OSIPP Discussion Paper: DP-2018-E-003

Structure Demand Estimation of the Response to Food Safety Regulations in the Japanese Poultry Market

March 30, 2018

Qizhong YANG†
JSPS Research Fellowship for Young Scientists (PD)
Keiichiro HONDA
Faculty of Administration, Prefectural University of Kumamoto
Tsunehiro OTSUKI
Professor, Osaka School of International Public Policy, Osaka University

【Keywords】Poultry consumption, Maximum residue limit, Random-coefficient model

【JEL Classification】D18, F14, L10

【Abstract】Since their implementation in 1995, the Agreements on the Application of Sanitary and Phytosanitary Measures and Technical Barriers to Trade of the World Trade Organization have played an increasingly important role in the conduct of international negotiations. This study employs the method of moments estimator proposed by Berry, Levinsohn, and Pakes (1995) and Nevo (2001) to estimate the effect of Japanese pesticide residue standards on poultry consumption with a particular focus on the maximum residue limits (MRLs) on pesticide and veterinary drugs. The results confirm that more stringent MRLs on pesticide and veterinary drugs enhance the demand for poultry imports by ensuring higher food safety. The results shed light on Japanese consumers' robust preference for food safety. Further counterfactual experiments of alternative MRLs show that the demand-enhancing effect may vary among the exporting countries, and appears to be more prominent for imported poultry from developed countries.

† Corresponding author. Osaka School of International Public Policy, Osaka University,
Address: 1-31 Machikaneyama, Toyonaka, Osaka 560-0043, JAPAN.
E-mail: u759184c@alumni.osaka-u.ac.jp

1. Introduction

Since the Agreements on the Application of Sanitary and Phytosanitary (SPS) Measures and Technical Barriers to Trade (TBT) of the World Trade Organization (WTO) came into force in 1995, there have been an increasing number of trade disputes related to these Agreements. SPS measures and TBT raised concerns that they may constitute nontariff barriers although they are implemented primarily to ensure human, animal, and plant health related to the consumption of products in the domestic and import markets. These trade disputes largely stem from the contrasting effect of the SPS measures (and TBT) on producers and consumers. For producers, SPS measures and TBT may impose high compliance costs on firms such as the fixed costs involved in the upgrading of facilities, the acquisition of certificates, and conformity in marketing requirements. Therefore, the proliferation of SPS measures and TBT can significantly reduce a country's imports from its trading partners, and even drive some foreign suppliers out of the market (Xiong and Beghin (2014)).

On the demand side, however, SPS measures and TBT may have a positive effect on a country's import demand if the regulations address market imperfections (Thilmany and Barrett (1997)). For example, mandatory labeling requirements in meat products can boost meat demand by conveying quality information to consumers. Moreover, SPS measures can promote social well-being, in the form of better public health, greater animal welfare, or a more sustainable environment. In economies where consumer awareness of food safety, animal welfare, and plant health is high, SPS could stimulate demand for products under regulation (Josling *et al.* 2004). Thus, SPS measures are generally thought to enhance market demand.

Therefore, the ambiguous effect of SPS measures and TBT on international trade depends on the balance between the different effects on producers and consumers. This dual effect calls for a different analytical framework from those used to analyze the impact of conventional tariff measures. The conventional wisdom that trade liberalization improves market access and welfare does not necessarily carry over to SPS measures and TBT. Theoretical analyses do not provide any definitive conclusions on the overall effect linked to regulation, which requires economists to draw on empirical evidence. What makes the question more complex is consumer heterogeneous preference across countries of origin because the physical characteristics of the product differ across producing countries. In other words, SPS measures and TBT may have an asymmetric effect on imported products from different countries.

In this study, I estimate the impact of Japanese pesticide and veterinary drug residue standards on poultry imports using monthly data for major exporter countries from 2001 to 2013 with a particular focus on the maximum limits on pesticide and veterinary drug residues. While the extant literature dealing with this topic has failed to control for the endogeneity of poultry prices, this study overcomes the problem by using instruments for the endogenous price variable. A structure estimation methodology proposed by Berry (1994) and Berry *et al.* (1995) and extended by Nevo (2001) is employed to control for the heterogeneity of consumer preference that was not considered in previous work. I also incorporate the method proposed by Xiong and Beghin (2014) to estimate the effects of maximum residue levels (MRLs), as a particular SPS measure, on the imports of poultry products into the Japanese market. According to the Ministry of Agriculture, Forestry and Fisheries (MAFF), due to growing consumer health consciousness, poultry consumption has increased by 20% in the period 2006-2016[1]. Depending on the fiscal year, Japan's poultry imports have varied between 40,000 and 500,000 tons in recent years. The MRLs set limits on harmful substances, such as pesticide residues, veterinary drug residues, and other harmful substances, that importing countries allow on similar imported and domestic products as implied by national treatment. MRLs are usually specific to substance, product, and country. Countries have a legitimate right to set science-based MRLs in the presence of health risks. MRLs can also be used to impede trade to protect domestic producers rather than to protect health or the environment. Unlike Xiong and Beghin (2014), I use average Japanese MRLs instead of the international standards recommended by the Codex Alimentarius to compute MRLs. Those values that exceed the average level are defined as protectionist or "excessively stringent" beyond the average level, and this is thus a simple criterion.

The results confirm the prior expectation that more stringent MRLs on pesticide and veterinary drugs enhance the demand for poultry import by ensuring higher food safety.

[1] The yearly poultry consumption increased from 1,974 thousand tons in 2006 to 2,369 thousand tons in 2016, while the yearly consumption of pork and beef remain flat in the past 10 years.
Source: http://www.maff.go.jp/j/chikusan/shokuniku/lin/attach/pdf/index-107.pdf

The results highlight Japanese consumers' robust preference for food safety. Further counterfactual experiments of alternative MRLs show that the demand-enhancing effect may vary among the exporting countries, and appears to be more prominent for imported poultry from developed countries. The own- and cross-price elasticities further indicate the sensitivity of imported poultry meat to the change in domestic poultry price.

This study contributes to the literature from the following perspectives. First, by using market-level data, I show that MRL standards on veterinary drugs in poultry products do not necessarily reflect protectionism. This study provides the evidence that MRLs enhance the total demand of poultry meat. Second, the approach employed here enables us to control for the endogeneity of the poultry prices, a factor that was overlooked in previous work. Finally, the approach also allows for heterogeneity in consumer preference in the demand estimation.

The remainder of this paper is organized as follows. Section 2 provides a brief review of the background. Section 3 presents the estimation models and the data used. Section 4 provides the estimation results and discussion. Section 5 concludes.

2. Background

2.1 World's and Japan's SPS/TBT Regulations

Global food and agricultural trade has rapidly expanded in recent decades. The world's total food and agricultural exports increased from 459 billion USD in 1995 to 685 billion USD in 2005 and 1.3 trillion USD in 2015 (UNCTAD, *Merchandise trade matrix*). This increasing trade has triggered a dramatic increase in trade disputes regarding SPS measures. According to the WTO, the total number of notifications per year submitted to the WTO increased threefold from approximately 470 in 2000 to around 1,420 in 2010 (WTO G/SPS/GEN/804/Rev.4, 2011). The SPS Agreement is implemented to ensure human, animal, and plant health related to the consumption of products in the domestic and import markets. Although the Agreement is also aimed at preventing unnecessary barriers to trade, many countries continue to maintain their own restrictive food safety standards based on consumers' requirements.

In the Japanese market, the Food Sanitation Act was introduced in 1947, followed by the Plant Quarantine Law in 1950 and the Domestic Animal Infectious Diseases Control

Law in 1951. Before the introduction of MRLs in 1992, any use of synthetic antimicrobial drugs was prohibited according to the Food Sanitation Act. Since May 2006, the so-called “positive MRL list system” for regulating pesticide residues in food has been active. This system was primarily aimed at controlling pesticide residues in imported crops from foreign countries and a default level of 0.01 ppm is uniformly applied to chemicals for which MRLs have not been determined. This means that the level of 0.01 ppm—significantly lower than existing MRLs—is also applicable to any registered pesticides in Japan if there is unintentional exposure (through drift) of neighboring crops for which an MRL has not been established[2]. Japanese consumers always appear to give more credence to domestic foods or to the imported foods whose source countries have more stringent standards than those of Japan. Nevertheless, regarding the MRL, the change is not particularly likely to be perceived by consumers.

