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Investigating the impact of maximum residue limit standards on the vegetable trade in Japan

RESEARCH ARTICLE

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Abstract

Countries have become increasingly concerned about the safety of their food. Many countries have imposed standards on both domestically produced and imported food. In particular, countries have implemented regulations to control the quantity and quality of vegetable imports. Maximum Residue Limit (MRL) standards are one of the main restrictions adopted by numerous countries. Japan has one of the strictest MRL standards in the world. This study builds on previous studies to explore the impact of MRL standards on Japanese vegetable imports. Gravity models are used to analyze how MRL standards influence the Japanese imports of different types of vegetables (fruit vegetables, leafy vegetables, bulb vegetable, and root vegetables). The results reveal that the trade impacts of MRL standards are different for different types of vegetables, with the most significant impact on imports of leafy and fruit vegetables and the least significant impact on imports of bulb vegetables.

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1. Introduction

With outbreaks of a myriad of food-borne diseases, food safety has become a global concern. Consumers are becoming more aware of eating safer and healthier food that is domestically produced and imported from other countries. In an effort to import safe food, governments have sought ways to set up trade restrictions to ensure that imported food is safe. These restrictions include Maximum Residue Limit (MRL) standards. MRL standards set the maximum acceptable level of a specific pesticide residue on agricultural products that may enter the agricultural markets. According to the Food and Agriculture Organization and the World Health Organization (2006), strict MRL standards naturally reflect how serious nations are about their food quality, and they can help improve food safety. However, when the MRL standards are too strict, they may act as technical barriers to trade because governments may use the MRL standards to limit imports and protect the domestic food industry (Martinez and Thornsbury, 2010). These strict restrictions can generate considerable welfare losses for domestic consumers and merchandise losses for food exporters.

Previous research showed that MRL standards affect the trade of agricultural products between countries. Achterbosch *et al.* (2009) analyzed the impact of MRL standards on the trade of fresh fruit between Chile and the European Union and found that more stringent MRL standards negatively affect trade volume. Similar results were also confirmed by Bao and Qiu (2009), who examined China's trade barriers to imported agricultural products and processed food in China. Their papers used the gravity model to compare MRL standards between nations and how these differences affected a country's trade. They argued that the MRL standards' impact on trade is different for developed and developing countries. Wei *et al.* (2012) and Yue *et al.* (2010) analyzed the MRL standards' impact on China's honey exports and tea exports. These studies have confirmed that the trade volume is negatively affected by the stringency of MRL standards.

Wilson and Otsuki (2004) reported how governments' pesticide regulations were influenced by MRL standards. They have also confirmed that stricter MRL standards affect the trade volume negatively. Otsuki, Wilson and Sewadeh (2001a,b) also analyzed the impact of Aflatoxin standards on trade between nations. These studies concluded that Aflatoxin standards negatively affect the trade value of groundnuts. Liu and Yue (2012) extended the previous studies to analyze how the similarity of MRL regulations between nations affected substitution elasticity of domestic and imported goods by using a variable elasticity of substitution model. They found that developing countries could expand their exports to developed countries by setting stricter MRL standards.

Japan is among the top countries that import a large quantity of fruits and vegetables. Japan has also applied the most stringent MRL standards in the world. The MRL standards apply to domestic vegetables as well as imported vegetables. In short, if vegetables do not meet the standards, they are not allowed to enter the market or cannot be imported in the first place. Using similarity indexes, Liu and Yue (2012) and Drogue and DeMaria (2010) compared the MRL standards' stringencies between countries. Their studies confirmed Japan has the strictest MRL standards for each vegetable.

To export vegetables to Japan, exporters must pay close attention to Japan's strict MRL standards even though their own MRL standards are far less strict. For exporters whose own countries' MRL standards are not as strict as Japan's, meeting those standards means adding relatively high costs to their products. However, when the costs are too high, some exporters cannot afford to export their products to Japan because the profit margin is too narrow. In these cases, Japan's strict MRL standards become technical barriers to trade for these exporters. Both foreign and domestic vegetable producers striving to meet Japan's high MRL standards have to bear MRL compliance costs, which lead to higher production costs and thus decrease the profit margins. However, for countries where the input costs are lower than Japan (for example, Vietnam and Philippine have lower labor costs; Australia and Canada have lower land costs), they can comply with the MRL standards with much lower costs. The lower compliance costs can help keep vegetable price lower than the vegetables produced in Japan.

Japan's strict restrictions and regulations on agricultural product imports have led to some trade disputes in the World Trade Organization. For example, in 1997, the United States requested consultations with Japan to discuss Japan's prohibition of imports of certain agricultural products such as apricots, apples, and walnuts. The United States complained that Japan prohibits importing each variety of a product that requires quarantine treatment until the quarantine treatment has been tested for that variety, even if the treatment was proved as effective for other varieties of the same product (WTO, 2013a). In the same year, the European Commission contended that certain measures affecting imports of pork and its processed products imposed by Japan violated Japan's obligations under certain articles(Articles I, X:3 and XIII) of the GATT 1994 and nullified or impaired benefits accruing to the Commission (WTO, 2013b). In 2002, the United States complained to Japan about its measures including prohibition of imported apples from orchards in which any fire blight was detected. Japan required that export orchards be inspected three times annually for the presence of fire blight and other problems. The United States claimed that these measures were inconsistent with Japan's obligations (WTO, 2013c). Despite the fact that countries have complained about Japan's strict restrictions and regulations of agricultural imports, some of which led to trade disputes, Japan has persisted in maintaining the strictest MRL standards.

