Each country's government is obliged to report its domestic outbreaks of AI to the OIE. Such reports should distinguish HPAI and LPAI (in accordance with the relevant virus) and include the official date of outbreaks in birds, the type of avian influenza virus, cases of new outbreaks and the number of total susceptible animals (Information on AI outbreaks is collected from the World Animal Health Information Database (WAHIS Interface) developed by OIE. The monthly data cover information on new outbreaks, the total of dead animals, the total cases, the total of animals slaughtered, the total of animals destroyed, the total of susceptible animals, and the total of animals vaccinated. Considering data quality, data on new outbreaks, the total of dead animals and the total of susceptible animals are most likely to account for the severity of AI outbreaks. However, as data on the total of dead animals only cover HPAI outbreaks because

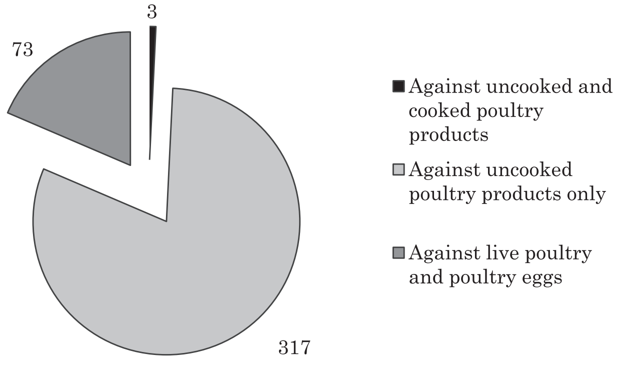

Figure 1 Composition of AI-related SPS measures.

cases of animal death caused by the LPAI virus are rare, the total of susceptible animals is preferred.

Based on the cases of new outbreaks, we can obtain information on whether AI outbreaks occur in China and its trading partners. From 2005 to 2013, there were 34 HPAI outbreaks and 23 LPAI outbreaks in China, and 3,399 HPAI outbreaks and 197 LPAI outbreaks in the 122 importing countries. There is a possibility that LPAI outbreaks may develop into HPAI outbreaks (OIE 2016). However, this possibility is negligible in our sample because the impacts of HPAI and LPAI are measured separately. Among the 122 countries that trade with China in poultry, 66 are free from AI, 38 only experienced HPAI, six only experienced LPAI, and five suffered from both HPAI and LPAI.

Data on NTMs at the four-digit HS level were collected from the WTO website. WTO members must notify the WTO of their NTMs. Each notification covers information on the notifying country, the affected country and product, the type of barrier, the dates of initiation (when the implemented data are missing, the initiation date is used instead), implementation, and revocation of the barrier. Data on notifications are not necessarily available in terms of a bilateral dimension. With rare exceptions, measures are enforced unilaterally by importing countries and applicable to all exporting countries. For example, in July 2007, the Minister of Agriculture, Food and Consumer Protection in Albania successively issued two SPS measures against AI outbreaks in the Czech Republic and Germany. However, all the WTO members are affected, which means that if AI outbreaks occurred in a specific country, Albania would stop its imports of poultry products that were not treated using the thermal process. Our empirical analysis focuses on measures notified under the SPS measures and technical barriers to trade (TBT) agreements. There were 523 SPS and 547 TBT measures on poultry products initiated by China's 122 trading partner countries in the sample period (not necessarily after AI outbreaks). Using these data, we have econometrically estimated the impact of AI outbreaks on SPS and TBT measures and then evaluated the policy effects on AI outbreaks.

There are 34,668 observations in total in our balanced panel sample (detailed information of the trade data is available in the Tables A2 and A3 Appendix S1). Among these, 35% apply to China's uncooked poultry exports and 65% to China's cooked poultry exports. In terms of trade volume, cooked exports are approximately five times the volume of uncooked exports. In terms of trade value, cooked exports are more than 10 times the value of uncooked exports. The number diverges so significantly because the price of cooked poultry products is higher. Our sample also has the common characteristics of trade data. There are prevailing zero trade flows for approximately 29,409 observations, which represent approximately 85% of the total observations. Uncooked poultry products have approximately 86% zero trade flows, and cooked poultry products have 84%. In addition, country-level characteristics and trade information are included in the data set. We obtained the information on the free trade area (FTA) of each trading partner country and China from the service network of China's FTA. Annual data on GDP were from the World Bank. We have also included bilateral data on geographic distances between capitals and shared borders from the Centre d'Etudes Prospectives et d'Informations Internationales. Description and summary statistics of all the variables can be found in Table 1.

