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The Economic Impact of Government Policy on Market Prices of Low-Fat Pork in South Korea: A Quasi-Experimental Hedonic Price Approach

Hyun No Kim [1] and Ik-Chang Choi [2,*]

[1] Department of Sustainable Development Research, Korea Environment Institute, Sejong 30147, Korea; hnkim@kei.re.kr
[2] Bayreuth Center of Ecology and Environmental Research, University of Bayreuth, 95440 Bayreuth, Germany
* Correspondence: ikchangchoi@gmail.com; Tel.: +82-44-415-7985

Received: 19 February 2018; Accepted: 19 March 2018; Published: 20 March 2018

Abstract: The implementation of government policy can have an influence on market environment and market prices of pork in consequence. In South Korea, consumers prefer high-fat pork cuts due to the prevalence of roosting pork over a hot grill. This paper examines the impact of the government policy which aims to increase the consumption of low-fat pork cuts because of the concerns regarding asymmetric consumption between high-fat and low-fat pork cuts. Using hedonic price methods combined with quasi-experimental approaches we estimate the subsequent impact of food policy on the price of low-fat pork cuts using a time series of sales data. This study utilized an effective approach which has been widely employed for policy evaluation to produce plausible estimates of the economic values generated by the government policy. We find the existence of market segmentation and different impacts of the policy between markets. While the market price for high-fat pork cuts has remained stable, the price for low-fat pork cuts has slightly increased since the policy has been implemented. This paper illustrates that government's policy can be a good strategy to maintain sustainability of the food industry by improving the balance in pork consumption and the management of stocks.

Keywords: low-fat pork cuts; hedonic price method; government policy; market segmentation; sustainability of food industry

1. Introduction

As the economy grows and households' incomes increase, the meat consumption in South Korea has steadily increased. The pork consumption accounts for nearly 50%, which is the highest among meat consumption in South Korea [1]. However, the consumers' preferences for pork consumption vary depending on meat cuts. Because roasting pork over a hot grill is prevalent in Korea the pork cuts that consumers prefer most include high-fat cuts such as belly, shoulder, and ribs in which these cuts represent about 22.6% of a pig [1]. While the increase in demand for these cuts has resulted in increase in domestic supply and imports from other countries to meet the demand, the stock of other low-fat parts such as foreleg, hind legs, tenderloin, sirloin etc. has consequently increased due to excess supply. In order to retrieve a great loss associated with inventory holding costs of low-fat parts, meat retailers/processors push the sales price up for the high-fat parts, which in turn serves as hindrance factors for the sustainable development of pork industries.

It is well known that pork meat is high in good protein, key fat-soluble vitamins and minerals [2,3]. However, high fat intake through consuming red meat, e.g., pork belly may increase the risk of developing non-communicable diseases including cardiovascular disease, obesity, dyslipidemia, and cancer [2–5]. It is largely undisputed that a high fat consumption is closely related to dyslipidemia and cardiovascular disease [6]. To sum up, it is very likely that excessive consumption of high-fat pork cuts as part of an asymmetric diet results in worsened nutrient (undue fatty acid) intake, thus having adverse health effects in the long-term.

Because of the concerns regarding asymmetric consumption of pork cuts and its negative health effect, the Korean government announced *Structural Improvement Measures of Agricultural Marketing in* May 2013. This measure aims to resolve imbalanced consumption trend between pork cuts by improving distributional channels and consumption of relatively healthy low-fat pork. In response to this government policy, Ministry of Agriculture, Food and Rural Affairs (MAFRA) and Ministry of Food and Drug Safety (MFDS) jointly established new institutional frameworks that allow to process pork products using low-fat cuts at the store itself and sell them instantly to consumers. Besides, MAFRA provides systematic supports to foster balanced consumption of pork cuts and improved nutrient intake via financial support, manpower training, and investment in R&D, etc. In addition, Korea Pork Producer Association continuously performs several events such as discount event and free sampling event at various stores as well as releasing advertising campaign via media source to promote sales of low-fat cuts. For example, these institutions have advertised several times a healthy diet of low-fat cuts to change consumers' awareness.