Although Japan has the largest number of pesticide restrictions, the strictest MRL standards, and restrictions that cover almost all vegetables, no study has investigated how Japan's strict MRL standards could affect vegetable imports to Japan. This research aims to fill this gap in the literature. First, little work has examined how the MRL standards could affect the trade of different types of food. In this study, we investigate how Japan's MRL standards affect vegetable imports. Second, vegetables are categorized into different types and we analyze how the MRL standards might affect the imports of these different types of vegetables (i.e. leafy vegetables, fruit vegetables, bulb vegetables, and root vegetables) in different ways. The study will help determine whether the stringency of MRL standards impedes Japanese vegetable imports, and if so, to what extent the stringency of MRL standards has impeded vegetable imports. Third, we examine whether the degree to which MRL standards impede the different types of vegetables imports differently can be measured. Possible policy implications from this study are whether or not the Japanese government should make their MRL standards less strict. If so, this then demands an answer to the question of whether or not the Japanese government should adjust their MRL standards for different types of vegetables to the same extent.

The rest of this paper is organized as follows: the first section is the materials and methods section that introduces the similarity index, the description of the gravity model we used, and the vegetables chosen for our analysis, a detailed description of the data used. The second section covers the results and discussion. Finally, the last section concludes the paper with a discussion of important policy implications and possible future research topics.

2. Materials and methods

In this section, the similarity index is introduced firstly to better understand differences between countries' MRL standards, and the gravity model is presented. The vegetables used in our analysis, how to categorize the vegetables, and the data description are presented in great detail.

The similarity index

Numerous research studies have attempted to understand the discrepancy of MRL standards among countries. They have created indexes to explain the extent to which the MRL standards are different between nations. Achterbosch *et al.* (2009) used an index of regulatory heterogeneity to analyze the impact of differences in MRL standards on the fresh fruit trade between Chile and the European Union. They studied how the relative differences in MRL regulations affected trade flows between importing and exporting countries. Their results showed that more similar MRL regulations with the European Union standards would increase exports of Chilean fruit. Winchester *et al.* (2012) also used the heterogeneity index of MRL standards for their study of the agricultural food trade between the European Union and nine other countries. They found that imposing stricter MRL standards could reduce the trade volume. However, this index falls short of capturing the MRL standards' differences if the MRL standards' levels are similar but the number of MRL standards is different. In addition, Drogue and DeMaria (2010) used Pearson's coefficient correlation index to capture the difference of MRL standards for apples and the distance between countries.

The most widely used index is Jaffe's (1986) similarity index. The strength of the index is that it can capture the ratio between a country's MRL standard and the highest MRL standards. Some researchers have adopted the similarity index to compare the similarities between certain regulations across nations or regions. For example, Anderson (2009, 2010) used the index to compare the regional regulation similarity between Australia and other countries. By using the similarity index, he analyzed the degree to which the similarity of regulations affected the trade of wine. In the current study, Jaffe's similarity index is adopted to understand the extent to which the MRL standards are different between Japan and other nations. The similarity index is defined as follows:

$$MRL_{ij} = \frac{\sum_{n=1}^{N} r_{in}\, r_{jn}}{(\sum_{n=1}^{N} r_{in}{}^2)^{0.5}\, (\sum_{n=1}^{N} r_{jn}{}^2)^{0.5}} \quad (1)$$

where r_{in} is the ratio of the MRL level in country i to the highest MRL level of pesticide n. N is the total number of pesticides regulated for a product. The index is symmetric and varies from 0 to 1. This index is 1 if the MRL standards are identical between the importing and exporting countries, and is 0 if they are totally different. This study uses the index as a measure of the extent to which exporters' MRL standards are similar to those of Japan.

The gravity model

To estimate the trade impacts of MRL stringency on Japan's vegetable market, this study adopted the most widely used model: the gravity model. The gravity model has been widely used to estimate how MRL standards affect the food trade. Tinbergen (1962) applied the gravity model to understand bilateral trade flows, in general. Since Tinbergen's study, the gravity model has become one of the main methods for analyzing how certain factors affect international trade.

Several papers have investigated the appropriate practical forms for the gravity model. Silva and Tenreyro (2006) took the log of dependent and independent variable in a gravity model to verify unbiased estimator under heteroscedasticity exists. Also, Carrère (2006) used a gravity model to find out the appropriate number of dummy variables to identify trade diversion effects. More studies have studied how to analyze panel data using the gravity models (Egger and Pfaffermayr, 2003; Serlenga and Shin, 2007). In addition, Xiong and Beghin (2012) adopted the gravity model to analyze how the MRL standards affect the bilateral food trade between the U.S. and Canada. They concluded that imports to the U.S. are negatively affected by the stringency of MRL standards. Following Drogue and DeMaria (2012), we specify the gravity model as follows:

$$lnY_{ijt} = \beta_0 + \beta_1 ln(gdp_{jt}) + \beta_2 ln(pop_{jt}) + \beta_3 ln(gdp_t) + \beta_4 ln(jpop_t) + \beta_5 ln(ExchangeRate_{jt}) + \beta_6 index_{ij} + \beta_7 tariff_{it} + \beta_8 ln(dis_j) + \beta_9 Asian_j + \varepsilon_{it} \quad (2)$$

Y_{ijt}: the amount of imported vegetable i from country j at time t;
gdp_{jt}: exporter country j's gross domestic product (GDP) at time t;
pop_{jt}: exporter country j's population at time t;
$jgdp_t$: Japan's GDP at time t;
$jpop_t$: Japan's population at time t;
$ExchangeRate_{jt}$: Exchange rate between exporter j and Japan at time t;
$index_{ij}$: the similarity index for vegetable i and country j;
$tariff_{it}$: Japan's tariffs for vegetable i at time t;
$dist_j$: geographic distance between exporter j and Japan;

$Asian_j$: dummy variable indicating whether exporter j is in Asia;
ε_{it}: an error term for vegetable i at time t, and it is normally distributed.

