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# How is internal radiation exposure risk evaluated at the markets? Perceived quality degradation of Fukushima peach

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## Abstract

The Great Tohoku Earthquake and massive tsunami disabled the Fukushima Daiichi power plant cooling system, which resulted in a meltdown of the reactor core and hydrogen explosion of the reactor buildings. A large amount of radioactive substances was released into the environment and the agricultural production in surrounding area was severely damaged by the radioactive contamination. Many experimental studies have been conducted after the nuclear accident to understand how consumers evaluate the internal radiation exposure risk associated with the consumption of agricultural food produced in the affected region. The studies have reported that a typical consumer differentiates agricultural foods produced at the contaminated region from those produced at non-contaminated region and then spends non-negligible amounts of money to lower their perceived internal radiation exposure risk. However, only a few studies have examined how internal radiation exposure risk is evaluated at the market level. In this study, we analyze the sales data of Japanese wholesale markets to examine how consumers' valuation about agricultural food has been altered by the nuclear accident. By modifying the Dixit–Stiglitz demand model, we propose an empirical model to quantify the change in consumer's valuation between competitive agricultural products. We then apply the proposed model for the analysis of daily peach sales data obtained from Japanese wholesale markets. Our empirical results demonstrate that consumer valuation of Fukushima peach dropped significantly in the nuclear accident year, but it rapidly recovered in the following year. The result suggests that the measures against radioactive contamination are positively evaluated among Japanese consumers.

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# Perceived quality degradation of Fukushima peach

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## Abstract

The Great Tohoku Earthquake and massive tsunami disabled the Fukushima Daiichi power plant cooling system, which resulted in a meltdown of the reactor core and hydrogen explosion of the reactor buildings. A large amount of radioactive substances was released into the environment and the agricultural production in surrounding area was severely damaged by the radioactive contamination. Many experimental studies have been conducted after the nuclear accident to understand how consumers evaluate the internal radiation exposure risk associated with the consumption of agricultural food produced in the affected region. The studies have reported that a typical consumer differentiates agricultural foods produced at the contaminated region from those produced at non-contaminated region and then spends non-negligible amounts of money to lower their perceived internal radiation exposure risk. However, only a few studies have examined how internal radiation exposure risk is evaluated at the market level. In this study, we analyze the sales data of Japanese wholesale markets to examine how consumers' valuation about agricultural food has been altered by the nuclear accident. By modifying the Dixit–Stiglitz demand model, we propose an empirical model to quantify the change in consumer's valuation between competitive agricultural products. We then apply the proposed model for the analysis of daily peach sales data obtained from Japanese wholesale markets. Our empirical results demonstrate that consumer valuation of Fukushima peach dropped significantly in the nuclear accident year, but it rapidly recovered in the following year. The result suggests that the measures against radioactive contamination are positively evaluated among Japanese consumers.



**Keywords:** Dixit–Stiglitz Model, Internal Radiation Exposure Risk, Peach, Wholesale Market

## 1. Introduction

Food contamination is a problem that occurs relatively frequently. The World Health Organization (2017) estimates that almost 1 in 10 people worldwide (or 700 million people) fall ill after eating contaminated food and 420,000 die every year. On the other hand, the Centers for Disease and Control and Prevention (2011) estimates that roughly 1 in 6 Americans (or 48 million people) become ill, 128,000 are hospitalized, and 3,000 die of foodborne diseases every year.

The economic cost of food contamination is substantial. The United States of Department of Agriculture (2014) estimates that the annual cost of foodborne illnesses caused by the 15 pathogens is about U.S. $15.5 billion per year. When it is found that contaminated food entered the market, a regulatory agency asks a firm to recall their food. Such food recalls have been increasingly common in recent years (Hussain and Dawson, 2013). For instance, White-Cason (2013) reported that there were more than 600 recalls in the U.S. and Canada in a single year. When large-scale recalls are requested, firms not only lose sales, but also lose their brand value. Because of this, they regard food contamination as a major risk for their business.

To prevent food contamination, countries have established food safety management rules and have improved hygiene systems over many years. *Codex Alimentarius* was created in 1963 to harmonize international food standards. It is a joint intergovernmental body of the Food and Agriculture Organization of the United Nations and the WHO, with 187 Member States and one Member Organization (EU). In more recent years, firms have adopted the Hazard Analysis and Critical Control Point (HACCP) approach in which the hygiene management is focused on the hazard point where food contamination frequently occurs.

Although such hygiene management is important and highly effective, firms cannot prevent all food contamination as some food contamination problems are beyond the control of an individual firm.