According to the Food Safety Act, the submission of a sanitary certificate demonstrating compliance with Japanese food safety standards is obligated by the Ministry of Health, Welfare and Labor (MHWL) for importation to Japan. In addition, for food imported for the first time into Japan, there are mandatory inspections of pesticide and veterinary drug residues imposed by the MHWL, including ordered inspections, monitoring inspections, and administrative inspections. The ordered inspection requires products to be constantly tested for safety by the importing firms and import is permitted as long as products comply with Japanese food safety standards. While these inspections ensure compliance of imported food products with Japanese food safety standards, they do not ask for a level of food safety that exceeds the Japanese standards. In addition to the above inspections, importation of meat and meat products requires an inspection of livestock products based on the Livestock Infectious Diseases Prevention Law and import inspection based on the Food Sanitation Act.

2.2 Japanese Poultry Meat Market

[2] Typically, the “positive list” prohibits the distribution of foods whose pesticide residues exceed the standard regarding 799 kinds of agricultural chemicals and for other chemicals a uniform level of 0.01ppm was applied to. Before the implementation of the “positive list” system, the concept of regulation was so-called "the negative list", that is, there was no regulation on pesticide residues except the listed 250 pesticides and 33 veterinary medicines. As for this study, the MRL index used in the estimation is calculated using regulation data on the chemicals of the positive list, meaning that none has been applied to the uniform level MRL regulation.
Source: http://www.mhlw.go.jp/topics/bukyoku/iyaku/syoku-anzen/zanryu2/dl/060516-1.pdf

In recent years, consumption of animal meat has become increasingly popular especially among young people, although Japanese consumers are traditionally known as fish eaters. Figure 1 shows that beef, pork, and poultry are consumed almost equally in terms of their weights in the Japanese market. While beef consumption is notable in the western part of Japan and pork consumption is dominant in the east, poultry is consumed countrywide. The consumption of poultry and pork each constitutes approximately one-third of overall meat consumption and has been stable over time because of the country's slow income growth and aging population.

<Figure 1 inserted here>

In the Japanese poultry market, imported and domestic products appear to be close substitutes. Figure 2 shows that Japan's poultry self-sufficiency rate came down from above 92% in 1985 to 69% in 1995, partly because of the tariff cuts based on the WTO's Agreement on Agriculture under the General Agreement on Tariffs and Trade in the same year. Since the mid-1990s, the share of imported poultry in Japan has been almost constant. The threat of avian influenza has continued to affect Japan's poultry import demand, and the Japanese government banned the import of poultry products in response to the incidence of avian influenza overseas. MAFF has drawn up a list of 32 countries and regions[3] that specifies the importable poultry products in the case of a worldwide outbreak of avian influenza.

Similar to branded beef products such as "Kobe beef" and "Matsuzaka beef," domestic branded poultry meat has also been gaining popularity in line with the growing gourmet trend, with "Hinai-Jidori chicken" from Akita Prefecture and "Satsuma Native Fowl" from Kagoshima Prefecture. However, it should be noted that the broiler chicken is the dominant kind of poultry consumed in the Japanese market. According to MAFF, in 2016, branded poultry meat accounted for less than 1% of total poultry consumption. Furthermore, such poultry meat is not considered to be as luxurious as exported beef and pork, and the price is not significantly higher than that of imported poultry meat.

<Figure 2 inserted here>

[3] http://www.maff.go.jp/aqs/hou/pdf/JP_Pultry20171027.pdf
Poultry import from the listed countries and regions is allowed when an inspection certificate issued by the government agency of the exporting country is provided.

2.3 Literature Review

The gravity model has been typically used to estimate the countrywide aggregate impact of regulatory policies on imports because this model can effectively isolate the variation in bilateral trade flows caused by regulations and those caused by other importer- or exporter-specific factors by using panel dataset. For example, Disdier and Marette (2010) explored the link between gravity and welfare frameworks for measuring the impact of nontariff measures, and showed that in most cases, a stricter standard leads to an increase in both domestic and international welfare. However, as the gravity model can only estimate the impact of regulations on trade flows and trade regimes, some studies of this kind conveniently extended the methodology to allow the distinction between the demand and supply impacts of standards. Xiong and Beghin (2014) decomposed the impact of standards into the demand-enhancing effect (demand effect) and the trade-cost effect (supply effect), and estimated these effects.

One of the drawbacks of the gravity model lies in its assumption of a common coefficient for a regulatory variable across bilateral pairs of importers and exporters. It forces the same direction of change in trade on all samples, and thus, it does not allow for consumers' flexible rearrangement of bundles of goods across different origins. In reality, safety regulations can drive a composition change in imports from different origins as well as a change in the total amount of imports. Furthermore, the same can apply to the composition of domestic and imported goods as a group. The composition change can be accounted for by nonhomothetic consumers' preference.

The almost ideal demand system (AIDS) model, another commonly used model that specializes in demand analysis, is advantageous for capturing the demand effect of regulatory policies. Moreover, the AIDS model allows for asymmetric consumers' response to regulations across goods from different origins, which is not available in the gravity model, as well as the calculation of own- and cross-price elasticities. Honda *et al*. (2011) estimated the response of Japanese demand for poultry meat to food safety regulations using the AIDS model with a particular focus on MRLs on pesticides and veterinary drugs. Their results indicate that tightening the MRLs reduces domestic demand for poultry meat as well as demand for imports from China and the U.S., and increases demand for imports from Brazil. Honda and Otsuki (2016) employed a source-differentiated AIDS (SDAIDS) model to estimate the effect of Japanese pesticide residue standards on its orange imports and a domestically produced counterpart. Their findings indicate that a tighter pesticide MRL decreases the demand share of domestic oranges while it increases imports. The SDAIDS model was also applied by Yang *et al.* (1994) to estimate Japan's meat import demand, particularly focusing on beef, pork, and poultry.

While the AIDS model has its advantages compared with the gravity model, there remain some concerns. First, because the AIDS model is designed to estimate the substitution effect of differentiated goods, any changes in the total demand of the targeted good cannot be observed. While Honda *et al.* (2016) used the AIDS model to investigate the substitution effect among source-differentiated poultry products, their estimation scheme is not suitable to examine how MRLs affect the total demand of poultry. When equations are set up in the AIDS model reflecting the variety of products that differ in product attributes, there are too many parameters to be estimated. In addition, while the AIDS model uses the price of different types of product as the explanatory variable, the potential endogeneity of the price has not been addressed. Furthermore, the AIDS model is not appropriate for estimating the consumer heterogeneity.

The next section introduces a methodology proposed by Berry (1994) and Berry *et al.* (1995) to overcome these drawbacks in the gravity model and the AIDS model.

3 Empirical Framework

3.1 The Demand

The product demand is described by a discrete choice model where the product quality is defined as a bundle of perceived characteristics. This widely used model in the industrial organization literature was proposed by Berry (1994) and subsequently developed to allow consumer heterogeneity in Berry *et al.* (1995)[4] based on the same setup, followed by other studies applying the model into the electronic device industries, e.g. Carranza (2010) and Fan and Yang (2016)[5]. The application was extended to the differentiated food industry by Nevo (2001) and beverage industry by, for example, Kiesel, Villas-Boas (2007) and Liu *et*

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[4] Berry *et al.* (1995) employed this model to investigate the market demand of automobile industry.
[5] Carranza (2010) studied the effect of competition on product innovation in the market for digital cameras and Fan and Yang (2016) focused on the demand of U.S. smartphone industry.

al. (2014)[6].

This section first introduces the model of Berry (1994), which modeled the demand function within the discrete-choice framework. The drawback of the methodology—known as the independence of irrelevant alternatives (IIA) problem—is also indicated. Its improved version using a nested logit model is then introduced with a remark on its limitation, namely the restrictive assumption of homogeneous consumer preference. Finally, the model presented in Berry, Levinsohn, and Pakes (1995) is explained (henceforth referred to as the BLP model). The BLP model allows heterogeneous consumer preference; it is typically recognized as the most developed model and is thus most often employed in the recent literature. While my policy implication will be derived mainly from the BLP model, I employ all three models for demand estimation for the sake of comparison.