Some papers also include the common border dummy variable to capture if the exporting and importing countries share common land borders (Drogue and DeMaria, 2010). Because Japan is an island country and does not share common borders with any country, this study includes the dummy variable '$Asian_j$' to capture if the exporter j is from the same continent as Japan.

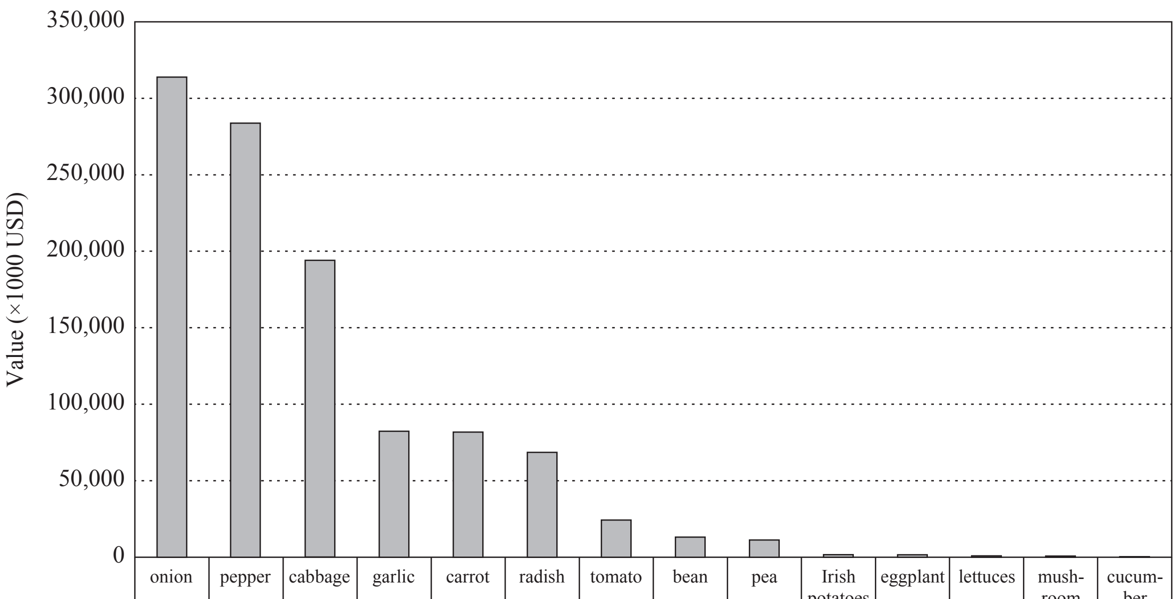
The expected signs of coefficients for the exporter j and Japan's GDP and population are positive. That is, the higher the GDP and population of an exporting country, the more vegetables Japan imports from that country. Negative signs are anticipated for the exchange rate and distance. The signs for tariffs are expected to be negative and the signs for the similarity of MRL standards are expected to be positive.

Vegetables used in the analysis and data description

More than 40% of Japan's imported vegetables are fresh (Dyck and Ito, 2004). Figure 1 shows that from 2008 to 2010, Japan's leading imported vegetables by value were onions, peppers, cabbage, garlic, and carrots. During this three-year period, the value of the three main imported vegetables – onions, peppers, and cabbage – was more than \$700 million in total.

According to the Japanese Ministry of Agriculture, Forestry, and Fisheries (2012), cabbage, onions, radishes, Irish potatoes, and carrots had the highest consumption in the Japanese vegetable market. Figure 2 shows the quantity of Japanese domestic vegetable production and sales, which shows that Irish potatoes, cabbage, and onions were the top three most produced vegetables from 2001 to 2010.

Irish potatoes, cucumbers, and eggplant were imported from only one or two countries, including South Korea and China, so they were excluded from this analysis. In addition, the quantities of imported peas and beans were too small to analyze the effects of MRL stringency on trade so they were also excluded from this analysis.



	onion	pepper	cabbage	garlic	carrot	radish	tomato	bean	pea	Irish potatoes	eggplant	lettuces	mush-room	cucum-ber
Import	313,832	283,742	194,069	82,359	81,812	68,554	24,323	13,168	11,287	1,695	1,620	915	793	380

Figure 1. Japan's total vegetable imports for the each of the top imported vegetables between 2008 and 2010 (adapted from Japanese Ministry of Agriculture, Forestry, and Fisheries (2013)).