The radioactive contamination studied in this paper is a new type of food contamination with distinctive features worthy of economic analysis. The first of these features is the great uncertainty. If a person intakes food contaminated by radioactive substances, then they will be internally exposed to radioactive materials. However, the health risk of internal exposure is not clear. Indeed, there is great diversity in opinions regarding the magnitude of the increased health risk[1]. Although research on internal exposure is very limited presently, we cannot expect that sufficient scientific knowledge will be accumulated in the near future.

The second feature is a long problem duration. Unlike other food contamination problems, it takes a very long period of time to solve the radioactive contamination problem. Although the half-life of iodine is only about 8 days, that of Cesium 137 is 30 years. As long as soil and water contamination problems continue, we cannot eliminate consumer concerns about food produced at the affected region. However, if we wait for complete decontamination, agricultural production in the affected region will be shut down.

The last feature is outstanding externality. Radioactive contamination will not be limited to specific foods. All of the foods produced in the contaminated area can be affected by radioactive materials. Once it is found that a specific food is contaminated, consumers may start to avoid all the foods from the affected area.

In short, although the immediate health risk of radioactive contamination is smaller than

[1] Some scientists argue that the impact is relatively minor when taking into account the fact that people ingest radioactive substances in their daily life (Hayashi and Midorikawa, 2013). Other scientists claim that such an argument oversimplifies the health-risk analysis (Heley, 2014).

for other food contaminations, its impact on local economy is more serious and a complete resolution cannot be expected for at least several decades.

Since the nuclear accident, Japanese farmers, government, distributors, and food producers have implemented various measures to reduce radionuclide migration on the farms. For instance, farmers initially stopped using grass hay to avoid radionuclide migration to animals. Later, they tried to decontaminate farmland by removing top soil and plowing deeply (Ministry of Agriculture, Forestry and Fisheries (MAFF), 2017a). Immediately after the nuclear accident, the Ministry of Health, Labour and Welfare (MHLW) set the regulation limits and established an extensive monitoring system to ensure food safety. Prefectures have been inspecting food items at predetermined frequency and the central government has been publicizing the test results (MAFF, 2017b). In the accident year, some agricultural products produced at Fukushima and neighboring prefectures, such as beef, leafy vegetables, raw milk, and rice, exceeded the regulation limits and their shipments were suspended. However, after 2014, only edible wild plants, game meat, fish, and wild mushrooms exceeded the regulation limits[2].

Many countries have regulated the import of Japanese agricultural products after the nuclear accident. Although the EU requested a certificate of radioactive material inspection or "origin certificate," Middle Eastern countries, such as Iraq, Egypt, and Kuwait stopped the import of agricultural products also from the western part of Japan, which is the area not affected by the nuclear accident. Even in December 2017, China and Korea continue to stop importing agricultural products from the eastern part of Japan (MAFF, 2017c).

Japanese researchers conducted research to understand how consumers evaluate the

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[2] The proportion of foods produced in Fukushima prefecture that exceeded the regulation limit decreased from 3.3% in 2011 to 0.6% in 2014 (Gibney, 2015).

internal radiation exposure risk associated with the consumption of the agricultural products produced at the contaminated regions. Most studies used a stated preference approach to elicit consumer evaluation about the internal radiation exposure risk. Ito and Kuriyama (2017) and Ujiie (2012, 2013) use choice experimental approaches, whereas Aruga (2016) uses the Contingent Valuation Method. They studied a variety of agricultural products and confirmed that a typical consumer spends a non-negligible amount of money to lower the internal radiation exposure risk. These scholars also show that consumers differentiate between agricultural products from affected and non-affected regions even if they are informed that the contamination risks are the same. This result suggests that consumers rely on food origin information for their food quality evaluation.

Contrary to the accumulation of the stated preference studies, only a few market-level studies have been conducted. Tajima et al. (2016) conducted a hedonic regression analysis to assess the impact of the nuclear accident on fresh vegetable prices sold at Tokyo's wholesale market. They found that the price of vegetables grown in Fukushima prefecture decreased by 10–36% after the nuclear accident and that such price reductions persisted for three years after the accident. While their empirical finding is interesting, they do not show how consumer evaluation changed between agricultural products before and after the nuclear accident.

We analyze the market data also in this study, but intend to evaluate the change in quality perception caused by the nuclear accident. We first modify the Dixit–Stiglitz demand model and propose an empirical model that enables to evaluate the change in consumer valuation between competitive products. Although the proposed model is rather simple, we believe the model is easily applicable for the empirical analysis of the quality evaluation of other agricultural products.