3.1.1 Models with Homogeneous Consumer Preference

The demand for poultry product is modeled within a standard binary-choice framework. Following Berry (1994), I construct the demand system by aggregating over the discrete choices of homogeneous individuals in the first step. Consumers are assumed to be homogeneous in income as well as in their tastes for certain product characteristics. Two types of product characteristics are distinguished in the model: those that are observable, which are denoted by x; and those are unobservable, denoted by ξ. The utility of consumer i from consuming a certain poultry product j at time t can be described as:

$$u_{ijt} = x_{jt}\beta + \alpha p_{jt} + \xi_{jt} + \varepsilon_{ijt} = \delta_{jt} + \varepsilon_{ijt}, \quad (1)$$

where p_{jt} is the price of product j at time t. $\delta_{jt} = x_{jt}\beta + \alpha p_{jt} + \xi_{jt}$ denotes the mean utility of consuming the product j for all consumers. The term ε_{ijt} denotes the individual-specific taste parameter for product j in time period t, modeled as zero mean i.i.d. random variable with a Type 1 extreme-value distribution. The utility from choosing poultry products depends on the interaction between a consumer's characteristics and a product's characteristics. Instead of purchasing the poultry product, consumers may also decide not

[6] Nevo (2001) examined consumers' reaction to the product with nearly collusive pricing behavior and intense nonprice competition by using the data collected from the ready-to-eat cereals market of the United States. Kiesel and Villas-Boas (2007) investigated consumer reactions to changes in information provision regarding organic milk and Liu *et al.* (2014) examine the policy impact on consumption of carbonated soft drinks.

to purchase, in which case they consume the "outside good." In this study, I define the outside good as the typical meat product sold in the Japanese market including beef, pork, and the other animal meat and the mean utility of consuming the outside good is normalized as zero (i.e. $\delta_{0t} = 0$).

Under the assumption of ε_{ijt} , the probability of consumer *i* to purchase product *j* can be derived as:

$$Prob_j = f_{ijt} = \frac{e^{\delta_{jt}}}{1+\sum_{j=1}^{J} e^{\delta_{jt}}}. \quad (2)$$

The right-hand side only depends on δ_{jt}, that is, the mean utility of product *j*, which means that the probability of choosing product *j* is identical for each individual. Therefore, by multiplying the market size *M*, the market demand for product *j* can be written as: $q_{jt} = Ms_{jt}$. As the purchase options also include the outside good, the market size here also contains those potential consumers who chose the outside good. By dividing by the share of outside good and then taking the logarithm for both sides of Eq. (2), the demand for product *j* can be estimated by the following equation:

$$\ln s_{jt} - \ln s_{ot} = \delta_{jt} = x_{jt}\beta - \alpha p_{jt} + \xi_{jt}. \quad (3)$$

Of note is that price p_{jt} is an endogenous variable that may be correlated with the unobserved characteristics ξ_{jt}, since firms may take ξ_{jt} into account in their pricing decisions. The common identification assumption is that the observed product characteristics x_{jt} are exogenous, uncorrelated with the error terms of all products. To deal with the endogeneity of p_{jt}, I specify a vector of instruments, z_{jt}, as the poultry prices in the U.S., Thailand, and Brazil, along with the poultry feed price of the Japanese market. These instrumental variables are assumed to be uncorrelated with the error term ξ_{jt}, implying the aggregated population moments $E[\xi_{jt}, z_{jt}] = 0$.

Finally, the own- and cross-price elasticities of the market share s_{jt} can be derived as:

$$\frac{\partial s_{jt}}{\partial p_{rt}} \frac{p_{rt}}{s_{jt}} = \begin{cases} -\alpha p_{jt}(1 - s_{jt}) & if\ j = r \\ \alpha p_{rt} s_{jt} & otherwise \end{cases}. \quad (4)$$

As indicated by Eq. (4), the ratio of the share of two goods only depends on the average utility of these two goods, namely quality and price, which means that the ratio will not be affected by the change of the prices or qualities of any other products. The nested logit model is known to be able to alleviate the IIA problem. The estimation equation of the nested logit model is given as follows:

$$\ln s_{jt} - \ln s_{ot} = x_{jt}\beta - \alpha p_j + (1-\lambda)\ln(s_{j/g(j)}) + \xi_{jt}$$

$$=\delta_{jt} + (1-\lambda)\ln(s_{j/g(j)}) + \xi_{jt}, \quad (5)$$

where $s_{j/g(j)}$ denotes the share of product j within its group $g(j)$. Regarding the distributional assumption of ε_{ijt} in the utility function of Eq. (1), I follow McFadden (1978) by using the generalized extreme value (GEV) model that generates a nested logit allowing for consumers to be more likely to substitute among groups than to the option of no purchase. Here, λ is the parameter capturing the importance of inside–outside segmentation. As shown in McFadden (1978), λ should range between 0 and 1 for the nested logit model to be consistent with the utility maximization problem. In particular, in the case of $\lambda = 1$, the nested logit model corresponds to the logit model and indicates that while no substitution of goods between groups occurs, goods within the group are perfect substitutes of each other. The difference of the estimation equation between the logit model is the within-group share on the right side. The notable point is that the within-group share is endogenous as it is correlated to the dependent variable, that is, the total share s_{ij}. Therefore, it is necessary to use instrumental variables to address the endogeneity of $s_{j/g(j)}$ in addition to p_{ij} while estimating Eq. (5). In the analysis, I use the average of characteristics of the products belonging to the same group of country j, that is, $\frac{1}{n_{g(j)}-1}\Sigma x_{-j/g(j)}$, as an instrument. With these assumptions, the elasticities of the nested logit model then can be calculated as:

$$\frac{\partial s_{jt}}{\partial p_{rt}}\frac{p_{rt}}{s_{jt}} = \begin{cases} -\alpha p_{jt}\left[\frac{1}{\lambda} - \left(\frac{1-\lambda}{\lambda}\right)s_{it/g(j)} - s_{jt}\right] & if\ j = r \\ \alpha p_{rt}\left[\left(\frac{1-\lambda}{\lambda}\right)s_{rt/g(j)} + s_{rt}\right] & if\ j \neq r, j \in g(r) \\ \alpha p_{rt}s_{rt} & otherwise. \end{cases} \quad (6)$$

3.1.2 Model with Heterogeneous Consumer Preference

Although the IIA problem for goods belonging to different groups is alleviated by using the nested logit model, a similar problem still arises among goods belonging to the same group; this is known as the independence of irrespective nests (IIN) problem. If the grouping process is appropriate, IIA and IIN in the nested logit model will not be a critical problem. However, grouping according to the difference in quality of each good is not straightforward. As a solution, I further employ the demand system of heterogeneous individuals following Berry *et al.* (1995). The utilized discrete-choice model (e.g., Nevo (2000); Nevo (2003)) also offers flexibility in incorporating consumer heterogeneity with regard to poultry characteristics. The BLP model allows substitution relationships to differ according to the closeness between the observed characteristics of product, without requiring information on grouping. In the model, the utility function can be written as:

$$u_{ijt} = x_{jt}\beta_i - \alpha_i p_j + \xi_j + \varepsilon_{ijt}. \quad (7)$$

Different from Eq. (1), the coefficients related to the characteristics and prices are individually identified, making it possible to estimate the consumer's heterogeneity. With reference to Nevo (2000), I model the distribution of consumers' taste parameters for the characteristics as multivariate normal with a mean that is a function of parameters to be estimated, and a variance–covariance matrix to be estimated. That is,

$$\binom{\alpha_i^*}{\beta_i^*} = \binom{\alpha}{\beta} + \sigma v_i \quad v_i \sim N(0, I_{k+1}). \quad (8)$$

Thus, Eq. (7) can be rewritten as:

$$u_{ijt} = x_{jt}\beta_i - \alpha_i p_j + \xi_j + [x_{jt}, p_j] * (\sigma v_i) + \varepsilon_{ijt}$$

$$= \delta_{jt} + \mu_{ijt} + \varepsilon_{ijt,} \quad (9)$$

where k is the dimension of the observed characteristics vector and σ is a scaling matrix. This specification allows the individual characteristics to consist of unobservable characteristics denoted by v_i. Eq. (9) shows that the probability of purchasing product j

can vary across individuals, and further indicates that one cannot derive the demand of product j through simply multiplying s_{ijt} by the market size, that is, $q_{jt} \neq Ms_{ijt}$. Instead, the predicted share of each good is used as the dependent variable, which is computed as the following equation using the Monte Carlo simulation[7]:

$$s_j = \int s_{ij}\left(1 - s_{ij}\right) dP_v(v). \quad (10)$$

The BLP model nests all of these other models listed above and has several advantages (Nevo (2000)). First, it allows for flexible own-price elasticities, which is driven by the different price sensitivity of different consumers who purchase the various products, not by functional form assumptions about how price enters the indirect utility. Second, since the composite random shock, $\mu_{ijt} + \varepsilon_{ijt}$, is no longer independent of the product characteristics, the cross-price substitution patterns are driven by these characteristics. Such substitution patterns are not constrained by a priori segmentation of the market, yet at the same time, can take advantage of this segmentation. The own- and cross-price elasticities are given by the following equation:

$$\frac{\partial s_j}{\partial p_r}\frac{p_r}{s_j} = \begin{cases} -\frac{p_j}{s_j}\int \alpha_i s_{ij}\left(1 - s_{ij}\right) dP_v(v) & if\ j = r \\ \frac{p_j}{s_j}\int \alpha_i s_{ir} s_{ij} dP_v(v) & otherwise. \end{cases} \quad (11)$$