These endogenous actions conducted by several institutions can have an influence on change in the consumption of pork cuts and management of stocks, which can lead to maintain sustainability of the food industry by improving the balance in pork consumption and reducing inventory holding costs of stocks. In other words, the government policy can have an impact on market environment (both demand and supply side) and this can result in changing market equilibrium price that buyers and sellers agree upon. In other words, the impact of government's endogenous measures such as advertising, marketing campaigns, and public relations can be captured in market prices of the foods. For instance, if the consumer's demand for particular products is increased by a policy the retailers/suppliers will increase sales prices of those products. Since the sales prices are market-clearing prices on which consumers and sellers reach some agreement, the influence of the government's policy can be assessed by examining change in market prices before and after the policy implementation holding other factors which can also have an effect on market prices constant. Therefore, it is worthwhile to examine the effectiveness of the policy implementation for the accomplishment of its goals and the magnitudes of the policy impact measured in economic aspects.

We estimate economic impact of the food policy associated with encouraging consumption of low-fat pork using hedonic price methods. The econometric models used in this study are specified to evaluate the differential impacts of the policy based on different pork cuts (i.e., high-fat pork versus low-fat pork sold in the same region) and with respect to low-fat pork sold in an adjacent market. To estimate the causal impact of policy interventions on pork prices we used retail sales data in metropolitan areas including Seoul, Gyeonggi-do, and Incheon from year 2012 to 2014.

In conducting economic analysis, we combined hedonic price methods with quasi-experimental methods, known as difference-in-difference (DD) and difference-in-difference-in-difference (DDD) approaches. These approaches have been widely used in various research fields to derive the difference of average values in outcome variable caused by a policy or events between a treatment group and a control group [7–14]. Following Heintzelman [11] and Kim et al. [14], we incorporate a region fixed effect into the model to capture time-invariant unobserved influences on pork prices between pork cuts and to control for spatial dependencies. For example, pork prices are more likely to be correlated within the same region (e.g., city, province, or administrative districts in the city) but are less likely to be affected by the prices sold in other areas. From our analysis, the economic impact of the government policy can be captured in change in market prices and the magnitude of these values can represent the effectiveness of policy implementation.

This study can be distinguished from the existing food-related literatures in that: (1) while most of the studies examined the causal impact of livestock disease emergence such as foot-and-mouth disease (FMD) or avian influenza (AI) on meat consumption, this study may be the first attempt to identify the impact of government policy on change in market prices of pork cuts; (2) This study applies the combination of hedonic price and quasi-experimental methods, which can be regarded as an effective approach to explore credible estimates of the monetary values generated by the government policy.

This paper is organized as follows: the next section presents a review of relevant literature. Section 3 represents theoretical basis of hedonic price method. The data employed in the analysis are then described followed by a section that outlines our empirical model specifications. The empirical results are then presented and discussed. This article closes with a brief conclusion.

2. Review of Related Literature

Numerous studies using hedonic price model in the context of valuation of environmental policy and/or event have been undertaken with regard to water quality [15–18] and water quantity (or level) [19–21]. However, the conduction of hedonic price studies of assessing the effect of controlling water quality and quantity on residential property values in a quasi-experimental framework that considers the water policy is recent. For example, Heintzelman [11] conducted a DD analysis to measure the effect of the Massachusetts Community Preservation Act, which was passed with intent to preserve open space and cultural assets, upon property values. Zabel and Guignet [12] estimated the effect of leaky underground storage tank areas on property values through the leak discovering model as the experimental treatment applied to a specific treatment group.

There are also a number of studies on identifying factors affecting food prices and consumption using different methodological approaches. In South Korea, several studies have examined the impact of change in market environment caused by advertising to promote pork consumption. Jeong et al. [22] estimated the effects of a generic pork advertising (GPAD) on demand for the less-favored specialty pork cuts by using a limited dependent variable model using the ordered logit estimation to solve the ordered character of pork consumption. The model includes the recognition and favor of pork consumers for GPAD as demand shifters. They founded that the consumption for the less-favored specialty pork cuts could be increased and expanded by GPAD. Kim et al. [23] evaluated the impact of GPAD on the revenue of live-hog producers. The analysis of the marginal impact of GPAD on the farm level price (price effect analysis) facilitates directly deriving the revenue of hog-producers. It was, as a result, founded that GPAD had a positive impact on the producers' revenue. Cho et al. [24] developed a nonlinear Rotterdam Model with a generic advertising (GAD) variable (demand shifter) which evaluates the impacts of GAD on monthly domestic and imported beef, pork and poultry demand. The results showed that GAD of pork had a considerable effect on decline in demand for domestic and imported beef as consumers have a vital concern about food safety and BSE.