We will focus on peach sales in this study. Peach is a fruit in which quality difference appears conspicuously and reflects directly on the price. Hence, peach is an ideal agricultural product to analyze the effect of radioactive contamination on food quality. In addition, it is a major agricultural product for Fukushima prefecture. In the next section, we provide basic information about the Japanese peach market and present the sales trends at the wholesale markets. We propose our empirical model in Section 3 and then apply it for the analysis of peach sales data in Section 4. The empirical results show that consumers' valuation of peach quality from Fukushima prefecture dropped by 22.5–23.6% in the nuclear accident year. However, we found that such quality degradation is a temporal phenomenon and that consumer valuation in recent years returned to the level prior to the nuclear accident. This result suggests that the measures against radioactive contamination are positively evaluated among Japanese consumers.

## 2. Japanese Peach Market

### 2.1. General market conditions

Although the cultivation of peach dates back over 1,000 years, peaches were not a popular fruit among Japanese ancestors. Instead, peaches were consumed as a medicine until the white peach was imported from China about 100 years ago (FoodsLink, 2017). A wide variety of peaches has been developed since then and peaches have become very popular among Japanese people today. The total yield of peach in 2016 is 127,300 tons, which follows the yields of mandarin orange (805,100 tons), apple (765,000 tons), Japanese pear (247,000 tons), Japanese persimmon (232,900 tons), and grape (179,200 tons) (MAFF, 2017d).

The four seasons of Japan are clear and the food seasons are clear also. The national land of Japan extends from the southwest to the northeast and, thus, the seasons move in the same direction. Although the prime season differs slightly according to varieties and production areas, the general peach season is between summer and early autumn. Indeed, peach is one of the most common fruits that Japanese offer their ancestors during the Bon Festival held between August 13 and 16.

Peaches are produced mainly in five prefectures: their shipment shares in the entire country in 2016 are 32.16% by Yamanashi prefecture, 23.16% by Fukushima prefecture, 12.69% by Nagano prefecture, 7.79% by Wakayama prefecture, and 7.09% by Yamagata prefecture based on the survey by MAFF (2017d). Due to its warm weather, the Wakayama peach season arrives in June, which is earlier than the remaining four prefectures. The market share of Yamagata prefecture is relatively small. In addition, Yamagata prefecture is adjacent to Fukushima prefecture and, therefore, consumers may be concerned about the radioactive contamination of agricultural products from there. Considering the sales and geographical conditions of these two prefectures, we decide to focus on peach sales of the remaining three prefectures, namely, Fukushima, Nagano, and Yamanashi prefectures.

**Insert Figure 1 and Table 1 Near Here**

In the following empirical analysis, we will use the daily sales data available from the Vegetable Total and Aggregate Network provided by the Agriculture and Livestock Industries Corporation (2018). The handling volume of agricultural products at each market is determined by the geographical distance and the connection condition of the highway leading from the production prefecture as well as the size of the market. Because we want to examine how the internal radiation exposure risk was evaluated at the markets, we focus on Fukushima peach data in the following analysis. Although the records of the fourteen wholesale markets are included in the above mentioned dataset, the sale shares of Fukushima prefecture is very small at six wholesale markets. Therefore, we decided to use the data of the remaining eight wholesale markets: namely, Sapporo, Sendai, Tokyo, Yokohama, Osaka, Kita-Kyushu, Fukuoka, and Okinawa markets. The locations of the eight wholesale markets are presented in Figure 1 together with the location of the three production prefectures. Fukushima, Yamanashi, and Nagano prefectures accounted for high sales shares at the eight wholesale markets. Although the share at Osaka market in 2010 was 69.26%, the share at Tokyo market was 98.87% (see Table 1). It is worth mentioning that the share of Fukushima peach was particularly high in the Sapporo, Sendai, and Kita-Kyushu markets. In contrast, Yamanashi peach had dominant market share in the Tokyo, Yokohama, Osaka, and Okinawa markets.

## 2.2. Effects of the nuclear accident on the sales of Fukushima peach

After the nuclear accident, farmers in Fukushima prefecture cleaned the surface of bark with high-pressure water to remove radioactive cesium deposited on the above-ground parts of fruit trees. Owing to such an effort, farmers could prevent much of the radionuclide migration in fruit production. Although in the nuclear accident year, 182 samples out of 2,732 fruit and nut samples inspected throughout Japan were confirmed to exceed the safety standard, in the subsequent year, only 13 samples out of 4,478 fruit samples were confirmed to exceed it (MAFF, 2013). The samples that exceeded the reference value are citrus junos, chestnut, fig, kiwi fruit, Japanese plum, persimmon, and pomegranate. None of peach samples have exceeded the safety standard since the nuclear accident.

Because there is no record that Fukushima peach is contaminated by radioactive substances, there is no reason for consumers to be concerned about Fukushima peach even in the nuclear accident year. However, Hangui (2013) examined the peach sales at Tokyo wholesale market in the nuclear accident year and confirmed that the sales volume of Fukushima peaches increased markedly but their price dropped sharply from the previous year. This suggests that due to the nuclear accident, Fukushima farmers were forced to sell high-quality gift peaches prepared for direct sales as low-quality peaches at the wholesale market.