Although an estimation, the key point is to exploit a population moment condition that is a product of instrumental variables and an error term, to form a GMM estimator. Formally, let $Z = [z_1, \dots, z_m]$ be a set of instruments (as mentioned above) such that $E[Z', \theta]$, where $\theta = (\alpha, \sigma)$ denotes the true value of the parameters to be estimated. The GMM estimate is

$$\left(\hat{\theta}, \hat{\beta}\right) = \arg\min_{\theta,\beta} \omega(\theta, \beta)' ZWZ' \omega(\theta, \beta), \quad (12)$$

where $W(L \times L)$ is a weight matrix. Solving Eq. (12), we can derive the following equation:

[7] In this specification I draw a sample of 500 individuals.

$$\hat{\beta}(\hat{\theta}) = (X'ZWZ'X)^{-1}X'ZWZ'\delta(\hat{\theta}). \quad (13)$$

Here, $\delta(*)$ is the mean utility function that has the same definition as with the logit model. Berry *et al.* (1995) calculated this mean utility, which is consistent with the share, by using the following contraction mapping method:

$$\delta^{h+1} = \delta^h + \ln s - \ln s(\delta^h, \theta). \quad (14)$$

In Eq. (14), an initial value δ^0 is given and δ^1 is calculated. $\delta(\hat{\theta})$ is determined when the value of $\epsilon = \delta^{h+1} - \delta^h$ is acceptably small[8]. Given $\delta(\hat{\theta})$, the term $\hat{\beta}(\hat{\theta})$ can be calculated and then the BLP estimator can be derived by solving the optimization problem of Eq. (13).

3.2 The Supply

The supply model is derived from the profit maximization behavior of the firms, assuming Bertrand-Nash competition in prices between manufacturers. Suppose there are *F* firms, each of which produces some subset, $\mathcal{J}$, of the $j = 1, \ldots, J$ different kinds of poultry product. The profits of firm *f* at time *t* are

$$\Pi_{ft} = \sum_{j \in \mathcal{J}} (p_{jt} - mc_{jt}) M s_{jt}(p) - C_f, \quad (15)$$

where $s_{jt}(p)$ is the market share of product *j* at time *t*, which is a function of the product prices, *M* is the size of the market, and C_f is the fixed cost of production. Assuming the existence of a pure-strategy Bertrand–Nash equilibrium in prices, and that the prices that support it are strictly positive, the price p_{jt} of any product *j* produced by firm *f* must satisfy the following first-order condition:

$$s_{jt}(p) + \sum_{l \in \mathcal{L}} (p_{lt} - mc_{jt}) \frac{\partial s_{lt}(p)}{\partial p_{lt}} = 0. \quad (16)$$

Eq. (16) can be written into vector notation as:

[8] ϵ is defined as 10e-6.

$$s(p) - \Omega(p - mc) = 0, \quad (17)$$

where $s(*), p,$ and mc are $J \times 1$ vectors of market shares, prices, and marginal cost, respectively. $\Omega(*)$ denotes a $J \times J$ matrix whose factor (j, r) is defined as $\Omega_{jrt} = H_{jrt} \times (-\frac{\partial s_{rt}}{\partial p_{jt}})$. H_{jrt} is a $J \times J$ matrix whose factor (j, r) equals one if product *j* and product *r* are produced by the same firm, and zero otherwise. This implies the following markup equation:

$$p - mc = \Omega^{-1} s(p). \quad (18)$$

3.3 Data

The monthly data on poultry meat imports are collected from the Trade Statistics of the Ministry of Finance from January 2001 to December 2013. Exporting countries are selected based on the import share during the sample period. China and Thailand are chosen among Asian countries, and the U.S. and Brazil among countries outside Asia. The other countries are aggregated into a single category "the rest of the world (ROW)" for completeness with reference to Honda and Otsuki (2016). For the nested logit model estimation, poultry products are categorized into three groups based on their origins: domestic poultry; poultry imported from Asian countries; and poultry imported from outside of Asia. The data on domestic sales of poultry meat are available from Japan's Agricultural and Livestock Industries Corporation[9], and the data on import bans due to the avian influenza outbreak are from MAFF's Animal Quarantine Services[10].

The MRL regulation for product *j* is measured by the index MRL_j defined as in Eq. (19) with reference to Xiong and Beghin (2014), and is included as a product characteristic into x_{jt} of each model:

$$MRL_j = \frac{1}{N_{(j)}} \sum_{n(j)=1}^{N(j)} \exp\left(\frac{\overline{MRL}_{jn(j)} - MRL_{jn(j)}}{\overline{MRL}_{jn(j)}}\right), \quad (19)$$

[9] http://www.alic.go.jp/english/

[10] http://www.maff.go.jp/aqs/english/

where $\overline{MRL}_{jn(j)}$ means the average level of product j with regard to n kinds of targeting pesticide. While Xiong and Beghin (2014) used the Codex Alimentarius MRL standards as the nonprotectionist, science-based reference level, instead I use the average level of the Japanese market because of the limited MRL data available for one specific kind of product in Codex (i.e. the poultry in this study). MRLs that exceed the average level are defined as protectionist or "excessively stringent" beyond the average level, and this is thus a simple criterion. According to Eq. (19), if we assume the average value to be exogenous, the tougher a country's MRL regulation toward a product is, the larger is the index for that combination of country and product. In addition, the stringency index reduces to one if a country never changes its MRLs. The data on MRLs are collected from the Japan Food Chemical Research Foundation[11]. Monthly data are available only from January 2001 or if the limit changes later, assuming that there was no regulation beforehand. This database contains 389 limits of materials for the muscular portions of poultry, consisting of pesticide residues, veterinary drugs, and others based on EU classifications. I aggregate all of these after standardization of each material and construct the MRL index of all the residue limits as mentioned above.

Tables 1 and 2 show descriptive statistics of variables and instruments used in the analysis. From the perspective of mean share, Brazil is the largest exporter followed by China for the Japanese market. According to Figure 3, imported poultry products have similar shares before 2004, after which they continued to decrease except for Brazil, which significantly increased its share after 2004, coinciding with the avian influenza outbreak in the other exporter countries[12]. On the other hand, Brazil does not provide the cheapest import price, the U.S. does, while the share of the U.S. is only about one-fourth that of Brazil. The preference of Japanese consumers for domestic poultry can be observed from the high price (higher than any imported prices) and the large share of domestic poultry.

<Table 1 inserted here>

<Table 2 inserted here>

For the other explanatory variables, the maximum and minimum values of the MRLs are

[11] http://www.ffcr.or.jp/zaidan/ffcrhome.nsf/TrueMainE?OpenFrameSet

[12] Due to the outbreak of avian influenza, poultry import from the U.S was banned in March 2003, followed by those from China and Thailand in January 2004. Typically, poultry meat with heat treatment can be imported, it was not a complete import ban.

respectively 1.2 and 0.9, as shown in Table 2. *MRL* has fewer observations (from January 2002 to December 2013) due to limited data availability. Figure 4 illustrates the time trend of the MRL index from 2001 to 2013. The instrumental variables are the yen-converted domestic poultry prices of the exporting countries and indicate a cheaper price compared with Japan. These instruments are selected with reference to Nevo (2001). The last instrument *feed_jpn* shows Japan's poultry feed price (Yen/t)[13], and is the instrument that is considered to affect the cost function.