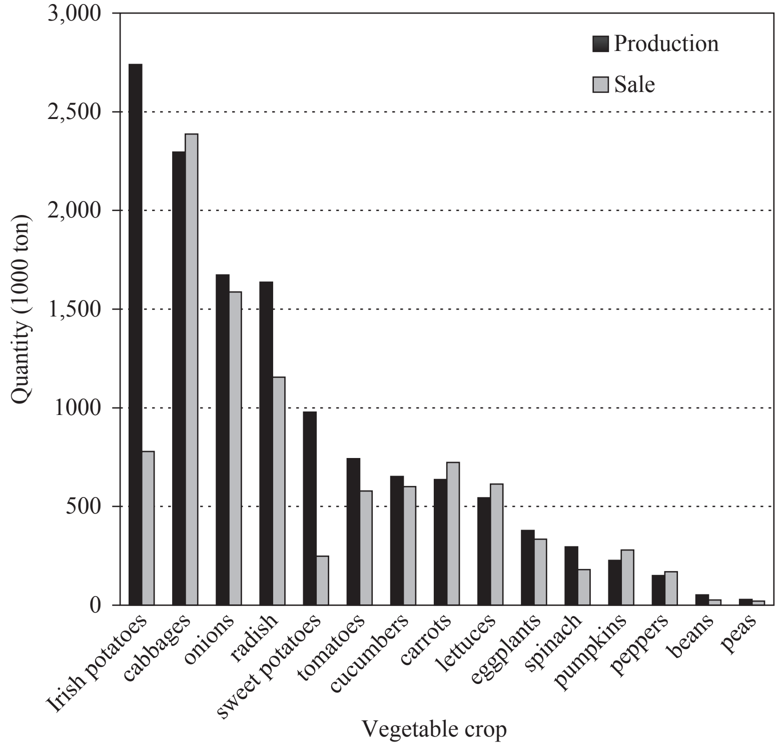


Figure 2. Japan's average quantity of production and sale for the top produced vegetables (2001-2010) (adapted from Japanese Ministry of Agriculture, Forestry, and Fisheries, 2012).

Tomatoes, peppers, lettuce, cabbage, onions, garlic, carrots, and radishes were included in this analysis because they are among the top 15 imported and domestically produced vegetables in Japan, and they come from the broadest array of other countries according to the Ministry of Agriculture, Forestry, and Fisheries (2013).

The eight vegetables are classified into four types: (1) fruit vegetables – tomatoes and peppers; (2) leafy vegetables – lettuce and cabbage; (3) bulb vegetable – onions and garlic; and (4) root vegetables – carrots and radishes. We adopted a classification system based upon botany and the edible part method used by Yamaguchi (1983), who grouped vegetables by the part of the vegetable people eat.

The classification of the four types of vegetables matches well with the pesticides used on each type. Peirce (1987) found that the major disease problems for peppers are the same as those for tomatoes. Thus, tomato and pepper production needs to use the same chemical components of pesticides. Moreover, Deshpande and Salunkhe (1998) pointed out that the most serious pests for lettuce are the same as those for cabbage, and as such the same chemical components of pesticide are used for lettuce and cabbage production. In addition, carrots and radishes are free from most diseases (Kotecha *et al.,* 1998), but suffer from some root rot diseases (Masalkar and Keskar, 1998). Alliums including onions and garlic are susceptible to the same diseases and insects (Peirce, 1987).

We analyzed how the similarities in MRL standards between Japan and other countries affected Japan's vegetable imports between 1996 and 2010. The trade data were obtained from the United Nations Commodity Trade Statistics Database (Comtrade, 2013) of the United Nations Conference on Trade and Development (UNCTAD). The study used HS2 – 1996 6-digit codes for fresh tomatoes (070200), peppers (070960), lettuce (070519), cabbage (070490), onions (070310), garlic (070320), carrots (070610), and radishes (070690). Data on total vegetables (070000) were also collected from the same source.

GDP and population data for exporters and Japan were retrieved from the World Bank Database (World Bank, 2013). In addition, exchange rate data were obtained from the Federal Reserve Bank (2013) and OANDA (2013). The distance between countries was calculated in miles and collected from the MapCrow database (MapCrow, 2013) based on the distance between the capitals. Each vegetable's tariff and total tariffs were obtained from the World Trade Organization (2013d). According to these data, Japanese tariffs for vegetables have declined since 2000.

Different countries have different MRL standards for vegetables. More than 30 countries' MRL standards were obtained from the Homologa (2011) database including Argentina, Australia, Bolivia, Brazil, Cameroon, Canada, Chile, China, Columbia, Egypt, European Union, Ghana, India, Israel, Japan, Kenya, Malaysia, Mexico, Morocco, New Zealand, Norway, Philippines, Russia, Singapore, South Africa, South Korea, Switzerland, Tanzania, Thailand, Togo, Turkey, Ukraine, USA, Vietnam, and Zimbabwe.

3. Estimation results and discussion

Table 1 describes the similarity indexes between Japanese vegetable MRL standards and MRL standards for the 34 countries. The Codex International Food Safety Standards are set by the Codex Alimentarius Commission. The Codex uses science-based reference levels and is provided to countries so that they can set their minimum levels of standards (Li and Beghin, 2012). Bolivia, Cameroon, Columbia, Egypt, Ghana, Kenya, Morocco, Tanzania, Togo, and Zimbabwe have adopted the Codex level of MRL standards for their vegetables. From Table 1, we can see Japan's MRL standards are the least similar to the Codex, Mexico, Malaysia, and South Africa and they are the most similar to the standards of Chile, China, European Union, South Korea, Switzerland, Turkey, and Ukraine. The average of the indexes is about 0.53, which is much lower than one. This indicates Japan's MRL standards are much stricter, by far, than those of other countries. Additionally, Japan's MRL standards are quite different from the Codex standards, which means that Japan's standards are far stricter than science-based reference levels.