Around the world, many economists have paid much attention on the investigation of influence of food safety or product recall information which gains media coverage on demand for food and its market environment [25–34]. Piggott and Marsh [30], in particular, developed a theoretical model of consumer response to publicized food safety information on U.S. meat consumption. They found that pre-committed levels of meat consumption are influenced by seasonal factors, time trends, and contemporaneous own- and cross-commodity food safety concerns. The consumer demand response on average to food safety concerns is small, particularly compared to price effects, and to previous estimates of health-related issues. This small effect hides periods of significantly larger responses in accordance with notable food safety events. However, the larger effects do not last long without evident food safety impacts on demand for meat. Mazzochhi and Stefani [35] developed a measure of a loss in consumer welfare related to hidden information on bovine spongiform encephalopathy (BSE) linked to food safety by retrieving a cost function from a dynamic Almost Ideal Demand System (AIDS). The results of this study show that consumers endured a considerable welfare loss due to the postponed disclosure of information about BSE linked to food safety. Mazzochhi [36] developed a stochastic parameter method which includes the time-varying impacts of food scares (bacterial contamination and BSE) on meat consumption instead of including news coverage indices in the demand function. The demand model including the time-varying parameters facilitates eliciting the impact of information on food safety and improved predictions in the short-term.

A few studies have examined the impact of policy actions such as tax, subsidy and food labelling regulations on change in food consumption patterns. Darmon et al. [37] and Hyseni et al. [38] particularly found the evidence that pricing mechanism (price intervention) on increase and decrease in prices of unhealthy and healthy foods through taxes and subsidies can change food consumption patterns and improve the nutritional quality of diets. Miller and Cassady [39] investigated the impact of providing additional nutrition information on healthy dietary intake promotion. They found that consumers' nutrition knowledge is important for communication of nutrition information through labels on package foods. However, only consumers with prior knowledge are more likely to use label information effectively, which means that policies on positive promotion and sufficient provision of nutrition knowledge on food labels can help consumers make healthful dietary decisions.

In our analysis, we follow the quasi-experimental literature and exploit the government strategy as an experimental treatment. In DD analysis, since we have information about the meat cuts sold, we grouped each sale into two groups; a treatment group which consists of low-fat cuts, and a control group that includes high-fat cuts. However, this DD approach is extended to a DDD analysis by including low-fat and high-fat cuts sold in a different, nearby housing market as an additional control. These frameworks allow us to estimate the difference in sales prices between these meat groups, both before and after the implementation of the policy to evaluate the economic impact of the food policy on the market prices of pork meat.

3. Theoretical Basis of Hedonic Price Method

The consumer's maximization problem associated with purchasing pork meat subject to a budget constraint can be described as follows:

$$\max_{\{z,q\}} u(z,q)$$

$$\text{s.t } y = z + P(q)$$

where z is the numeraire good with which price is normalized to one and q is the vector of pork related attributes such as pork cuts, brand, and packing size etc. In the constraint y is the household's income and P(q) is the hedonic price function which is assumed to be an equilibrium price and is described as a function of a bundle of attributes, q. Assuming an interior solution, the first order condition (FOC) maximizing consumer's utility is organized as the following condition:

$$\frac{\partial u/\partial q_i}{\partial u/\partial z} = \frac{\partial P(q)}{\partial q_i}\ i = 1,\ \ldots, n \tag{1}$$

where left-hand side in Equation (1) is the marginal rate of substitution (MRS) between q_i and z and right-hand side is the slope of hedonic price function associated with an attribute, q_i.