2.2 The baseline gravity model

We adopt a gravity model to study the impact of AI outbreaks on the poultry product trade between China and its trading partners. Following Peterson *et al.* (2013), who reported that consumer preferences in the destination region are based on a CES subutility function, the export quantity of commodity k (k is the type of poultry products) from region i (i.e. China) to j, x_{ijk}, can be represented as follows:

Table 1 Variables and description

Variables	Description	Uncooked		Cooked	
		Mean	SD	Mean	SD
Trade flows					
Volume	China's export quantity (tons)	30.500	171.489	89.415	835.756
Value	China's export value (10,000 USD dollars)	6.396	41.449	35.090	329.008
Avian Influenza					
$HPAI_C$	$HPAI_C = 1$ if highly pathogenic avian influenza (HPAI) outbreaks occurred in China	0.213	0.409	0.213	0.409
$HPAI_P$	$HPAI_P = 1$ if highly pathogenic avian influenza (HPAI) outbreaks occurred in China's trading partners	0.053	0.224	0.030	0.170
Measures					
NTM_p	$NTM_p = 1$ if China's trading partners reported new NTMs including SPS and TBT measures to the WTO	0.586	0.235	0.035	0.184
Other variables					
GDP_C	GDP of China measured in real terms as of 2,000 US$ prices (10,000 USD dollars)	0.412	0.175	0.412	0.175
GDP_p	GDP of China's trading partner measured in real terms at 2,000 US$ prices (10,000 USD dollars)	0.719	1.130	2.127	2.186
WTO	Dummy variable, 1 = China's trading partner is a WTO member, 0 = otherwise	0.679	0.467	0.853	0.354
FTA	Dummy variable, 1 = China and its trading partner are part of the same FTA, 0 = otherwise	0.237	0.426	0.167	0.373
Border	Dummy variable, 1 = China and its trading partner share a land border, 0 = otherwise	0.279	0.449	0.076	0.265
Distance	Distance of capitals between China and its trading partner (1,000 km)	5.744	3.236	7.880	3.542

$$x_{ijk} = \alpha_{ijk}(T_{ijk}P_{ik})^{-\sigma_k}E_{jk}\mathrm{PI}_{jk}^{\sigma_k-1}, \tag{1}$$

with α_{ijk} representing the preference parameter, σ_k representing the elasticity of substitution between all varieties of commodity k and P_{ik} representing producer prices in the country of origin. E_{jk} and PI_{jk} are the expenditure and price indexes, respectively, of commodity k in region j. T_{ijk} represents all the trading costs associated with selling commodity k from region i to region j.

To estimate this equation, E_{jk} is a proxy of the gross domestic products (GDPs) of region j. Trading costs are measured using the bilateral capital distance between both partners. In addition, after tariff reduction in the agricultural sector, the tariffs have remained minimal for years, so we follow prior studies by excluding tariffs faced by country i's exporters in j in the gravity equation (Otsuki *et al.* 2001). Empirical studies also show that the effects of tariffs on the poultry trade are not significant (Wieck *et al.* 2012). However, in order to distinguish the potential impact of tariffs on the poultry trade from the potential impact on AI outbreaks, two dummies, namely WTO_{ijt}, and FTA_{ijt}, are included in our econometric model. The WTO system, by design, focuses on mutually agreed reductions of trade barriers. Members that negotiate reciprocal most favoured nation (MFN) tariff cuts with other members are more likely to enjoy expanded bilateral trade than non-members that do not (Subramanian and Wei 2007). The impact of WTO membership on the poultry trade may be significantly positive. In addition, as suggested by Baier and Bergstrand (2004), FTAs enhance trade because the presence of an FTA aims to increase trade among members by removing trade barriers, such as tariff concessions.

A major concern about the gravity equation in empirical studies is selection bias. When taking a logarithm to estimate the equation, the dependent variable has to be limited to country pairs where trade is strictly positive. The bias caused by the omission of zero trade flows from the gravity model has recently been documented by Santos Silva and Tenreyro (2006) and Helpman *et al.* (2008). If there are large unobservable trade barriers that are potentially correlated with the variables in trade costs T_{ijk}, zero trade flow is observed when none of the firms in the potential exporting country is productive enough to overcome the fixed costs imposed by the destination market. As defined by Heckman (1979), the omission or mistreatment of zeros in our sample could lead to sample selection bias.

The most effective method to deal with zero-valued trade flows when estimating gravity equation parameters has been discussed widely. However, there is no commonly accepted solution. In dealing with zero trade observations, the common practice is to delete the zeros completely or substitute the zeros with a small positive constant. However, these methods are considered inappropriate because they are without any strong theoretical or empirical justification and can distort the results significantly (Linders and de Groot 2006; Burger *et al.* 2009). Heckman (1979) also posits that deleting zeros may lead to information loss and adding an arbitrary constant can result in selection bias. Several more appropriate estimation techniques, such as the Tobit model proposed by Tobin (1958) and the sample selection model developed by Heckman (1979) and Helpman *et al.* (2008), have been employed to deal with zero trade flow issues.