The panel data were analyzed using the Pooled Ordinary Least Square (POLS) model and Ordinary Least Square model with Random Effect (RE) in order to estimate how the similarity of MRL standards affects trade (Scheepers *et al.,* 2007). Because some of the MRL standards and the distance have the same values throughout the years, this study did not adopt the fixed effect model and the first difference model. Additionally, serial correlations were detected for total vegetables, cabbage, onions, and carrots. Possible explanation for this is that ε_{it} in Equation 2 could be rewritten as $\varepsilon_{it} = u_i + v_{it}$. u_i could affect explanatory variables positively or negatively.

Thus, the RE model was adapted to adjust the correlations under main assumption that u_i is not correlated to explanatory variables. Min and Choi (2009) demonstrated that the RE estimation is more consistent and effective when there is correlation and when the main assumption above holds. The RE estimation also has an advantage when it comes to estimating the coefficients of time invariant variables such as the similarity index and distance.

First, total vegetables were analyzed in order to understand how similarities in MRL standards influence Japan's overall vegetable imports. Table 2 shows the results of both POLS and RE estimations for 396 observations. The results indicate that the similarity index of MRL standards between Japan and other nations significantly affects the imports of total vegetables at a 1 or 5% significance level and in a positive way. Most importantly, in RE model, the similarity index affects total vegetable imports at 5% significance level. This means that if Japan's MRL standards were not as strict as they are at present, vegetable imports would greatly increase. Generally, RE model has smaller *t*-statistics than POLS because RE adjusted the correlations. Tariff does not affect the vegetable imports significantly, but the exporters' GDP and population significantly influence Japan's vegetable imports. On the other hand, the exchange rate and Japan's GDP and population do not have significant impacts on Japan's vegetable imports. Asian dummy variable and distance are not statistically significant in the RE model.

Table 1. The similarity index for vegetables between Japan and other countries.

Country	Total	Tomato	Pepper	Lettuce	Cabbage	Onion	Garlic	Carrot	Radish
Argentina	0.55	0.53	0.57	0.59	0.53	0.54	0.54	0.58	0.57
Philippine, Singapore, Vietnam	0.54	0.55	0.54	0.56	0.50	0.60	0.58	0.55	0.55
Austria	0.55	0.51	0.55	0.54	0.52	0.48	0.49	0.54	0.54
Brazil	0.55	0.58	0.52	0.56	0.57	0.52	0.51	0.53	0.53
Canada	0.55	0.54	0.54	0.54	0.52	0.55	0.56	0.51	0.51
Codex	0.47	0.44	0.48	0.46	0.47	0.50	0.48	0.46	0.47
Switzerland	0.59	0.55	0.54	0.59	0.55	0.56	0.55	0.58	0.57
Chile	0.57	0.59	0.52	0.53	0.56	0.59	0.58	0.59	0.57
China	0.60	0.58	0.54	0.56	0.56	0.55	0.56	0.55	0.55
European Union	0.58	0.57	0.57	0.59	0.57	0.59	0.58	0.56	0.55
India	0.48	0.47	0.50	0.53	0.47	0.46	0.47	0.49	0.46
Israel	0.51	0.56	0.50	0.51	0.49	0.47	0.50	0.53	0.51
South Korea	0.57	0.59	0.57	0.60	0.58	0.53	0.54	0.52	0.52
Mexico	0.48	0.48	0.50	0.52	0.50	0.47	0.48	0.49	0.47
Malaysia	0.49	0.51	0.50	0.50	0.51	0.48	0.49	0.50	0.48
Norway	0.50	0.51	0.50	0.51	0.50	0.51	0.51	0.50	0.51
New Zealand	0.55	0.54	0.53	0.53	0.53	0.48	0.49	0.53	0.54
Russia	0.51	0.51	0.50	0.57	0.50	0.58	0.52	0.53	0.51
Thailand	0.54	0.57	0.48	0.50	0.53	0.54	0.53	0.53	0.53
Turkey	0.56	0.58	0.52	0.55	0.53	0.53	0.55	0.57	0.55
Ukraine	0.56	0.51	0.50	0.54	0.56	0.55	0.56	0.52	0.56
USA	0.54	0.54	0.52	0.54	0.52	0.53	0.54	0.53	0.52
South Africa	0.45	0.47	0.47	0.48	0.43	0.48	0.45	0.43	0.43

Table 2. Gravity model estimation results for Japan's total vegetable imports.[1,2,3]

	Total vegetable imports	
	pooled OLS	**RE**
ln_gdp	0.0801*** (2.73)	0.171 (1.42)
ln_pop	0.598*** (5.11)	0.891**(2.25)
ln_jgdp	-0.971 (-0.63)	-0.605 (-1.11)
ln_jpop	7.141 (0.17)	-12.30 (-0.77)
ln_ExchangeRate	0.0843** (2.18)	0.0324 (0.75)
total tariff	0.114 (0.25)	0.0722 (0.56)
total index	25.70*** (7.84)	29.09** (2.51)
ln_dist	-1.613*** (-7.67)	-0.983 (-1.20)
Asian	-1.251*** (-3.21)	-0.597 (-0.41)
Constant	-102.9 (-0.13)	234.1 (0.76)
Number of observations	396	396

[1] * = P<0.10; ** = P< 0.05; *** = P<0.01.

[2] t-statistics in parentheses.

[3] OLS = Ordinary least square; RE = Random effect.