Household's bid function which is defined as the maximum amount of money household would be willing to pay for a particular product and is comprised of attributes (q), income (y), and baseline utility (u_b) is expressed as $\varphi(q, y, u_b)$. By definition, it must be true that after purchasing a product, the amount of money left over household income can be spent on consuming composite good, z. Mathematically,

$$y - \varphi(q, y, u_b) = z \tag{2}$$

Holding utility constant at the baseline level (u_b) while other elements, z and q can vary is expressed as

$$u(z, q) = u_b \tag{3}$$

Substituting Equation (2) into Equation (3) gives the following expression:

$$u(y - \varphi(q, y, u_b), q) = u_b \quad (4)$$

Taking total differential of Equation (4) with respect to q_i can be written as:

$$\frac{du}{dq_i} = -\frac{\partial u}{\partial z}\frac{\partial \varphi}{\partial q_i} + \frac{\partial u}{\partial q_i} = 0 \quad (5)$$

Arranging Equation (5) in terms of the slope of bid function associated with q_i yields the result as follows:

$$\frac{\partial \varphi}{\partial q_i} = \frac{\partial u/\partial q_i}{\partial u/\partial z} \quad (6)$$

Finally, comparing two conditions, Equations (1) and (6) provides an interesting and important result that has been used in hedonic literatures.

$$\frac{\partial P(q)}{\partial q_i} = \frac{\partial u/\partial q_i}{\partial u/\partial z} = \frac{\partial \varphi}{\partial q_i} \quad (7)$$

The condition, Equation (7) shows that household's bid function for marginal change in q_i is equal to the slope of hedonic price function at the optimum.

To recover an inverse demand function and derive consumer surplus, the 1st stage hedonic analysis can be extended to the 2nd stage hedonic method. This approach, however, is challenging to apply since it must deal with issues such as data availability in terms of buyer's socioeconomic information and two significant econometric-related issues to overcome to obtain consistent parameters. Based on these contexts, estimating hedonic price function is prevalent in hedonic literature to assess the marginal value of an attribute.

4. Data

We used retail sales data obtained from the Rural Development Administration (RDA) who collected household's purchasing information associated with pork cuts from January 2012 to November 2014 in Seoul, Gyeonggi-do, and Incheon (Note that data were available from 2009 to 2014 but a reviewer suggested focusing on the 2012 to 2014 period because of the concerns regarding the parallelism of the time paths before and after policy implementation.). After deleting sales information which obviously involved incorrect and/or some missing information, a final sample of 218,656 observations in total (82, 513 in Seoul, 112,299 in Gyeonggi-do, and 23,844 in Incheon) was used for econometric analysis. The data included purchasing date, region (city and province), pork cuts purchased, and the sales prices for each cut, but missed the information regarding country of origin, brand, and packing size etc. for which these attributes can affect market price. Table 1 provides definitions and mean values of the variables used in the hedonic regressions.

Table 1. Variable definitions and means of variables used in the analyses.

Variable	Variable Description	Mean	St. Dev.
price	retail price (won/100 g, constant 2010 KRW)	1289.1	591.7
Belly	belly = 1, otherwise = 0	0.112	0.316
Foreleg	foreleg = 1, otherwise = 0	0.112	0.316
Hindleg	hind leg = 1, otherwise = 0	0.103	0.304
Rib	rib = 1, otherwise = 0	0.112	0.315
shin	shin = 1, otherwise = 0	0.111	0.315
shoulder	blade shoulder = 1, otherwise = 0	0.112	0.316
sirloin	sirloin = 1, otherwise = 0	0.113	0.316
special	special part = 1, otherwise = 0	0.113	0.316
tenderloin	tenderloin = 1, otherwise = 0	0.112	0.315
year12	year 2012 = 1, otherwise = 0	0.344	0.475

Table 1. *Cont.*

Variable	Variable Description	Mean	St. Dev.
year13	year 2013 = 1, otherwise = 0	0.341	0.474
year14	year 2014 = 1, otherwise = 0	0.315	0.465
policy	after policy implementation = 1, otherwise = 0	0.543	0.498
treatment	low-fat cuts (foreleg, hindleg, shin, sirloin, or tenderloin) = 1, otherwise = 0	0.550	0.497
holiday	national holiday effect (February or September) = 1, otherwise = 0	0.173	0.378
Seoul	Seoul = 1, otherwise = 0	0.377	0.485
Gyeonggi-do	Gyeonggi-do = 1, otherwise = 0	0.514	0.500
Incheon	Incheon = 1, otherwise = 0	0.109	0.312
N	218,656		