However, the Heckman sample selection model and the Tobit model have been criticised on the grounds that they may deliver biased estimates when trade data exhibit heteroscedasticity (Santos Silva and Tenreyro 2006). The new trade theory, pioneered by Melitz (2003), posits that the absence of trade can be attributed to firms' self-selection behaviour and suggests that zeros can be seen as generated from a selection process, which gives credence to the Heckman sample selection model (Heckman 1979) and, to a lesser degree, the Tobit model (Eaton and Tamura 1994). In the Heckman sample selection model, the selection equation fully captures zeros and explains why trade takes place, while the outcome equation characterises the volume of trade conditional on trade occurring. The Tobit model treats zeros as censored outcomes and assumes that there is a minimal threshold to jump if trade flows are to be observed (Eaton and Tamura 1994). The Poisson pseudo-maximum likelihood (PPML) estimator permits zeros by estimating trade flows in levels. Some variants of the PPML estimator are also proposed. For example, Burger *et al.* (2009) consider the negative binomial pseudo-maximum likelihood estimator (NBPML) and the zero-inflated Poisson pseudo-maximum likelihood estimator (ZIPPML). We also used the ZIPPML to address the issue; however, the results were not consistent, so these are not reported in the paper.

The PPML estimator, proposed by Santos Silva and Tenreyro, accounts for zero trade flows naturally and has been shown to be robust to a wide range of heteroscedastic patterns. As Santos Silva and Tenreyro (2006) show, if the true gravity equation model is in its multiplicative form and heteroskedasticity is present, estimates from log-linearised gravity equation models can be severely biased.

In a model with finite number of importers and exporters, the PPML estimators can be advanced to the multinomial pseudo-maximum likelihood (MNPML) estimators. The MNPML estimators feature a dependent variable of *market share*. In our case study, raw poultry exports flow from China to importing countries as a proportion of China's total poultry exports. With *market share* as a dependent variable, MNPML estimators are able to range from trivial to large levels of trade. Moreover, shares prevent this dependent variable from obtaining values greater than one (Head and Mayer 2014). Taking the characteristics of our sample data, 84.83% of which are zeros, we applied the MNPML estimator to the gravity equation. According to studies on international trade (Head and Mayer 2014; Kareem 2014), the MNPML estimator is the preferred estimator when there is a high percentage of zero trade flows with a finite number of buyers and sellers. With regard to the MNPML estimator, the market share $\pi_{ijkt} = x_{ijkt}/x_{ikt}$ of the exporting country i is used as the dependent variable, instead of x_{ijkt} as with other estimators (Head and Mayer 2014). Thus, based on the Poisson estimation framework, with all the proxies and dummies, a gravity equation is presented below. Hereafter, for simplicity, the exporting region i is denoted as c (China), and the importing region j is denoted as p (partner):

$$\begin{aligned}\ln \pi_{cpkt} = & \alpha + \delta_1 \mathrm{AI}_{ct} + \delta_2 \mathrm{AI}_{pt} + \delta_3 \ln \mathrm{GDP}_{ct} + \delta_4 \ln \mathrm{GDP}_{pt} \\ & + \delta_5 \mathrm{WTO}_{cpt} + \delta_6 \mathrm{FTA}_{cpt} + \delta_7 \mathrm{Border}_{cp} + \delta_8 \ln \mathrm{Distance}_{cp} \\ & + \sum_{y=2006}^{2013} \mathrm{Year}_y + \sum_{m=2}^{12} \mathrm{Month}_m + \varepsilon_{cpk}\end{aligned} \tag{2}$$

In Equation (2), π_{cpkt} is the market share at time t; AI_{ct} represents the AI status of c at time t, whether there is an outbreak or not; AI_{pt} represents the AI status of p at time t, whether there is an outbreak or not; GDP_{ct} and GDP_{pt} are measured in real terms for the year 2000 in US dollars; WTO_{cpt} is a binary variable that equals one if both regions c and p are members of the WTO at time t; FTA_{cpt} is a dummy that is one if regions c and p are part of the same FTA at time t; $\mathrm{Distance}_{\mathrm{cp}}$ is the geographical distance between the capitals of countries c and p measured in kilometres; $\mathrm{Border}_{\mathrm{cp}}$ is a dummy that is one if regions c and p share a land border; Year_y and Month_m are the dummies for years and months, respectively; and ε_{cpk} is the remaining error term.

Our data sample only includes China and countries importing poultry products from China. However, information on other poultry exporters that export poultry products to the 122 importing countries in competition with China is not included in the data set. Consecutive monthly poultry export data of some other major poultry exporting countries are available from UN Comtrade website from 2010 to 2015. The time period and commodity codes of the data are different from China's monthly poultry export data (obtained from China Customs) that we use in this research. To consider multiple exporters' cases in which exporters may affect each other in trade, we conducted a regression of multiple exporters with the data from the UN Comtrade website without China. The results are not much different from the single exporter's case, but some trade diversion from AI outbreak exporting countries to problem-free countries can be observed. Results are available in the online appendix, in the section on various model specifications. In this paper, we only focus on China, the single exporter's case.

Given the panel nature of our sample data, it is important to adopt an appropriate econometric method to avoid heterogeneity biases and separate time-series and cross-sectional effects. Some studies (Otsuki *et al.* 2001; Wilson and Otsuki 2004; Disdier *et al.* 2008) use fixed-effects models to control the country-specific fixed effects that may affect trade flows. These fixed effects include consumption preferences and each country's multilateral resistance when faced with partners in the rest of the world (Anderson and Wincoop 2003; Feenstra 2004). However, fixed-effect estimators eliminate all time-invariant variation, such as the geographic distance between trading countries (Egger and Pfaffermayr 2004). Hence, following Anders and Caswell (2009), we treat corresponding country effects as random and adopt random-effect estimators due to the importance of the time-constant distance variable for trade flow analysis. The Hausman test results are reported with each regression model. In addition, we introduce annual and monthly dummies in the gravity model to capture the time trends that could affect the poultry product trade at annual and monthly levels, besides the AI outbreaks.