**Insert Figure 2 Near Here**

Because the peak season of Fukushima peach is August, we use August data in the following analysis. Figure 2a shows the change in August's sales volume in Tokyo market from 2004 to 2017. The figure describes that the sales volume of Yamanashi prefecture has been decreasing during the sampling period while that of Nagano prefecture has been increasing. Similarly, the sales volume of Fukushima prefecture has been increasing. The figure also shows that the sales volume of both Fukushima and Yamanashi prefectures increased greatly in the nuclear accident year.

Figure 2b shows the change in the average price. The figure shows that the average prices of both Yamanashi and Nagano peaches have been increasing steadily. However, the price difference between Yamanashi and Nagano peaches remained at about 80–100 yen/kg during the whole sampling period. The figure also shows that the average price of Fukushima peach dropped sharply from 2009 to 2011 but has been increasing since then.

The nuclear accident influenced both the production conditions in Fukushima prefecture and the consumer valuation about Fukushima peach. In the following empirical section, we intend to separate the change in market share caused by the price change from the change caused by the consumer valuation.

## 3. Empirical Model

We modify the model developed by Dixit and Stiglitz (1977) to investigate how the nuclear accident changed consumer valuation about Fukushima peach[3]. Suppose that the utility that a typical consumer obtains from peach consumption at date $t$ can be expressed by the following CES utility function:

$$u^t = \{\sum_{i=1}^{n}(\theta_i^t q_i^t)^{\rho}\}^{\frac{1}{\rho}},$$

where $q_i^t$ is the sales volume of peach from prefecture $i$, $\theta_i^t$ is a parameter indicating the quality of peach, and $\rho \in [-1, 0) \cup (0, \infty)$ is the constant elasticity of substitution, which is $\rho \equiv (\sigma - 1)/\sigma$. Given the standard budget constraint and the weak separability assumption, we solve the utility maximization problem. Subsequently we obtain the relative expenditure share:

$$S_{cf}^t = \frac{p_c^t q_c^t}{p_f^t q_f^t} = \frac{\left(p_c^t/\theta_c^t\right)^{1-\sigma}}{\left(p_f^t/\theta_f^t\right)^{1-\sigma}}, \qquad (1)$$

where $f$ indicates Fukushima prefecture and $c$ indicates a compared prefecture. We take a log of the both sides of Equation (1). Then, we have

$$\ln S_{cf}^t = (1-\sigma)\ln\frac{p_c^t}{p_f^t} - (1-\sigma)\ln\frac{\theta_c^t}{\theta_f^t}. \qquad (1)'$$

[3] The following approach is similar to the one proposed by Hallak (2006) and Matsumoto (2011).

Similarly, we calculate the log at the reference date 0 as

$$\ln S_{cf}^{0} = (1-\sigma)\ln\frac{p_c^0}{p_f^0} - (1-\sigma)\ln\frac{\theta_c^0}{\theta_f^0}. \qquad (1)"$$

By subtracting Equation (1)" from Equation (1), we obtain the following expression:

$$\ln S_{cf}^{t} - \ln S_{cf}^{0} = (1-\sigma)\left[\ln\left(\frac{p_c^t}{p_f^t}\right) - \ln\left(\frac{p_c^0}{p_f^0}\right)\right] - (1-\sigma)\left[\ln\left(\frac{\theta_c^t}{\theta_f^t}\right) - \ln\left(\frac{\theta_c^0}{\theta_f^0}\right)\right]. \qquad (2)$$

The first term of the right-hand side of Equation (1) measures the impact of the relative price change while the second term measures the impact of the relative quality change. We substitute the three years' sample average from 2004 to 2006 into $S_{cf}^{0}$ and $p_c^0/p_f^0$.

For the empirical analysis, we estimate the following equation:

$$\ln S_{cf}^{t} - \ln S_{cf}^{0} = \beta\left[\ln\left(\frac{p_c^t}{p_f^t}\right) - \ln\left(\frac{p_c^0}{p_f^0}\right)\right] + \gamma I_{T,} \qquad (2)$$

where $I_T$ is an index variable that takes a value of one for the samples within period *T*. Using the estimated parameters, we can calculate the quality change as

$$\lambda = exp\left(-\frac{\gamma}{\beta}\right) = \frac{\theta_c^T/\theta_f^T}{\theta_c^0/\theta_f^0}, \qquad (3)$$

where $\theta_c^T/\theta_f^T$ is the relative quality within period *T* and $\theta_c^0/\theta_f^0$ is the relative quality at the reference date. If a consumer evaluates that the quality of Fukushima peach dropped due to the radioactive contamination, then the value of Equation (3) becomes greater than one. Alternatively, $1/\lambda$ indicates the degree of perceived quality degradation within period $T$. The main object of the following exercise is to estimate this value.