Correlations were not identified for the fruit vegetables: tomatoes and peppers. Thus, the results of the POLS and RE estimations are the same. Although coefficients are the same, *t*-statistics are smaller in RE estimations which provide more accurate standard errors. As shown in Table 3, the similarity index significantly and positively impacts Japan's imports for tomatoes and peppers at a 1 and 5% significance level, respectively. The indexes have greater influence on Japanese tomato and pepper imports than on total vegetable imports because the coefficients of tomatoes (61.89) and peppers (38.78) for the similarity indexes are much larger than that of total vegetables (29.09). Hence, for fruit vegetables, the strict MRL standards are influential when it comes to controlling the quantities of imports. Exporter's GDPs are significant in both estimation results, but the signs of the coefficient are opposite. As expected, the signs of GDP for tomatoes are positive. However, the signs of GDP for pepper are negative. As expected, distance affects the tomato and pepper imports significantly and negatively, which means if distances between Japan and exporters are large, the fruit vegetable imports decreases. The exchange rates and Japan's population are not important factors affecting vegetable imports. The Asian dummy variable negatively affects Japan's tomato and pepper imports, which means Japan imported more tomatoes and peppers from non-Asian countries.

Table 4 presents the leafy vegetables' estimation results. The coefficients of the similarity indexes are significant at a 1% significance level and they are positive for both lettuce and cabbage imports as expected. In other words, if Japan's MRL standards were more similar to those of the exporters, the quantities of lettuce and cabbage imports would increase. For leafy vegetables, the exporters' GDP and population, Japan's GDP, and the Asian dummy variable significantly affect imports while other variables such as Japan's population, distance, and exchange rate are not significant.

The estimation results for bulb vegetables and root vegetables are summarized in Table 5 and Table 6. The similarity indexes for total vegetables, fruit, and leafy vegetables indicate that the indexes affect the imports significantly and positively. However, the coefficients of the similarity indexes for bulb vegetables and root vegetables are not significant, so the impact of the indexes on imports of bulb vegetables and root vegetables is negligible.

Table 3. Gravity model estimation results for Japan's tomato and pepper imports.[1,2,3]

	Tomato		**Pepper**	
	pooled OLS	**RE**	**pooled OLS**	**RE**
ln_gdp	1.072*** (4.89)	1.072*** (7.61)	-0.526*** (-20.66)	-0.526*** (-31.87)
ln_pop	2.199*** (6.78)	2.199*** (9.59)	-0.177 (-1.11)	-0.177 (-1.04)
ln_jgdp	1.767(0.87)	1.767 (0.57)	1.853* (1.81)	1.853** (1.97)
ln_jpop	-139.8* (-1.85)	-139.8 (-1.61)	54.52 (1.16)	54.52 (0.71)
ln_ExchangeRate	0.114 (0.53)	0.114 (0.49)	-0.394 (-1.43)	-0.394 (-1.33)
tomato tariff	-2.535** (-2.31)	-2.535** (-2.49)		
tomato index	61.89** (2.46)	61.89*** (5.11)		
ln_dist	-57.19*** (-6.98)	-57.19*** (-7.32)	-2.803*** (-3.46)	-2.803*** (-3.31)
Asian	-122.6*** (-7.26)	-122.6*** (-7.75)	-2.272* (-1.89)	-2.272* (-1.86)
pepper tariff			-0.346 (-0.52)	-0.346 (-0.51)
pepper index			38.78*** (5.35)	38.78*** (4.85)
Constant	2,967.0** (2.07)	2,967.0* (1.85)	-1,038.4 (-1.19)	-1,038.4 (-0.71)
Number of observations	71	71	67	67

[1] * = P<0.10; ** = P< 0.05; *** = P<0.01.

[2] *t*-statistics in parentheses.

[3] OLS = Ordinary least square; RE = Random effect.

Table 4. Gravity model estimation results for Japan's lettuce and cabbage imports.[1,2,3]

	Lettuce		Cabbage	
	pooled OLS	RE	pooled OLS	RE
ln_gdp	0.604*** (8.26)	0.604*** (14.64)	0.544*** (24.07)	0.459*** (7.46)
ln_pop	0.564*** (2.86)	0.564*** (5.31)	0.879*** (8.01)	0.919*** (4.68)
ln_jgdp	-6.349** (-2.40)	-6.349** (-2.08)	-4.990*** (-3.29)	-4.346** (-2.57)
ln_jpop	38.13 (0.36)	38.13 (0.23)	-84.86 (-1.36)	-102.1* (-1.90)
ln_ExchangeRate	-0.0531 (-0.24)	-0.0531 (-0.32)	-0.136** (-2.02)	-0.212* (-1.86)
lettuce tariff	0.837 (0.70)	0.837 (0.55)		
lettuce index	66.72*** (4.45)	66.72*** (4.80)		
ln_dist	-0.0354 (-0.05)	-0.0354 (-0.06)	-0.591 (-1.56)	-0.439 (-0.52)
Asian	-5.317*** (-4.69)	-5.317*** (-3.62)	-3.176*** (-4.75)	-2.638*** (-3.04)
cabbage tariff			-0.477 (-0.57)	-0.742 (-1.17)
cabbage index			34.14*** (7.06)	33.51** (2.42)
Constant	-579.2 (-0.30)	-579.2 (-0.18)	1,700.9 (1.46)	2,005.2** (1.99)
Number of observations	41	41	126	126

1 * = P<0.10; ** = P< 0.05; *** = P<0.01.

2 t-statistics in parentheses.