2.3 Policy effects of AI outbreaks

In the WTO system, importing nations have the right to use NTMs to protect their own poultry populations from the introduction of diseases, such as AI. NTMs play a significant role in the agri-food trade, including the poultry trade (Rae and Josling 2003; Disdier *et al.* 2008; Schlueter *et al.* 2009; Wieck *et al.* 2012). NTMs include SPS measures, TB measures, quantitative restrictions, antidumping measures, special safeguards and tariff-rate quotas. In our case study, most NTMs imposed by China's trading partner countries are SPS and TB measures. Countries importing uncooked poultry from China have implemented 396 cases of SPS, 224 TBT, 3 QR and 11 SSG (2.21%) measures during the period from 2005 to 2013. Countries importing cooked poultry from China have implemented 127 cases of SPS, 323 TBT, 5 QR and 4 SSG (1.96%) measures during the period from 2005 to 2013.

Several studies have investigated the effects of NTMs on the meat trade (Alston and Scobie 1987; Paarlberg and Lee 1998; Peterson and Orden 2005; Schlueter *et al.* 2009), the impact of animal diseases on the animal product trade (Djunaidi and Djunaidi 2007; Kawashima and Sari 2010; Tozer and Marsh 2012) and the impact of animal disease-related regulatory policies on the poultry meat trade (Wieck *et al.* 2012). However, the extent to which animal disease outbreaks influence trade by affecting trade policymaking, has so far received little attention in the literature. Hence, in this research, we have estimated the indirect impact of AI on trade through policy effects.

In order to measure the indirect effects of AI outbreaks, we undertake estimations in two stages. At the first stage, we identify the effects of AI outbreaks on the importing countries that imposed NTMs. In our case study, 98% of the NTMs imposed by China's trading partner countries are SPS and TB measures. We only focus on the effects of AI outbreaks on the presence of SPS and TB measures. Observing the data, the chance of having SPS and TB simultaneously in a month is rare. When either SPS or TB is imposed in a month, the percentage is slightly above 1%. So, using a dummy variable equals one when imposing either SPS or TB is appropriate. We constructed a dummy variable to account for this NTM variable. The variable equals one when there are new cases notified to the WTO at the four-digit HS level[1] in a particular month. The estimation equation is as follows:

$$\begin{aligned}\text{NTM}_{pkt} =& \varphi + \varphi_1\text{AI}_{ct} + \varphi_2\text{AI}_{pt} + \varphi_3\text{NTM}_{pkt}(t-1) + \varphi_4 \ln \text{GDP}_{ct} \\ &+ \varphi_5 \ln \text{GDP}_{pt} + \varphi_6\text{WTO}_{cpt} + \varphi_7\text{FTA}_{cpt} + \varphi_8\text{Border}_{cp} \\ &+ \varphi_9 \ln \text{Distance}_{cp} + \mu'_{pk}\end{aligned}, \quad (3)$$

where NTM_{pkt} is 1 when there is either an SPS or TBT measure covering commodity k from country p at time t, and zero otherwise; the variable $\text{NTM}_{pkt}(t{-}1)$ equals 1 if there are NTMs applied to the same product in the last month, and zero otherwise; μ'_{pk} is a error term; and φ is the constant term. The remaining variables are defined in the same way as in Equation (2). In order to estimate the first-stage Equation (3), we use a Probit estimation framework.

At the second stage, we distinguish between the policy effects and nonpolicy effects of AI outbreaks. The predicted values of NTMs from the first stage are used in the gravity model to capture the policy impact of AI outbreaks as follows:

$$\begin{aligned}\ln \pi_{cpkt} =& \alpha_{pk} + \gamma_1\text{AI}_{ct} + \gamma_2\text{AI}_{pt} + \gamma_3\hat{\text{NTM}}_{pkt} + \gamma_4 \ln \text{GDP}_{ct} + \gamma_5 \ln \text{GDP}_{pt} \\ &+ \gamma_6\text{WTO}_{cpt} + \gamma_7\text{FTA}_{cpt} + \gamma_8\text{Border}_{cp} + \gamma_9 \ln \text{Distance}_{cp} + \mu''_{pk}\end{aligned}. \quad (4)$$

The structure of Equation (4) follows Equation (2) except that the predicted values of the policy variable NTM from the first stage are added. Year and month dummies are omitted in order to simplify writing. The parameters of interest are γ_1, γ_2 and γ_3. The former two measure the nonpolicy effects of AI outbreaks, including the impact of AI outbreaks on consumer demand and producer supply. The latter measures the policy effects on China's poultry exports during AI outbreaks in China and its importers.