**Insert Table 2 Near Here**

We constructed two datasets. Yamanashi and Fukushima peaches are included in the first dataset while Nagano and Fukushima peaches are included in the second. We will use the first dataset to examine the degree of quality degradation of Fukushima peaches against Yamanashi and the second dataset to examine the quality reduction of Fukushima peaches against Nagano peaches, respectively.

The total number of days in our sampling period is 341 (= 31 days/year × 11 years). Because there are eight markets, the potential number of trading days is 2,728 (= 341 days/market × 8 markets). However, the markets are closed on Sunday as well as during the Bon Festival period. In addition, peaches are not traded at the market every day. After removing the non-trading days, the number of sampling days from the first dataset became 1,424 and that from the second dataset became 2,668. Table 2 shows the descriptive statistics of the two datasets.

## 4. Empirical Results

### 4.1. Magnitude and duration of the impact

We initially estimated a model that includes only the price effect. Model 1 in Table 3 presents the result. According to our calculations, the elasticity of substitution between Fukushima and Yamanashi peaches is 3.773 while that between Fukushima and Nagano peaches is 3.133. Hence, not surprisingly, we find that peaches from the two prefectures are found to be close substitutes of each other.

**Insert Table 3 Near Here**

We created an index variable that takes a value of one only for the samples in the nuclear accident year, 2011. We then substituted that index variable into $I_T$ in Equation (2). The regression result provides a positive value for the parameter $\gamma$ in both the Yamanashi and Nagano cases (see Model 2 in Table 3). The results imply that the quality of Yamanashi and Nagano peach against Fukushima peach was improved in the nuclear accident year. According to our calculation, the quality of Fukushima peach against Yamanashi peach dropped by 22.5% while the quality of Fukushima peach against Nagano peach dropped by 23.6%.

To examine the duration of the impact of the nuclear accident, we created an alternative index variable that takes a value of one for the samples in 2011 and 2012. We then substitute this index variable into $I_T$ in Equation (2). As presented in Model 3, the index variable became positive but did not become statistically significant. Together with the result of Model 2, we conclude that although the perceived quality of Fukushima peach dropped in the nuclear accident year, it went back to the original position in the following year.

## 4.2. Variation between markets

In the previous analysis, we assumed that all factors other than the price change affecting the market share, come from the change in the perceived quality of Fukushima peach. However, the index variable $I_T$ might be correlated with time-specific supply-side factors other than a change in the perceived quality. To consider such a possibility, we decided to investigate whether the impact of the nuclear accident varies among the eight markets in the following model:

$$\ln S_{cf}^{t} - \ln S_{cf}^{0} = \beta \left[ \ln\left(\frac{p_c^t}{p_f^t}\right) - \ln\left(\frac{p_c^0}{p_f^0}\right) \right] + \gamma I_{2011} + \sum_{m=1}^{7} \gamma_m I_{2011,m}, \quad (4)$$

where $I_{2011}$ is the index value that takes value of 1 for the samples in the nuclear accident year. We choose the Tokyo market as the base market and introduce the year-market specific dummy variables $I_{2011,m}$ for the remaining seven markets. If the change in the market share comes from the time-specific supply-side factors, then we will not observe the variations in $\gamma$ across the markets.

The estimation results of Equation (4) are presented in Table 4. In the Tokyo market, the quality of Fukushima peach against Yamanashi peach dropped by 27.9% while the quality of Fukushima peach against Nagano peach dropped by 26.5%. However, the table shows considerable variation in perceived quality degradation across the markets. This shows that the impact of the nuclear accident is minor in Sappro, Sendai, and Kita-Kyushu markets. As shown in Table 1, in these three markets, the market share of Fukushima peach was high in the year prior to the nuclear accident. If consumers in all markets are equally concerned about the radioactive contamination risk, then a larger market share decline should be observed in the markets where the market share was high prior to the accident. However, Table 4 presents the opposite result. Given the considerable variation in $\gamma$ across the markets, we conclude that consumers in different markets changed their valuation of Fukushima peach differently in the nuclear accident year.

## 5. Conclusion

Radioactive contamination in food supplies caused by the Fukushima nuclear accident is a new type of food contamination that no society has experienced. There is not yet scientific knowledge as to the seriousness of health effects caused by the ingestion of radioactively contaminated food. However, we cannot expect to completely restore the areas contaminated by radioactive substances with current science and technology. To continue agricultural production in contaminated areas, we need to prevent contaminated agricultural products from entering the market. Agricultural products from the contaminated areas have been examined intensively and the test results have been publicized since the nuclear accident. However, previous studies based on the stated preference approach have reported that consumers are still concerned about agricultural products from contaminated areas.