3 OLS = Ordinary least square; RE = Random effect.

Table 5. Gravity model estimation results for Japan's onion and garlic imports.[1,2,3]

	Onion		Garlic	
	pooled OLS	RE	pooled OLS	RE
ln_gdp	0.223*** (4.10)	0.128 (0.36)	0.266*** (3.88)	0.266*** (3.28)
ln_pop	-0.0565 (-0.28)	-0.00255 (-0.01)	0.280 (1.47)	0.280 (1.46)
ln_jgdp	0.767 (0.38)	0.812 (1.49)	7.217*** (4.60)	7.217** (2.39)
ln_jpop	23.44 (0.62)	-24.18 (-0.86)	-105.9 (-1.33)	-105.9 (-1.31)
ln_ExchangeRate	0.759*** (6.96)	0.757** (1.98)	0.940*** (6.96)	0.940*** (6.38)
onion tariff	0.0421 (0.34)	0.0884 (1.35)		
onion index	11.64 (1.14)	14.04 (0.69)		
ln_dist	-0.00396 (-0.01)	-0.435 (-0.37)	-0.864 (-0.48)	-0.864 (-0.42)
Asian	2.186*** (3.62)	3.420 (1.28)	4.041 (1.07)	4.041 (0.94)
garlic tariff			-0.199 (-0.22)	-0.199 (-0.26)
garlic index			17.50 (1.05)	17.50 (0.95)
Constant	-459.6 (-0.64)	429.4 (0.82)	1,759.8 (1.18)	1,759.8 (1.18)
Number of observations	153	153	61	61

1 * = P<0.10; ** = P< 0.05; *** = P<0.01.

2 t-statistics in parentheses.

3 OLS = Ordinary least square; RE = Random effect.

In both cases, the similarity indexes are affected positively but insignificantly. We can see that an exporter's GDP and exchange rate are the most significant among the other variables for bulb vegetables in Table 5. Japanese population, tariff, distance and even the similarity index do not have significant impacts on bulb vegetable imports. The similar results are shown for root vegetables in Table 6. Root vegetables' similarity index does not play any important role to affect root vegetable imports. Exporter's GDP, exchange rate, distance, and tariff for radish are somewhat significant for root vegetable imports.

Table 6. Gravity model estimation results for Japan's carrot and radish imports.1,2,3

	Carrot		Radish	
	pooled OLS	**RE**	**pooled OLS**	**RE**
ln_gdp	0.342*** (4.67)	0.361*** (2.81)	0.0264 (0.48)	0.0264 (0.35)
ln_pop	-0.296** (-2.42)	0.194 (0.38)	0.389** (2.40)	0.389 (1.50)
ln_jgdp	1.377 (0.69)	-1.207 (-0.60)	-1.714 (-0.91)	-1.714 (-0.89)
ln_jpop	18.36 (0.19)	-10.45 (-0.15)	-85.63 (-0.84)	-85.63 (-0.72)
ln_ExchangeRate	0.458*** (3.08)	0.218 (0.77)	0.490*** (4.27)	0.490*** (3.44)
carrot tariff	0.280 (0.21)	-0.0888 (-0.09)		
carrot index	19.95 (0.68)	3.039 (0.08)		
ln_dist	-2.416*** (-3.21)	-2.038* (-1.71)	-2.401*** (-3.66)	-2.401*** (-3.08)
Asian	-2.344 (-1.26)	-3.396* (-1.69)	0.152 (0.12)	0.152 (0.11)
radish tariff			-2.848** (-2.59)	-2.848** (-1.98)
radish index			42.36 (1.17)	42.36 (1.06)
Constant	-365.4 (-0.20)	245.7 (0.18)	1,654.8 (0.86)	1,654.8 (0.73)
Number of observations	84	84	68	68

[1] * = P<0.10; ** = P< 0.05; *** = P<0.01.

[2] t-statistics in parentheses.

[3] OLS = Ordinary least square; RE = Random effect.

Overall, the RE methods gives smaller t-statistics than Pooled OLS in most cases since the RE adjusted the correlations. Although correlation has been detected for some of the vegetables, we found the results of the RE estimation are very close to those of POLS. Also, for all vegetables in this study, tariffs are not as effective as the MRL standards to control vegetable imports in Japan. Table 7 represents all 8 vegetable RE results to compare each other.

In sum, the results show that Japan's strict MRL standards significantly impacted its vegetable imports, especially fruit and leafy vegetable imports. The higher the similarity index, the more similar Japan's MRL standards are to other countries, and the less strict the Japanese MRL standards are compared to other countries. Thus, Japan's stricter MRL standards significantly reduced imports for fruit and leafy vegetables, which is consistent with findings from previous research (Burnquist *et al.,* 2013; Drogue and DeMaria, 2012, 2013). However, Japan's MRL standards did not significantly reduce the imports of bulb and root vegetables. An interesting result is that the MRL standards' impacts on vegetable trades differ across different types of vegetables.

Many studies have shown that strict MRL standards could have greater impacts on imports than tariffs, quotas, and subsidies (Bao and Qiu, 2009; Drogue and DeMaria, 2012; Hejazi *et al.*, 2016). Hence, foreign vegetable producers should consider MRL standards in their business decisions. Our findings suggest producers in countries with higher similarity in MRL standards to Japan can increase fruit and leafy vegetable exports to Japan. Both foreign and domestic vegetable producers striving to meet Japan's high MRL standards have to bear MRL compliance costs, which lead to higher production costs and thus decrease the profit margins. However, for countries where the input costs are lower than Japan (for example, Vietnam and Philippine have lower labor costs; Australia and Canada have lower land costs), they can comply with the MRL standards with much lower costs. The lower compliance costs can help keep vegetable price lower than the vegetables produced in Japan. Our findings also indicate the MRL standards affect the imports of different kinds of vegetables differently. By improving the MRL levels and make them more similar to Japan while maintaining the compliance costs low, foreign fruit and leafy vegetable producers but not root vegetable products can potentially increase their vegetable exports.