When estimating the gravity equation, further justifications are made in order to capture more comprehensive trade flow changes when AI outbreaks occur. Specifically: (i) we distinguish between HPAI and LPAI as AI outbreaks, given that the two types of AI outbreak have different infection and mortality rate on birds. We mainly focus on HPAI given the more frequent occurrence of such outbreaks and potentially larger impact; however, we also estimate the impact of LPAI outbreaks to consider whether LPAI, with its lower probability of infection, could have a smaller impact on trade flow, related NTM implementation and NTMs-related indirect trade impacts as well; (ii) our research distinguishes uncooked and cooked poultry products given that they may be affected by AI in different ways; (iii) in

[1] There are limited notifications at the two-digit and eight-digit HS levels, therefore, we have matched these to the four-digit level.

addition to regress trade volume, we also apply the same model to trade value to reflect the potential price effects when AI outbreaks and when there is an indirect policy impact; (iv) to exactly measure the magnitude of AI outbreaks, instead of using the dummy of AI outbreaks, we also counted the number of AI cases and used the number to see its impact on trade and policy; (v) to disentangle the AI outbreak impacts in China and in importing countries, we also constructed AI outbreak dummies for outbreak in China only, outbreak in partner counties only, and outbreaks in both simultaneously; and (vi) we separated the sample into large import share and small import share countries to observe whether there are 'big country' effects. Specifically, we separated the top ten uncooked product importing countries, accounting for 84.46% of the total exports, and the top ten cooked poultry product importing countries accounting for 98.79% of the total exports.

All the regression results of the baseline model and two-stage models are presented in the following section for discussion.

3. Estimation results

3.1 Results of the impact of HPAI outbreaks on the poultry trade

This estimation is based on Equation (2). The results are summarised in Table 2. As the estimated coefficients do not show marginal effects as opposed to semi-elasticity effects (Chen 2014), in order to make it easier to understand how each variable affects the dependent variable, we interpreted the estimated coefficients in terms of incidence rate ratio (IRR); namely, the exponential value of the estimated coefficients. For all the results in the Section 3, we presented the original regression results of the MNPML estimators with corresponding IRR results in parentheses.

From Table 2, we observe that in general, HPAI outbreaks in China do not have a significant impact on uncooked poultry volume and value or cooked poultry volume and value. HPAI outbreaks in partner countries negatively affect the uncooked and cooked poultry trade. The impact is significant for the uncooked poultry trade, but not the cooked poultry trade. Specifically, with regard to uncooked poultry trade volume, the exponential value of −1.282 is 0.277. Thus, when an HPAI outbreak occurs in a partner country, China's poultry exports (the market share of exports to a particular partner country in terms of China's total poultry exports) are 72.3% less in volume, and China's poultry exports are 74.4% less in value. However, the negative effects are not significant for cooked poultry. This situation may occur because cooked products, with further processing, can be less affected by HPAI outbreaks. Rational consumers may consider cooked products as problem free despite AI outbreaks. The overall negative effects of HPAI outbreaks in partner countries on the uncooked and cooked poultry trades (whether they are significant or not) can be explained by two factors: (i) consumers' expectations; when HPAI outbreaks occur in importing

Table 2 Estimated impact of HPAI on China's Poultry Exports (MNPML)

Variables	Uncooked poultry		Cooked poultry	
	π_{Volume}	π_{Value}	π_{Volume}	π_{Value}
$HPAI_C$	0.023 (1.023)	0.023 (1.023)	−0.028 (0.972)	−0.031 (0.969)
$HPAI_P$	−1.282** (0.277)	−1.364*** (0.256)	−0.081 (0.922)	−0.112 (0.894)
Log GDP_C	−0.094 (0.910)	−0.097 (0.908)	−0.035 (0.966)	−0.046 (0.955)
Log GDP_P	0.618** (1.855)	0.625** (1.868)	−0.258*** (0.773)	−0.197** (0.821)
WTO	1.049*** (2.855)	1.075*** (2.930)	0.255 (1.290)	0.252 (1.287)
FTA	0.186 (1.204)	0.213 (1.237)	−0.369 (0.691)	−0.488 (0.614)
Border	2.228*** (9.281)	2.247*** (9.459)	−4.452*** (0.012)	−4.016*** (0.018)
Log distance	−0.023 (0.977)	−0.023 (0.977)	−2.187*** (0.112)	−2.113*** (0.121)
Constant	−4.283*** (0.014)	−4.315*** (0.013)	−0.148 (0.862)	−0.260 (0.771)
Constant lnalpha	0.725*** (2.065)	0.738*** (2.092)	1.193*** (3.297)	1.207*** (3.343)
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Product-country random effects	Yes	Yes	Yes	Yes
Wald chi^2	237.55***	229.69***	350.75***	362.62***
LR test of alpha = 0	554.78***	570.15***	1225.41***	1209.17***
Hausman test	56.19***	55.47***	9.24	1.02
Observations	11,988	11,988	22,680	22,680

Note The asterisks, ***, **, denote significance at the 1%, 5% levels, respectively.
Year fixed effects are controlled by eight-year dummies for 2006–2013. The dummy for 2005 is dropped. Month fixed effects are controlled by eleven-month dummies for February to December. The dummy for January is dropped.
The IRR results of the MNPML estimator are shown in the parentheses.
As the Hausman tests accept fixed effects for uncooked products but reject fixed effects for cooked products, we choose random effects for both products. The reason is that the coefficients with random effects are unbiased although not most effective (Chen 2014).

countries, consumers in importing countries become reluctant to consume poultry products, including imported products, hence, demand for imports drops, negatively affecting China's poultry exports; and (ii) trade diversion; with more safety concerns about consuming poultry products, consumers in importing countries may be more careful of choosing the source of imported poultry products. They may substitute poultry imports from countries that are perceived as less risky in AI outbreaks as China.