In this study, we analyzed wholesale market data to examine whether consumers concern about the radioactive contamination of the agricultural products produced in the contaminated area. The empirical results of this paper reveal that the reliability of agricultural products in the contaminated area declined in the nuclear accident year, but it immediately recovered in the following year. Our result provides an optimistic message about food contamination control. Even in the management of radioactive contamination problems, presumably thought to be the most difficult management, food inspection has successfully dispelled consumer concerns.

The empirical results show that there is considerable variation in the perceived quality degradation across the markets. Previous studies based on the stated preference approach report that consumers who reside far from the nuclear power plant care more about food contamination risk than consumers who live in nearby areas. Although we also find that the level of perceived quality degradation was small in the neighboring market, we also found that the market condition prior to the nuclear accident greatly affected the degradation level. Specifically, we find that the perceived quality degradation was smaller in markets where Fukushima peach had a large share prior to the nuclear accident.

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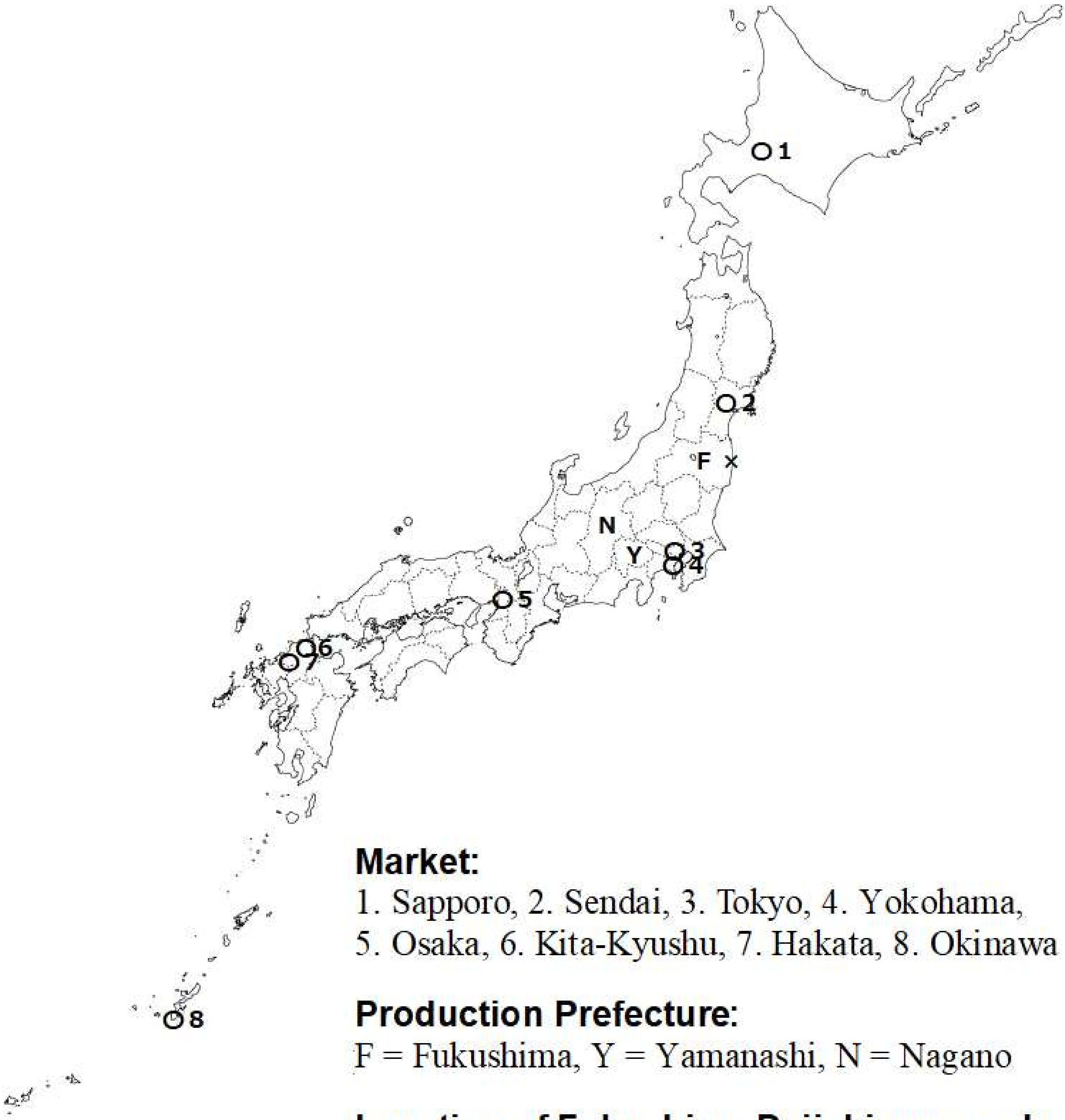
## Figure 1. Market and production prefecture