<Figure 3 inserted here>

<Figure 4 inserted here>

4 Empirical Results

4.1 The Demand

4.1.1 The Logit and Nested Logit Models

Table 3 shows the results of the logit model estimation based on Eq. (3). Columns 1 and 2 correspond to the results of ordinary least squares. Although the negative coefficient of ln*GDPp* in Column 1 contradicts the expectation, it becomes positively significant when the interaction terms with country dummy are added in Column 2. The result is almost the same when the panel fixed effect model is employed in Column 3. Column 4 lists the result of panel two-stage least squares (2SLS) regressions using instrumental variables along with the interaction terms of demographic variable and the country dummy. The price coefficient remains significant but the magnitude is slightly smaller in Column 4, indicating that the instrumental variables have controlled the unobservable characteristics that are positively related to the prices so that the endogeneity of ln*Price* has been alleviated. Most notably, *MRL*, the variable of interest, has a significant and positive coefficient, and the values are high (1.1–2.1) in all models, indicating that Japanese consumers are robustly sensitive to food safety. As a proxy of the product quality, ln*GDPp* is positively related to the share, and the magnitudes are identical, regardless whether the interaction terms are included. As poultry meat is not processed food, it is difficult to estimate the quality variable. Instead, I choose the per capita GDP of each country as the explanatory variable. According to Xiong and Beghin (2014), MRLs can hinder foreign exporters' supply and

[13] Data on the feed prices are obtained from MAFF. Monthly price of compound feed is used as instrument.

exporters from the less and least developed countries are more constrained than their competitors from the developed world. Thus, from the supply side, one can assume that imported poultry from developed countries may have higher quality and safety compared with that imported from less developed countries. From the demand side, consumers from developed countries are usually more sensitive to food safety. Based on these assumptions, I use the value of GDP per capita as the proxy variable of the characteristic of poultry product.

＜Table 3 inserted here＞

The own- and cross-price elasticities are reported in Table 4. Each entry *i*, *j*, where *i* indexes column and *j* row, gives the elasticity of product *i* with respect to a change in the price of *j*. As noted Section 3, the logit model yields restrictive and unrealistic substitution patterns, and therefore suffers from the IIA problem. The mean of the own-price elasticities is –3.33 with a standard deviation of 0.33. As the domestic product accounts for the largest ratio of poultry consumption, only the cross-elasticities of the imported product to the domestic one are found to be elastic.

＜Table 4 inserted here＞

The estimates of the nested logit model are based on Eq. (5). Columns 1 and 2 of Table 5 provide the results of the nested logit model using ordinary least squares, and Column 3 gives the results of the panel fixed effect model. Columns 4 and 5 use the panel 2SLS models. In Column 4, only the prices are treated as endogenous and Column 5 uses instruments for both prices and within-group shares. In the nested models, *MRL* remains positively significant, and the magnitudes are not significantly different between the logit models. Again, the price coefficients are negatively related to the shares and the coefficients of ln*GDPp* are positive and significant. The within-group share, *Share_group*, takes a value between 0 and 1 in all models as required for the consistency of the nested model and the values are significant except in the case that the within-group share is treated as endogenous in Column 6. The magnitudes are around 0.5, which means that poultry products within the same group are substitutable as well as those from different groups. This reflects the statement in Section 2.2 that imported and domestic poultry products are close substitutes.

For the price elasticities, the nested models provide more realistic values than the logit models, but still suffer from the IIN problem. The layouts of the table are the same with the logit model. The mean of the own-price elasticities (–3.55) does not significantly differ from those of the logit models with a slightly smaller standard deviation of 0.26. Unlike the logit model, imported poultry is found to be inelastic to the price of the domestic product.

＜Table 5 inserted here＞

4.1.2 The BLP Model

The estimates of the random coefficient model based on the BLP model are based on Eq. (9) and are computed using the procedure described in Section 3.1. The predicted market shares are computed using Eq. (10), and are based on the empirical distribution of independent normal distributions (for $\boldsymbol{\upsilon}$), and Type I extreme value (for $\boldsymbol{\varepsilon}$). The same instruments with the logit models for prices are used. Table 6 shows the results. In Columns 1 and 2, ln*GDPp* is treated as the variable with random coefficient. Column 3 additionally adds a random coefficient on ln*Price* and the same is done for *MRL* in Column 4. Most notably, the key variable, *MRL*, remains significant and its coefficients are mostly unchanged in all models while the standard error is not significant. In line with the first two models, this result indicates that Japanese consumers have a robust and homogeneous preference for food safety. The price coefficients are negatively significant and take similar magnitudes of around –2.5, which is slightly smaller than the previous models. In terms of ln*GDPp*, the sign and magnitudes are robust from the previous analysis and the standard error is also significant in Column 2. This significant standard error can be explained as consumers' heterogeneous preference. As the sign of the standard error is also positive, this result still contributes to the robust preference for food safety.

The random coefficient models have the advantage of providing more flexible and realistic price elasticities compared with the discrete-choice models. The mean of the own-price elasticities (–1.431) and the standard deviation (0.61) have slightly decreased. The changes in the domestic poultry price have the largest effect on the imported product with elasticities around 2%, while the imported product is inelastic to any change of other imported poultry meat.

＜Table 6 inserted here＞

4.2 The Supply

We now focus on the supply. The marginal costs and markups are listed in Table 7. The first column is for the real price of each product, which is the same with the summary statistics. The second column lists the marginal costs and the third column is for the markups. The markup of product *j* is defined as $\boldsymbol{Markup_j = 1 - \frac{mc_j}{Price_j}}$. Of note is that poultry meat imported from less developed countries has higher marginal cost than that imported from developed countries. This result corresponds to Xiong and Beghin (2014), who argue that less developed countries need to bear the higher compliance cost of MRLs, which also reflects the appropriateness of using per capita GDP as the proxy of product quality and safety. Not surprisingly, the markups are proportional to the marginal costs. Less developed countries have lower markups than developed countries, when the export destinations are developed countries. According to 2011 data of the USDA's *World Markets and Trade*, the U.S. and Brazil are the world's largest poultry exporters (37% for Brazil and 33% for the U.S. of total exports). Although both China and Brazil are developing countries (because the two countries have similar per capita GDP), their poultry exports can explain the difference in their marginal costs.

＜Table 7 inserted here＞

4.3 Robustness Checks

Table 8 presents a number of robustness checks. The first column shows the base specification. In Column 2, I theoretically justify a model with linear price from the perspective of consumers with heterogeneous incomes, with reference to Gowrisankaran and Rysman (2012). The qualitative results look similar to the base model. Typically, the coefficient of linear price becomes much smaller as expected, and ln*GDPp* along with its random coefficient, and the key variable MRL remain unchanged. Column 3 estimates a model with family income, ln*y*, to capture the income effect on poultry demand. The result shows that while family income has no effect on poultry demand, coefficients of other variables remain unchanged. This is possibly because of the highly substitutable relationship between poultry and the other meat products, as described in Section 3.4.

Columns 4–6 provide tests on the robustness of the random effects of the BLP model.

In Columns 4 and 5, I reexamine the logit model by adding the interaction term between ln*Price* and country dummy, and the interaction between *MRL* and country dummy, respectively. These interaction terms are treated as the quasi-random effect of the prices and MRLs on poultry demand. The results show no significant difference from the base specification. In Column 6, two extra random coefficients on ln*Price* and *MRL* are included in the BLP model, and still result in parameter estimates for mean coefficients that are very similar to those in the base specification. In particular, the signs of the mean coefficients on price and characteristics are all the same as in the base specification and statistical significance is similar across specifications, while the random coefficients on ln*Price*, ln*GDPp*, and *MRL* are insignificant, indicating the homogeneous preference of Japanese consumers for poultry price, quality, and safety.

<Table 8 inserted here>

4.4 Counterfactual Experiments

Using the estimates from the logit model, I present three cases for the different MRLs. These simulations are designed to demonstrate the impact of varying standards on pesticide and veterinary drug residues in poultry meat products consumed in Japan. The alternative MRLs are demonstrated in Figure 4, along with the real MRL index. The results are shown in Table 9. For each simulation, the predicted shares and the differences between the real shares of all products are listed in separate columns. The total share of imported products and the total share of poultry products, along with their simulated shares, are listed in the last two rows.

The first simulation is conducted under the scenario that the MRL did not change during the sample period. Under this condition, the value of MRL consistently equals the one based on Eq. (19). According to Columns 2 and 3 of Table 9, the consistent MRLs have a trivial effect on poultry meat except on that imported from Thailand, resulting in a slight increase in the share of imported products and the total share.

The second simulation is conducted under the scenario of stricter MRLs. The MRL value in each period is 50% the original one; in other words, the MRL index has a larger value than the real one. The result is shown in Columns 4 and 5 of Table 9. In this case, domestic meat greatly increases its share, as does imported poultry meat except that from China, whose GDP per capita is the lowest among the exporting countries. In addition, the total import share increases by 44% with stricter MRLs, indicating the trade-enhancing effect of MRL.

In contrast, in the third simulation, we see what would happen if the MRL index is smaller than the real level; in this scenario, the MRL value in each period is twice the original one. The result is shown in Columns 6 and 7 of Table 9. In contrast to the second simulation, most products lose their market shares, but to different extents. Total poultry import decreases by 13%, which also reflects the trade-enhancing effect of MRL.