The effects of the exporting country's (China) GDP are not significant for uncooked and cooked poultry products. However, the effects of the GDPs of importing partner countries are significant. When an importing country's GDP level increases by one, China's uncooked poultry export volume share increases by 1.855 times. With the price effect, the export value share increases by 1.868 times. However, China's cooked poultry export volume share decreases by 0.773 times. With the price effect, the export value share decreases by 0.821 times. By observing the real data scatter, this result reflects the general poultry export pattern of China. China's uncooked poultry products were mainly exported to lower income/less developed countries during the sample period. Among those importing countries, the higher the income, the greater the amount of uncooked products they continued to import from China.

The effects of WTO membership for China and its importing trade partners are significant for the uncooked poultry trade but not for the cooked poultry trade, although both effects are positive. The positive effects are as expected because the WTO's target is to facilitate trade among member countries. When both China and an importing partner country are WTO members, the volume of uncooked poultry exports from China to the partner country increases by 2.855 times, and the value increases by 2.930 times. The impact on the cooked poultry product trade is on a smaller scale and insignificant. This may be because cooked products are more likely to face non-tariff barriers, such as private standards that do not really match the WTO regime.

The effects of having FTAs for China and importing trade partners are not significant for either uncooked or cooked poultry products. Different to WTO membership, FTA can be limited to some specific commodity trade or service trade in which agricultural, and poultry commodities might not be included. In addition, importing countries may have FTAs on agricultural and poultry commodities with other major poultry exporting countries rather than China. Thus, having the same FTA may not necessarily affect the poultry trade significantly. For example, the China–Singapore FTA signed in January 2009 does not include poultry-related tariff reduction or removal (MOFCOM 2016).

The effects are significant when China and a trading partner country share a border. If they share a border, the volume and value of uncooked poultry exports are much larger than if they do not share a border. Uncooked poultry products require a shorter transportation time; thus, a close location facilitates China's exports to a neighbouring country. If China and a trading partner country share a border, the volume and value of cooked poultry exports from China are slightly smaller than if they do not share a border. The respective values are 98.8% and 98.2%, with just 1.2% and 1.8% decreases. Fourteen countries have borders with China. Most poultry imports to these countries from China are uncooked products. This variable, and the effects on China's poultry exports, is quite specific in our case study.

The effects of distance are negative on both uncooked and cooked poultry exports from China and are significant with regard to the latter. The negative impacts follow the intuition that the larger the distance between China and an importing trade partner, the smaller the poultry trade flow from China to that country. If the distance logarithm value increases by one unit, the volume of cooked poultry exports from China decreases 0.112 times and the export value from China decreases 0.121 times.

These results reflect the direct effects of HPAI outbreaks on China's poultry exports. Next, we captured the indirect effects of HPAI-induced NTMs on China's poultry exports.

3.2 Results of the impact of HPAI outbreaks on NTMs and the poultry trade

This estimation has two stages. Stage one adopts Probit regression for Equation (3). The purpose is to capture the impact of AI outbreaks on NTMs, specifically the impact of HPAI outbreaks. With the predicted NTM results, we estimated the effect of HPAI outbreaks on the poultry trade at stage two using an MNPML estimator. The results are presented in Table 3. From the results, we summarise our observations as follows.

With regard to the results of the first-stage Probit regression, we predict the probability of imposing NTMs. The effects of HPAI outbreaks in either China or importing partner countries do not significantly affect the predicted probability of imposing NTMs on the uncooked and cooked poultry product trades. The reasons why importing countries impose NTMs are complex. For example, outbreaks of HPAI, either domestically or in an exporting country, may not directly lead to NTMs. Further, there are 122 importing partner countries in our data sample. The heterogeneity of these many importing countries increases the complexity of the issue. Moreover, there are many other poultry exporters that are not included in the model. Whether these countries have HPAI outbreaks at the same time also affects the predicted probability of imposing NTMs on the poultry trade. In addition to the HPAI outbreak variable, most variables do not have a significant impact on NTM appearance. Other variables have significant impacts in the first stage as follows.