**Market:**
1. Sapporo, 2. Sendai, 3. Tokyo, 4. Yokohama,
5. Osaka, 6. Kita-Kyushu, 7. Hakata, 8. Okinawa

**Production Prefecture:**
F = Fukushima, Y = Yamanashi, N = Nagano

**Location of Fukushima Daiichi power plant:**
×

**Figure 2a. Sales volume in Tokyo market (August)**

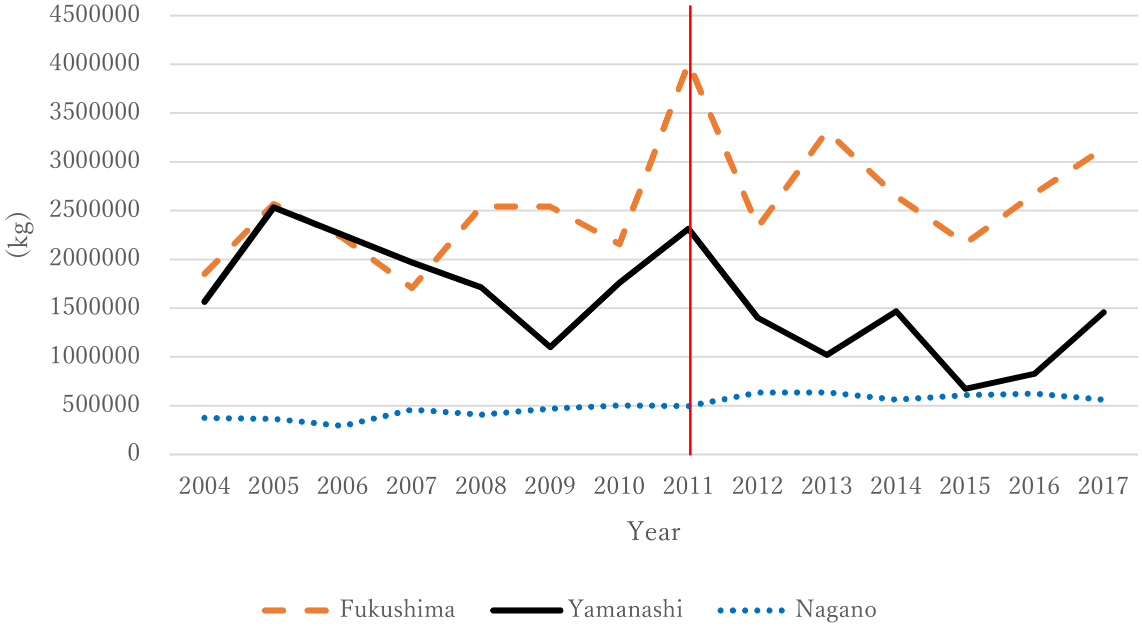



**Figure 2b. The average price in Tokyo market (August)**

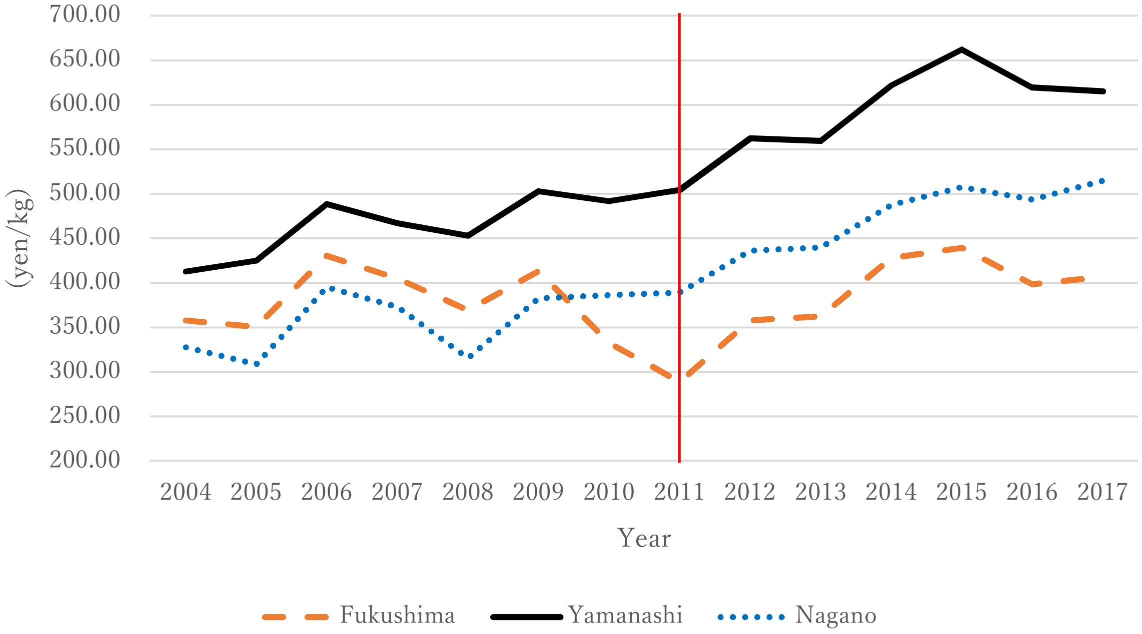


**Table 1. Market Shares of Three Major Prefectures (2010)**

| | Sapporo | Sendai | Tokyo | Yokohama | Osaka | Kita-Kyushu | Fukuoka | Okinawa |
|---|---|---|---|---|---|---|---|---|
| Fukushima | 59.42% | 62.56% | 29.71% | 15.45% | 15.32% | 46.80% | 36.93% | 20.93% |
| Yamanashi | 25.02% | 35.79% | 54.44% | 57.41% | 42.24% | 15.45% | 17.35% | 60.47% |
| Nagano | 0.92% | 0.52% | 7.63% | 3.99% | 11.71% | 17.55% | 26.03% | 11.63% |
| Total | 85.35% | 98.87% | 91.78% | 76.85% | 69.26% | 79.80% | 80.30% | 93.02% |

Source: Agriculture & Livestock Industries Corporation (2017).

**Table 2. Descriptive Statistics**

| | | Mean | St. Dev. |
|---|---|---|---|
| First datasets: Yamanashi vs. Fukushima (N = 1,424) | | | |
| Sales | Yamanashi | 9,941,761.0 | 16,100,000.0 |
| (yen) | Fukushima | 13,400,000.0 | 16,900,000.0 |
| Price | Yamanashi | 566.1 | 135.3 |
| (yen/kg) | Fukushima | 388.7 | 93.7 |
| Second dataset: Nagano vs. Fukushima (N = 2,668) | | | |
| Sales | Nagano | 7,510,460.0 | 12,600,000.0 |
| (yen) | Fukushima | 8,586,998.0 | 8,040,644.0 |
| Price | Nagano | 520.2 | 147.9 |
| (yen/kg) | Fukushima | 392.4 | 93.2 |