These results of the demand enhancement associated with MRLs are consistent with those in Xiong and Beghin (2014), and support the hypothesis that pesticide control measures alleviate information asymmetry by assuring food safety of the products under regulation. Therefore, MRL regulation in poultry products seems to achieve legitimate public objectives and does not necessarily reflect protectionism.

＜Table 9 inserted here＞

5. Conclusion

This study estimates the effect of Japanese pesticide and veterinary drug residue standards on poultry imports using monthly data for major exporter countries from 2001 to 2013 with a particular focus on the maximum limits on pesticide and veterinary drug residues. A method of moments estimator with reference to Berry (1994), Berry *et al.* (1995), and Nevo (2001) was employed to complement the gravity model and the AIDS model—the most commonly used approaches in the literature—by allowing for asymmetric and heterogeneous consumers' response to regulations across goods from different origins and controlling for the potential endogeneity of the poultry price.

The results confirm that more stringent MRLs on pesticide and veterinary drugs enhance the demand for poultry imports by ensuring higher food safety. The results elucidate Japanese consumers' robust preference for food safety. Further counterfactual experiments of alternative MRLs show that the demand-enhancing effect may vary among exporting countries, and appears to be more prominent for imported poultry from developed countries. Furthermore, the own- and cross-price elasticities show that the changes in the domestic poultry price have the largest effect on the imported product with elasticities of around 2%, while the imported product is inelastic to any change of other imported poultry meat, indicating the sensitivity of imported poultry meat to the change in domestic poultry price.

Future research could employ more direct explicit measures of the characteristics of nonprocessed meat products to reflect consumers' preferences more precisely. Furthermore, it would also be valuable to investigate the welfare implications of food safety regulation instead of the external or social benefits, such as improved human health in the long run.

References

Berry, S. (1994), 'Estimating Discrete Choice Models of Product Differentiation', *RAND Journal of Economics* **25**: 242-262.

Berry, S., J. Levinsohn, and A. Pakes (1995), 'Automobile Prices in Market Equilibrium', *Econometrica* **60**(4): 889-917.

Berry, S., J. Levinsohn, and A. Pakes (2004), 'Differentiated Products Demand Systems from a Combination of Micro and Macro Data: The New Car market', *Journal of Political Economy* **112**: 68-105.

Carranza, J. E. (2010), 'Product innovation and adoption in market equilibrium: The case of digital cameras', *International Journal of Industrial Organization* **28**: 604-618.

Fan, Y., and C. Y. Yang (2016), 'Competition, Product Proliferation and Welfare: A Study of the U.S. Smartphone Market', *CEPR Discussion Papers* 11423.

Disdier, A. C., and S. Marette (2010), 'The Combination of Gravity and Welfare Approaches for Evaluating Nontariff Measures', *American Journal of Agricultural Economics* **92**: 713-726.

Gowrisankaran, G., and M. Rysman (2012), 'Dynamics of consumer demand for new durable goods', *Journal of Political Economy* **120**(6): 1173-1219.

Honda, K., F. Kimura, and T. Otsuki (2011), 'Demand Response for Imported and Domestic Poultry Meat Products to Food Safety Regulations in Japan: An Application of the Almost Ideal Demand System Model', *OSIPP Discussion Paper*, DP-2011-E-007.

Josling, T., D. Roberts, and D. Orden (2004), '*Food Regulation and Trade. Toward a Safe and Open Global System*,' Washington, DC: Institute for International Economics.

Kiesel, K., and V. B. Sofia (2007), 'Got Organic Milk? Consumer Valuations of Milk Labels after the Implementation of the USDA Organic Seal', *Journal of Agricultural & Food Industrial Organization* **5**(1): 1-40.

Liu, Y. Z., A. L. Rigoberto, and C. Zhu (2014), 'The Impact of Four Alternative Policies to Decrease Soda Consumption', *Agricultural and Resource Economics Review* **43**(1): 53-68.

McFadden, D. (1978), 'Modelling the choice of residential location', In *Spatial Interaction Theory and Planning Models,* edited by Anders Karlqvist, Lars Lundqvist, Folke Snickars, and Jorgen W. Weibull. Amsterdam: North-Holland, 75-96.

McFadden, D. (1984), 'Econometric analysis of qualitative response models', *Handbook of Econometrics*, **2**: 1395-1457, Elsevier.

Nevo, A. (2000), 'A Practitioner's Guide to Estimation of Random Coefficients Logit Models of Demand', *Journal of Economics and Management Strategy* **9**(4): 513-548.

Nevo, A. (2001), 'Measuring Market Power in the Ready-to-Eat Cereal Industry', *Econometrica* **69**(2): 513-548.

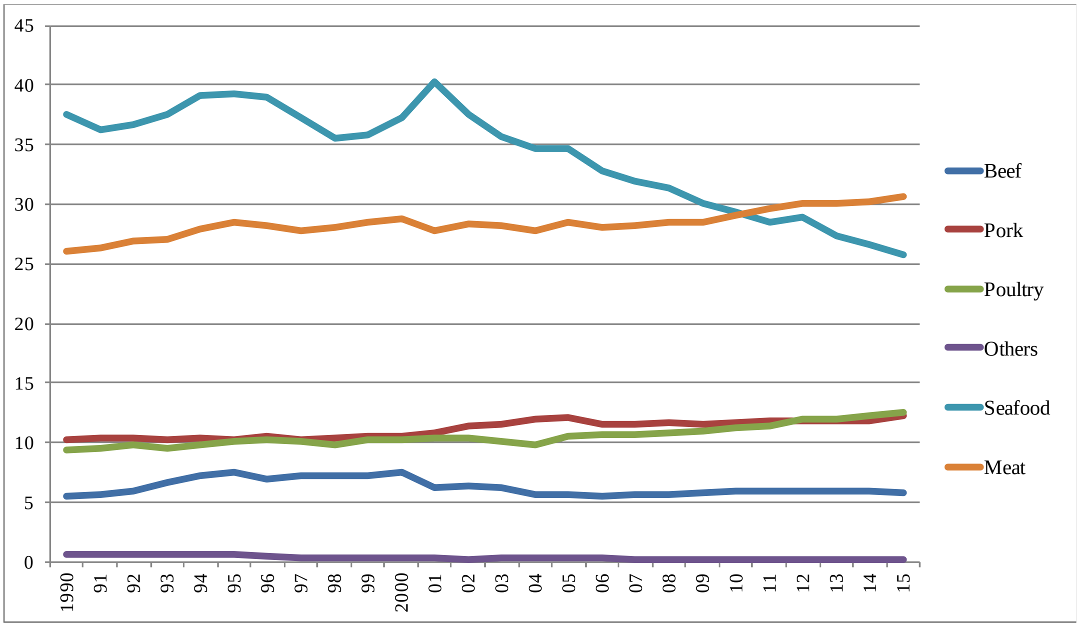
Nevo, A. (2003), 'New Products, Quality Changes and Welfare Measures Computed from Estimated Demand Systems', *Review of Economics and Statistics* **85**: 266-275.

Thilmany, D., and C. Barrett (1997), 'Regulatory Barriers in an Integrating World Food Market', *Review of Agricultural Economics* **19**: 91-107.

Xiong, B. and J. Beghin (2014), 'Disentangling Demand-enhancing and Trade-cost Effects of Maximum Residue Regulations', *Economic Inquiry* **52**: 1190-1203.

Yang, S. and W. W. Koo (1994), 'Japanese Meat Import Demand Estimation with the Source Differentiated AIDS Model', *Journal of Agricultural and Resource Economics* **19**: 396-408.