The GDP of a partner country has a significant positive impact on the probability of imposing an NTM on the cooked poultry products trade. An increase in the GDP logarithm level of an importing partner country increases the predicted probability of imposing an NTM on cooked poultry exports from China. The NTMs of our study are SPS and TBT

Table 3 Estimated impact of HPAI on China's Poultry Exports (two steps)

Variables	Uncooked			Cooked		
	1st stage dependent NTM_P (Probit)	2nd stage dependent π_{Volume} (MNPML)	2nd stage dependent π_{Value} (MNPML)	1st stage dependent NTM_P (Probit)	2nd stage dependent π_{Volume} (MNPML)	2nd stage dependent π_{Value} (MNPML)
$HPAI_C$	−0.084	−0.007 (0.993)	−0.009 (0.991)	−0.041	−0.014 (0.986)	−0.014 (0.986)
$HPAI_P$	0.132	−1.236** (0.291)	−1.316*** (0.268)	0.057	−0.121 (0.886)	−0.164 (0.849)
NTM_P	—	−0.354 (0.702)	−0.369* (0.691)	—	0.258 (1.294)	0.326 (1.385)
Log GDP_C	0.045	−0.079 (0.924)	−0.080 (0.923)	0.070	−0.052 (0.949)	−0.068 (0.934)
Log GDP_P	0.122	0.661** (1.937)	0.669** (1.952)	0.201***	−0.317*** (0.728)	−0.272*** (0.762)
WTO	—	1.059*** (2.883)	1.088*** (2.968)	—	0.263 (1.301)	0.260 (1.297)
FTA	−0.078	0.148 (1.160)	0.173 (1.189)	0.190	−0.448 (0.639)	−0.577 (0.562)
Border	−0.619**	2.006** (7.434)	2.012** (7.478)	−0.242	−4.389*** (0.012)	−3.945*** (0.019)
Log distance	−0.497**	−0.197 (0.821)	−0.206 (0.814)	−0.215	−2.136*** (0.118)	−2.053*** (0.128)
Constant	−0.547	−4.473*** (0.011)	−4.511*** (0.011)	−2.042***	0.395 (1.484)	0.433 (1.542)
Constant lnalpha		0.727*** (2.069)	0.739*** (2.094)		1.195*** (3.304)	1.207*** (3.343)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Product-country random effects	Yes	Yes	Yes	Yes	Yes	Yes
$NTM_P(t-1)$	0.703***	—	—	0.581***	—	—
lnsig2u	−0.543**			0.075		
LR test of rho = 0	457.050***			1065.070***		
Observations		11,877	11,877		22,470	22,470
Wald chi^2	205.860***	233.88***	227.90***	370.040***	354.08***	422.20***
LR test of alpha = 0		554.67***	569.95***		1207.92***	1192.54***
Hausman chi^2		78.71***	82.18***		2.05	2.99

Note The asterisks, ***, ** and *, denote significance at the 1%, 5% and 10% levels, respectively.
$NTM_P(t-1)$ represents NTM_P that lags for one phase.
As the Hausman tests accept fixed effects for uncooked products but reject fixed effects for cooked products, we choose random effects for both products. The reason is that the coefficients with random effects are unbiased although not most effective (Chen 2014).

measures. These two NTMs are mainly associated with product quality. Countries with higher income tend to be stricter about commodity quality and thus impose more NTMs on imported commodities. This approach may explain the positive coefficient of the variable. This variable also has a positive coefficient on uncooked products although not significant. In addition, the border and log distance variables also have significant negative impacts on the probability of imposing NTMs on uncooked products.

If an NTM is imposed in a prior month, the predicted probability of imposing an NTM on both uncooked and cooked poultry product exports from China is larger. When an NTM has been implemented previously, it is easier to continue it or to impose a new NTM in terms of administrative and management costs, and effort. One point to notice is having an NTM in a prior month has a larger impact on uncooked than cooked products. This may be because uncooked poultry products are relatively 'fresher' compared with processed cooked products. Hence, the former are more sensitive to an NTM when an HPAI outbreak occurs. Without further product processing, HPAI outbreaks could affect uncooked products directly over a longer period.

Based on the results of the second-stage MNPML estimation, we observed similar results to those in Table 2. The effects of the predicted probability of a partner country imposing an NTM are negative and significant on the value of uncooked poultry exports from China. Specifically, when an NTM is imposed, the value of uncooked poultry exports from China fall to 69.1% of the value that they have when an NTM is not imposed. This suggests that imposing an NTM increases trade costs which results in a decrease in trade value. The effects of the same variable on uncooked export volumes, cooked export volumes and cooked export values are not significant.

In addition to the NTM variables, the variable $HPAI_p$ has a significant negative impact on the trade volume and value of uncooked exports. Volume falls to 29.1% and value falls to 26.8% of the volume and value that apply when there are no HPAI outbreaks in a partner country. These results are similar to those of Table 2. In addition, variable $logGDP_p$, WTO, border and log distance all have estimated coefficients consistent with previous results in Table 2. The similarity of the results pattern to that of Table 2 implies that the predicted probability of imposing NTMs after HPAI outbreaks in either China or importing partner countries may not affect poultry trade flows much.