**Table 3. Impact of Nuclear Accident on the Valuation of Fukushima Peach**

| Yamanashi vs. Fukushima (N = 1,424) | | β | σ | γ | 1/λ |
|---|---|---|---|---|---|
| Model 1 | Price effect only | −2.773* | 3.773 | | |
| Model 2 | 2011 year dummy | −3.189* | 4.189 | 0.813* | 0.775 |
| Model 3 | 2011-2012 year dummy | −2.850* | 3.850 | 0.104 | 0.964 |
| **Nagano vs. Fukushima (N = 2,668)** | | **β** | **σ** | **γ** | **1/λ** |
| Model 1 | Price effect only | −2.133* | 3.133 | | |
| Model 2 | 2011 year dummy | −2.445* | 3.445 | 0.657* | 0.764 |
| Model 3 | 2011–2012 year dummy | −2.331* | 3.331 | 0.277 | 0.888 |

Note. The variables attached * became statistically significant at the 1% level.

**Table 4. Market Variations**

| | Yamanashi vs. Fukushima | | | Nagano vs. Fukushima | | |
|---|---|---|---|---|---|---|
| | Coef. | Robust Std. Err. | 1/λ | Coef. | Robust Std. Err. | 1/λ |
| β | −3.207** | 0.183 | | −2.449** | 0.141 | |
| γ | 1.048** | 0.264 | | 0.755** | 0.168 | |
| Market specific impact | | | | | | |
| Tokyo market (base) | | | 0.721 | | | 0.735 |
| Sapporo market | −1.052** | 0.379 | 1.001 | −1.201** | 0.288 | 1.199 |
| Sendai market | −0.920* | 0.383 | 0.961 | −0.751** | 0.286 | 0.998 |
| Yokohama market | 0.084 | 0.404 | 0.703 | 0.285 | 0.258 | 0.654 |
| Osaka market | 0.209 | 0.297 | 0.676 | 0.246 | 0.191 | 0.664 |
| Kita-kyushu market | −0.813** | 0.384 | 0.930 | −0.563** | 0.243 | 0.924 |
| Hakata market | 0.388 | 0.382 | 0.639 | 0.481* | 0.232 | 0.604 |
| Okinawa market | 0.218 | 0.827 | 0.674 | −0.020 | 0.704 | 0.741 |

Note. * and ** indicate statistically significant at 5% and 1%, respectively.