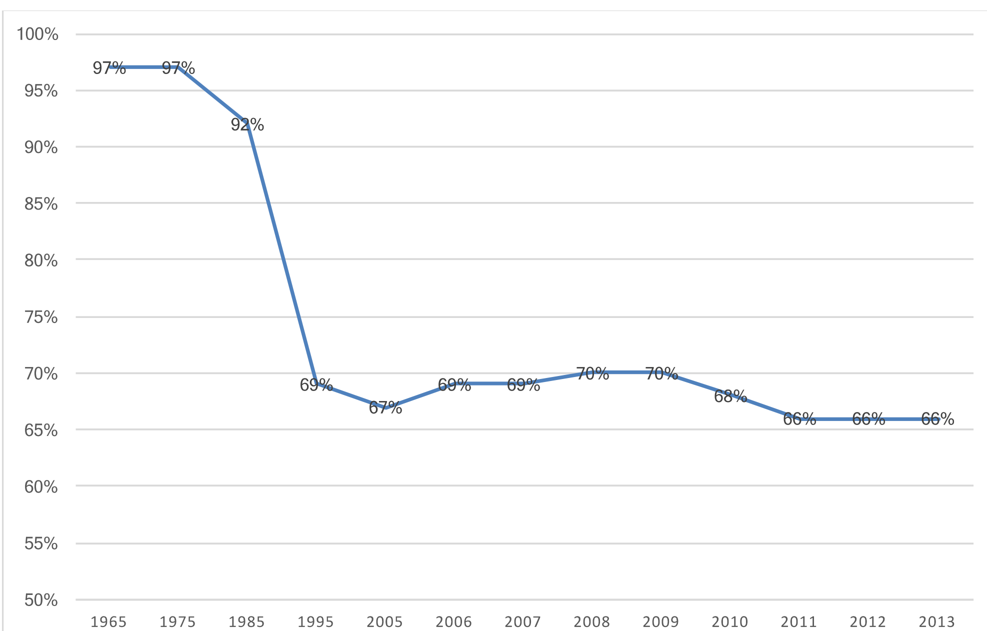
Figure 1. Japanese Consumers' Supply of Net Food per Year per Capita (kg)



Source: Ministry of Agriculture, Forestry and Fisheries.

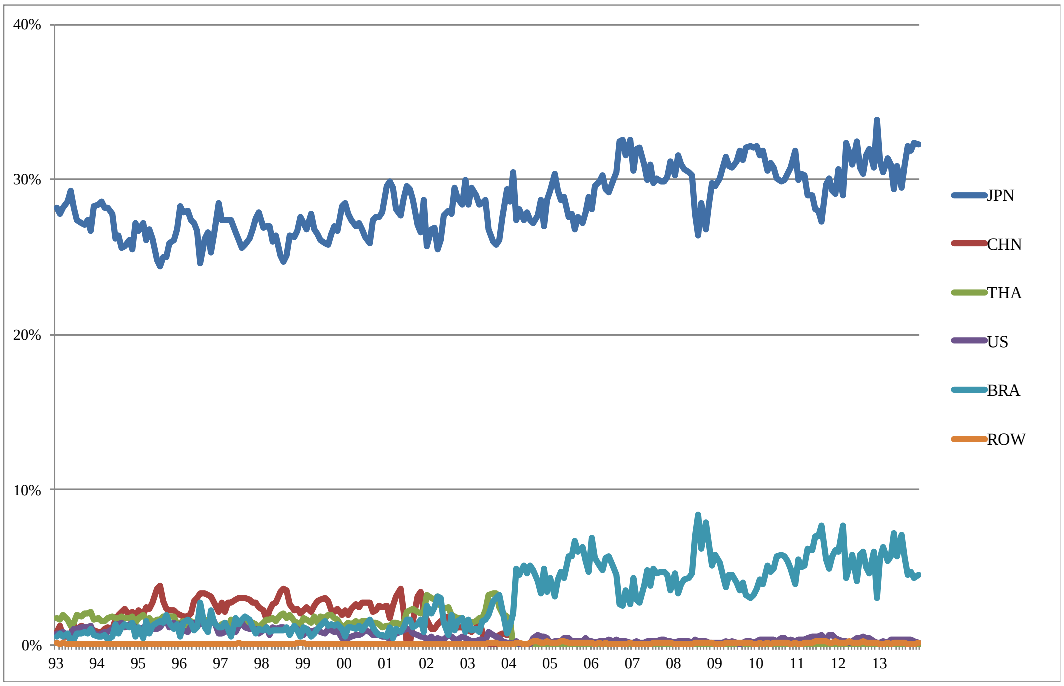
Note: The share of "meat" equals to the sum of "beef", "pork", "chicken", and "others".

Figure 2. Japan's Poultry Self-sufficiency Rate (based on weight)



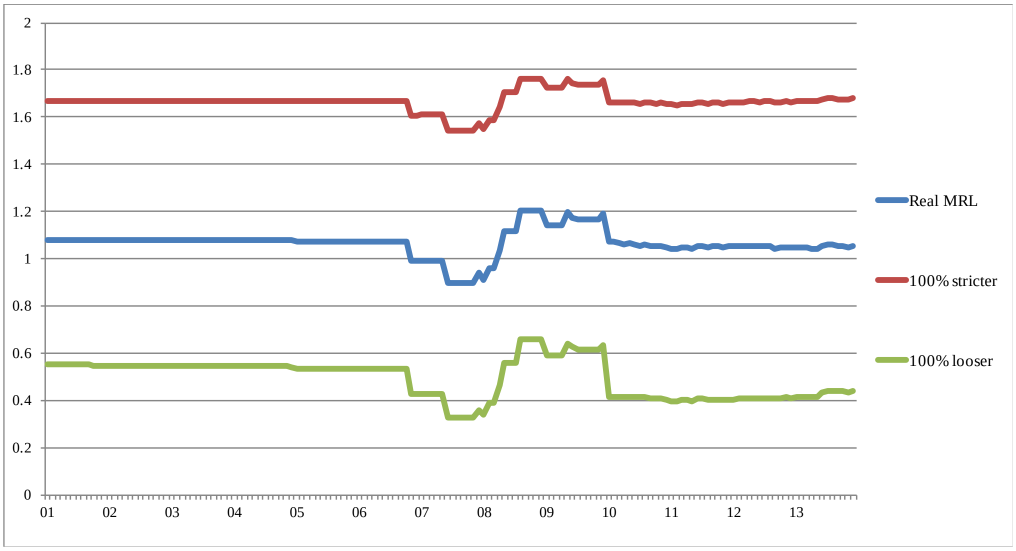
Source: Ministry of Agriculture, Forestry and Fisheries.

Figure 3. Market Shares of Domestic and Imported Poultry



Source: Author's calculation based on Japan's Agricultural and Livestock Industries Corporation and the Animal Quarantine Services of the MAFF.

Figure 4. Calculated MRL Indices



Source: Author's calculation based on the Japan Food Chemical Research Foundation.

Table 1. Summary Statistics of Prices and Shares by Origins

	Country	Obs	Mean	Std. Dev.	Min	Max
	Japan	252	427.589	43.523	338	553.5
	China	233	322.044	121.826	166.086	697.703
Price	Thailand	154	287.92	73.290	169.589	517.259
	U.S.	252	187.518	34.849	118.825	278.561
	Brazil	252	243.112	49.947	138.206	404.383
	ROW	252	342.759	94.315	185.905	773.806
	Japan	252	0.285	0.020	0.244	0.338
	China	252	0.011	0.012	0	0.039
Share	Thailand	241	0.010	0.009	0	0.033
	U.S.	252	0.006	0.004	0	0.016
	Brazil	252	0.030	0.021	0.002	0.084
	ROW	252	0.001	0.001	0	0.003

Source: Author's calculation.

Table 2. Summary Statistics of Explanatory Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
GDPp	1,512	16239.63	16930.39	377.390	52787.03
familynum	1,512	2.817	0.152	2.58	3.12
familyincome	1,512	594.567	47.581	528.9	664.2
MRL	936	1.066	0.058	0.898	1.202
Instrument Variables					
th_chicken	864	166.401	25.724	103.967	233.971
us_chicken	1,008	268.831	26.472	219.081	346.697
bra_chicken	804	167.032	47.529	86.998	274.156
feed_jpn	1,512	58315.32	8308.447	47115	79180

Source: Author's calculation.