In addition to the baseline model discussed in this section, we used other measures of AI outbreaks, captured time-lag impacts, aggregated the data sample, focused on top importers and the rest of the countries, and adopted alternative estimation methods to test the robustness of the baseline model. Moreover, subject to data limitation, we undertook analysis with additional specifications (removed time dummies, excluded disease outbreaks in importing countries, replaced poultry production with GDP, and used only

AI directly related NTMs), to elaborate the trade effects of AI outbreaks and NTMs on China's poultry exports. All the details and results are in the online appendix as supplementary information and materials.

4. Conclusion

We used monthly poultry export data from China to all its trading partner countries in order to identify the direct impact of AI outbreaks and the indirect impact of AI-induced NTMs on trade flow. The analysis which included justifications and robustness checks provided interesting results leading to the following conclusions.

First, different from prior studies (Peterson and Orden 2005; Djunaidi and Djunaidi 2007), we did not find a significant effect of AI outbreaks in China (as an exporting country) on poultry trade. This might be due to the fact that we modelled a single exporter's case of the poultry trade. Instead, AI outbreaks in importing countries more significantly reduce such countries' uncooked poultry imports. This result is fairly consistent throughout the variation of models but is particularly large in the case of LPAI outbreaks. This may be because consumers' expectations of imported poultry products are negatively affected by domestic AI outbreaks. In addition, after AI outbreaks, importing countries may choose poultry from other exporting countries that are perceived as less risky rather than from China.

Second, uncooked and cooked poultry products have different time-lag impacts of AI outbreaks in either exporting or importing countries. When a greater number of AI outbreaks occur in China, it may reduce the probability of importing partner countries imposing NTMs on cooked product imports from China. This result is immediate and temporary. It is because cooked poultry products are processed foods. Such food may be less affected by AI outbreaks compared with freshly produced agricultural products. Hence, fewer food safety and quality concerns may be raised. Moreover, cooked poultry products can serve to some extent as substitute products for uncooked poultry products. Another reason that can be trade diversion that importing partner countries could switch their imports of cooked poultry products to other poultry exporting countries without/with fewer number of AI outbreaks than China.

However, after a certain period (approximately 2 or 3 months), following an initial AI outbreak, importing countries would likely impose NTMs on cooked products. This is particularly true when importing countries are developed and high-income countries that tend to import more processed products and are strict about NTMs in the long-term. Also, after a certain period, other poultry exporting countries may also be affected by AI outbreaks in China. Therefore, universal nondiscriminant NTMs may be necessary for importing countries. On the other hand, uncooked products have long time-lag effects in terms of NTM imposition after AI occurs in either country.

Third, when NTMs are imposed because of AI outbreaks, the uncooked poultry products trade decreases. This is because NTMs mainly target agricultural products, such as uncooked products, rather than processed products, such as cooked products. This impact is particularly significant because poultry importers have a smaller market share of China's uncooked poultry exports. With regard to China, most of these importing countries are developed and high-income countries.

Last, with regard to China's poultry exports, developed and high-income countries mainly import cooked products. Such countries are strict about imports of agricultural products (uncooked poultry) and processed (cooked) products. Indeed, NTMs are mainly imposed by such developed countries. This finding is consistent with the literature on agricultural exports from developing countries (Jongwanich 2009). Such an export pattern for China's poultry products is also consistent with Jaud *et al.*'s (2013) study on supplier concentration. With the risk of AI outbreaks that affect food safety, the less risky exports of cooked poultry products from China are mainly shipped to developed and high-income countries. Although there is still the risk of strict NTMs when AI outbreaks occur, the trade/business relationship between China and importing countries is relatively stable. Indeed, NTMs' negative impact on cooked poultry imports from China after AI outbreaks is not significant.

Based on the above key findings, policy implications are derived. When AI occurs in export destinations, uncooked poultry product exporting countries expect a drop in exports. They can search for a new exporting destination or export cooked poultry products instead, to reduce potential economic loss. Developing countries should diversify their exporting products to minimise risks from AI outbreaks. Increasing their exports of cooked products is not only economically beneficial with more value added in exports, but also it could help to avoid such demand decreasing risk when AI occurs in importing countries.

Given the time-lag impacts, poultry exporting countries could plan ahead to minimise loss caused by NTM imposition. When AI occurs in an exporting country, cooked product exports should be prepared for NTM imposition, while uncooked product exports could have a longer period to prepare in advance. However, when AI occurs in importing countries, cooked product exports may decrease NTM imposition after about 2 to 3 months of the AI outbreaks.

In general, for the agricultural exporters of developing countries, exporting more processed products can provide better access to developed countries' markets. Although there may be more NTMs (and coming sooner after AI outbreaks domestically in exporting country) with stricter standards and quality requirements, developing countries' exporters could also benefit from a positive spillover. Once an export relationship is established, this can be stable and subject to fewer risks from external shocks, such as AI outbreaks.

With limited trade data, other major poultry exporting developing countries, such as Brazil and Thailand, are not included in our research. Further research on the impact of AI outbreaks on trade diversion can be conducted when more data are available. Research on NTM imposition schemes and food safety standards of poultry products imposed by developed countries in particular is also important to study. A clearer strategy for poultry exporters in developing countries to respond to AI outbreaks could be developed.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Appendix S1. Robustness checks and various model specifications.