Table 7. Gravity model estimation RE results for 8 vegetable imports.[1,2]

	Fruit		Leafy		Bulb		Root	
	tomato	**pepper**	**lettuce**	**cabbage**	**onion**	**garlic**	**carrot**	**radish**
ln_gdp	1.072***	-0.526***	0.604***	0.459***	0.128	0.266***	0.361***	0.0264
	(7.61)	(-31.87)	(14.64)	(7.46)	(0.36)	(3.28)	(2.81)	(0.35)
ln_pop	2.199***	-0.177	0.564***	0.919***	-0.00255	0.280	0.194	0.389
	(9.59)	(-1.04)	(5.31)	(4.68)	(-0.01)	(1.46)	(0.38)	(1.50)
ln_jgdp	1.767	1.853**	-6.349**	-4.346**	0.812	7.217**	-1.207	-1.714
	(0.57)	(1.97)	(-2.08)	(-2.57)	(1.49)	(2.39)	(-0.60)	(-0.89)
ln_jpop	-139.8	54.52	38.13	-102.1*	-24.18	-105.9	-10.45	-85.63
	(-1.61)	(0.71)	(0.23)	(-1.90)	(-0.86)	(-1.31)	(-0.15)	(-0.72)
ln_ExchangeRate	0.114	-0.394	-0.0531	-0.212*	0.757**	0.940***	0.218	0.490***
	(0.49)	(-1.33)	(-0.32)	(-1.86)	(1.98)	(6.38)	(0.77)	(3.44)
tariff	-2.535**	-0.346	0.837	-0.742	0.0884	-0.199	-0.0888	-2.848**
	(-2.49)	(-0.51)	(0.55)	(-1.17)	(1.35)	(-0.26)	(-0.09)	(-1.98)
MRL index	61.89***	38.78***	66.72***	33.51**	14.04	17.50	3.039	42.36
	(5.11)	(4.85)	(4.80)	(2.42)	(0.69)	(0.95)	(0.08)	(1.06)
ln_dist	-57.19***	-2.803***	-0.0354	-0.439	-0.435	-0.864	-2.038*	-2.401***
	(-7.32)	(-3.31)	(-0.06)	(-0.52)	(-0.37)	(-0.42)	(-1.71)	(-3.08)
Asian	-122.6***	-2.272*	-5.317***	-2.638***	3.420	4.041	-3.396*	0.152
	(-7.75)	(-1.86)	(-3.62)	(-3.04)	(1.28)	(0.94)	(-1.69)	(0.11)
Constant	2,967.0*	-1,038.4	-579.2	2,005.2**	429.4	1,759.8	245.7	1,654.8
	(1.85)	(-0.71)	(-0.18)	(1.99)	(0.82)	(1.18)	(0.18)	(0.73)
Number of observations	71	67	41	126	153	61	84	68

[1] * = P<0.10; ** = P< 0.05; *** = P<0.01.

[2] t-statistics in parentheses.

4. Conclusions

Food safety has presented a vexing problem in many countries, and as such, countries have attempted to control food-borne illness by improving the food safety quality of both domestic production and imports. In this regard, MRL standards have played a significant role. The extent to which MRL standards affect the trade of agricultural products has been widely studied. Few studies have examined how MRL standards affect the trade of different types of food differently. This study is intended to fill this knowledge gap in the literature by exploring the impact of MRL standards on the imports of different types of vegetable in Japan.

Using the widely used gravity model, this study analyzed how the MRL standards affect vegetable imports in Japan. The similarity index was adopted to evaluate the degree to which Japan's MRL standards are different or similar to other countries' standards. In addition, tariff, GDP, population, distance, and the exchange rate were included as explanatory variables. POLS and RE estimations were compared and applied to estimate the gravity model.

The main finding of this research is that total vegetables, fruit vegetables, and leafy vegetables are significantly affected by the degree of similarity in MRL standards between traders. By contrast, the similarity of MRL standards does not significantly affect Japan's imports of bulb vegetables and root vegetables such as onions and carrots. This study finds that the type of vegetables makes a difference when it comes to how the MRL standards affect imports. Thus, by setting strict MRL standards, Japan could effectively restrict fruit and leafy vegetable imports. From the exporters' perspective, the exporters have suffered great loss by the significantly reduced vegetable exports to Japan. In this study, we have not considered the exporters' actual costs as a result of complying with Japan's MRL standards. If these costs were considered, the exporters' loss would be even greater. Therefore, we concluded that the stringency of MRL standards has impeded Japanese imports for fruit and leafy vegetables (but not for bulb and root vegetables). If the Japan's MRL standards were less strict, fruit and leafy vegetable imports would greatly increase. On the other hand, exporters to Japan can set stricter MRL standards on fruit and leafy vegetables to increase their exports to Japan.

This study contributes to the empirical literature in understanding how Japan's food standards affect the imports of the four types of vegetables: fruit, leafy, bulb and root vegetables. If the cost of implementing and adjusting the MRL standards could be measured, it would help further explain how the MRL standards would affect producer and consumer prices, and thus the profits of exporters. This could be an interesting future research topic. How the stringency of MRL standards affects the consumption volume of fruits and vegetables, and thus human health could be another interesting future research topic.

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