Table 3. Results of Logit Models

	(1) OLS	(2) OLS	(3) Panel FE	(4) Panel 2SLS
ln*Price*	-3.232***	-1.144***	-1.144***	-1.528***
	(0.304)	(0.263)	(0.200)	(0.548)
ln*GDPp*	-0.767***	2.582***	2.582***	2.239***
	(0.213)	(0.408)	(0.594)	(0.833)
dban_US	0.298	0.0634	0.0634	0.155
	(0.467)	(0.322)	(0.289)	(0.187)
dban_CT				-0.758***
				(0.141)
MRL	2.164**	1.974***	1.974**	1.107**
	(1.016)	(0.756)	(0.972)	(0.503)
Year FE	Y	Y	Y	Y
Month FE	Y	Y	Y	Y
Demographic var	N	N	N	Y
ln*GDPp*country*	N	Y	Y	Y
Constant	24.24***	-10.43	-3.835	-2.141
	(2.571)	(6.553)	(5.783)	(5.045)
Observations	819	819	819	687
R-squared	0.833	0.916	0.674	0.599

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Own- and Cross-price Elasticities (%)

Logit	JPN	CHN	THA	US	BRA	ROW
JPN	-2.821	0.037	0.029	0.020	0.106	0.004
CHN	1.126	-3.406	0.029	0.020	0.106	0.004
THA	1.126	0.037	-3.114	0.020	0.106	0.004
US	1.126	0.037	0.029	-3.382	0.106	0.004
BRA	1.126	0.037	0.029	0.020	-3.462	0.004
ROW	1.126	0.037	0.029	0.020	0.106	-3.780
Nested	**JPN**	**CHN**	**THA**	**US**	**BRA**	**ROW**
JPN	-3.352	0.019	0.015	0.011	0.057	0.002
CHN	0.600	-3.503	1.719	0.011	0.057	0.002
THA	0.600	0.165	-3.272	0.011	0.057	0.002
US	0.600	0.019	0.015	-3.560	0.223	0.009
BRA	0.600	0.019	0.015	0.065	-3.579	0.009
ROW	0.600	0.019	0.015	0.065	0.223	-4.023
BLP	**JPN**	**CHN**	**THA**	**US**	**BRA**	**ROW**
JPN	-0.575	0.003	0.008	0.011	0.199	0.008
CHN	1.864	-1.304	0.067	0.007	0.065	0.005
THA	1.757	0.024	-1.418	0.010	0.076	0.006
US	2.255	0.003	0.012	-1.307	0.198	0.008
BRA	2.075	0.001	0.005	0.010	-1.520	0.010
ROW	2.046	0.002	0.009	0.011	0.252	-2.464

Note: Cell entries *i*, *j*, where *i* indexed column and *j* row, give the percentage change in market share of product *i* with a one percent change in price of *j*. Each entry represents the mean of the elasticisties from the sample period. “JPN”, “CHN”, “THA”, “US”, “BRA”, “ROW” represents Japan, China, Thailand, the U.S., rest of world, respectively.

Table 5. Results of Nested Logit Models

	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	Panel FE	Panel 2SLS	Panel 2SLS
Endogenous var				ln*ap*	ln*ap*
					lnShare_group
ln*Price*	-3.025***	-1.095***	-1.095***	-0.805**	-0.959**
	(0.280)	(0.232)	(0.182)	(0.319)	(0.391)
ln*GDPp*	-1.354***	3.570***	3.570***	2.284***	1.856***
	(0.213)	(0.393)	(0.545)	(0.414)	(0.711)
dban_US	0.437	0.243	0.243	0.219	0.170
	(0.494)	(0.300)	(0.263)	(0.281)	(0.186)
dban_CT				-0.847***	-0.804***
				(0.190)	(0.139)
MRL	2.215**	2.015***	2.015**	1.300**	1.146**
	(0.989)	(0.709)	(0.883)	(0.529)	(0.507)
ln*Share_group*	0.583***	0.664***	0.664***	0.501***	0.200
	(0.0901)	(0.0619)	(0.0516)	(0.0857)	(0.289)
Year FE	Y	Y	Y	Y	Y
Month FE	Y	Y	Y	Y	Y
ln*GDPp*country*	N	Y	Y	Y	Y
Constant	28.87***	-23.35***	-18.08***	-9.969	-30.38
	(2.630)	(6.876)	(5.370)	(46.65)	(51.35)
Observations	819	819	819	687	687
R-squared	0.848	0.931	0.731	0.639	0.624

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Random Coefficient Models

Random Coefficient var	(1) ln*gdpp*	(2) ln*gdpp*	(3) ln*gdpp* ln*ap*	(4) ln*gdpp* *MRL*	(5) ln*gdpp* ln*ap* *MRL*
ln*Price*	-1.625	-2.455**	-2.492**	-2.602**	-2.602**
	(1.168)	(1.205)	(1.213)	(1.217)	(1.219)
sd(ln*Price*)			0.216		0.000982
			(0.737)		(475.7)
ln*GDPp*	1.183***	2.794**	2.757**	2.705**	2.705**
	(0.169)	(1.306)	(1.309)	(1.315)	(1.329)
sd(ln*GDPp*)	0.181	0.889***	1.093	1.197	1.196
	(2.462)	(0.331)	(1.364)	(0.942)	(4.857)
dban_US	-0.0249	-0.192	-0.247	-0.252	-0.252
	(0.517)	(0.523)	(0.527)	(0.531)	(0.531)
dban_CT	-1.093**	-0.976**	-0.952**	-0.901*	-0.901*
	(0.462)	(0.472)	(0.475)	(0.477)	(0.477)
MRL	1.496***	1.262**	1.178**	2.222**	2.222**
	(0.562)	(0.520)	(0.503)	(1.050)	(1.051)
sd(*MRL*)				1.560	1.560
				(2.515)	(6.010)
Year FE	Y	Y	Y	Y	Y
Month FE	Y	Y	Y	Y	Y
Demographic var	N	Y	Y	Y	Y
Constant	-34.36	7.932	-37.99	-75.63	-75.59
	(107.5)	(235.0)	(235.5)	(236.1)	(238.9)
Observations	687	687	687	687	687

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. Marginal Costs and Markups

	Price(Yen)	Marginal Cost(Yen)	Markup (%)
JPN	427.589	52.259	87.778
CHN	322.044	255.777	20.577
THA	287.920	209.123	27.368
US	187.518	127.041	32.251
BRA	243.112	155.025	36.233
ROW	342.759	248.053	27.630

Note: The price is the same with the summary statistics of Table 2.

"JPN", "CHN", "THA", "US", "BRA", "ROW" represents Japan, China, Thailand, the U.S., rest of world, respectively.

Table 8. Robustness Checks

	(1) Base Specification	(2) Linear Price	(3) Income Included	(4) Extra Interaction Terms	(5)	(6) Extra Random Coeff
ln*Price*	-2.455**		-1.076**	-2.773**	-2.613**	-2.602**
	(1.205)		(0.443)	(1.203)	(1.128)	(1.219)
sd(ln*Price*)						0.000982
						(475.7)
Price		-0.00615*				
		(0.00324)				
ln*y*			0.265			
			(3.897)			
ln*GDPp*	2.794**	2.863**	1.577***	2.252**	1.980**	2.705**
	(1.306)	(1.258)	(0.596)	(0.958)	(0.926)	(1.329)
sd(ln*GDPp*)	0.889***	0.836**				1.196
	(0.331)	(0.354)				(4.857)
dban_US	-0.192	-0.314	0.139	0.215	0.249	-0.252
	(0.523)	(0.490)	(0.187)	(0.172)	(0.162)	(0.531)
dban_CT	-0.976**	-1.120***	-0.772***	-0.545***	-0.497***	-0.901*
	(0.472)	(0.419)	(0.141)	(0.121)	(0.114)	(0.477)
MRL	1.262**	1.489***	1.048**	1.242***	2.006**	2.222**
	(0.520)	(0.627)	(0.502)	(0.447)	(0.996)	(1.051)
sd(*MRL*)						1.560
						(6.010)
Year FE	Y	Y	Y	Y	Y	Y
Month FE	Y	Y	Y	Y	Y	Y
Demographic var	Y	Y	N	Y	Y	Y
ln*GDPp**country*	N	N	Y	Y	Y	Y
ln*Price**country*	N	N	N	Y	Y	N
*MRL**country*	N	N	N	N	Y	N
Constant	7.932	60.22		-2.091	-18.45	-75.59
	(235.0)	(228.5)		(81.86)	(78.27)	(238.9)
Observations	687	687	687	687	687	687
R-squared		0.124	0.597	0.692	0.727	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Share of Each Product with Alternative MRL levels (%)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Real	*MRL* =1		100% Stricter MRL		100% Looser MRL	
	share	share	Δshare	share	Δshare	share	Δshare
JPN	29.578	29.958	0.380	61.953	32.375	17.399	-12.179
CHN	0.329	0.033	-0.296	0.067	-0.261	0.020	-0.309
THA	0.496	3.820	3.324	7.892	7.396	2.342	1.846
US	0.347	0.245	-0.102	0.506	0.160	0.141	-0.206
BRA	4.151	4.163	0.012	8.598	4.447	2.367	-1.784
ROW	0.117	0.116	-0.002	0.238	0.121	0.066	-0.051
Imported	5.439	8.376	2.937	17.302	11.862	4.936	-0.503
Total	35.017	38.334	3.317	79.255	44.238	22.335	-12.682

Note: "JPN", "CHN", "THA", "US", "BRA", "ROW" represents Japan, China, Thailand, the U.S., rest of world, respectively.