The dependent variable, sales prices per 100 g were adjusted to constant 2010 KRW by applying a Consumer Price Index (CPI) to pork prices provided by Statistics Korea [40] to account for inflationary effects. Pork cuts are classified into nine parts: belly, shoulder, foreleg, hindleg, tenderloin, sirloin, rib, shin, and special. These variables were transformed into dummy variables for each pork cut and included in the econometric analysis to estimate the relative effect on sales prices. We also generated dummy variables for each year in order to capture indirect effects of time on sales prices. In Table 1, the *policy* variable is a dummy variable for the observations taken place after the implementation of the policy. The *treatment* variable is a dummy variable for low-fat cuts which include foreleg, hindleg, tenderloin, sirloin, rib, or shin. *Holiday* variable is equal to 1 for the months associated with Korean Thanksgiving Day or New Year's Day. *Seoul*, *Gyeonggi-do*, and *Incheon* represent a dummy variable for each region to control for unobserved differences that might affect pork prices between regions.

The proportional distribution of observations for the DD and DDD analysis are shown in Table 2. For the DD analysis, we used data sold in Seoul because instant processing shops using low-fat pork cuts in the super supermarkets (SSM) has been operated mostly in Seoul while for a DDD analysis we included data sold in Gyeonggi-do, and Incheon as well. Out of 218,656 cases, the sample sizes in Seoul, Gyeonggi-do, and Incheon constitute 37.7% (82,513), 51.4% (112,299), and 10.9% (23,844). For Seoul samples, 54.5% of total samples correspond to the observations sold after the implementation of the policy of which low-fat cuts account for 30.2% and high-fat cuts make up 24.3%. The observations for low-fact cuts sold after the enforcement of the policy in Gyeonggi-do and Incheon comprise 18.5% of total observations.

Table 2. The distribution of observations in three regions before and after policy implementation.

Area	Group	Observation		
		Before Policy	After Policy	Total
Seoul	Treatment	20,750	24,904	45,654
	Control	16,797	20,062	36,859
	Total	37,547	44,966	82,513
Gyeonggi-do	Treatment	28,344	33,433	61,777
	Control	23,089	27,433	50,522
	Total	51,433	60,866	112,299
Incheon	Treatment	5921	7009	12,930
	Control	4987	5927	10,914
	Total	10,908	12,936	23,844
Grand total		99,888	118,768	218,656

The proportion representing the DDD observations (i.e., low-fat cuts sold after the policy in Seoul) make up about 11.4% of total samples. In this merged data, the number of observations available to identify the impact of the policy is quite small (i.e., the treatment group is very small relative to the overall sample). Such cases may limit the statistical influence on capturing the impacts of the policy on prices [11,14]. Despite the relatively small treatment samples, however, we find that the government policy has had an influence on increase in sales prices for low-fat cuts.

5. Empirical Model Specifications

Given the available data, the first step of empirical analysis involved specifying the hedonic price equation and the appropriate functional form. Based upon Box-Cox regression procedures and examination of the previous hedonic studies we chose the log-linear functional form of the hedonic price equation.

5.1. Difference-in-Difference Estimation

The DD method has been widely used to analyze impacts of policy interventions. This approach is also regarded as a suitable approach to deal with omitted variable bias which is one of the econometric issues of concern [11,41,42] (As mentioned earlier, the data used in this study lack the information on other pork attributes such as country of origin, brand, and packing size etc. Estimating the hedonic model without these attributes may cause omitted variable bias since these attributes may have an impact on the determination of pork price. In such case, combining hedonic model with DD method can help reducing omitted variable bias [11,14].). Thus, we assumed that the government policy represents the policy intervention aimed at increasing the consumption of low-fat cuts, and that the values of low-fat pork cuts were significantly affected by policy intervention. The treatment group was considered to be the low-fat pork cuts and the control group high-fat pork cuts. To identify the sales that were affected by the policy in our time series of sales we created a dummy variable for the periods after the implementation of the policy (i.e., from May 2013 to November 2014).

Following previous literatures, this study used region fixed effects structure to control for unobserved differences that might affect pork prices between markets rather than relying on the cross-sectional estimates [11,14]. To deal with spatial dependencies (For instance, sales prices of food are more likely to be dependent on nearby market prices but are less likely to be affected by the prices in other areas.) we used general census zones in Seoul, which is divided into three areas; southern Seoul, northern Seoul, and western Seoul. In addition, we applied clustered standard errors at the level of region fixed effects to control for potential heteroscedasticity that might exist in the same census zone [14]. The econometric model for DD estimation was:

$$\mathrm{lnP_{igt}} = \beta_0 + \beta_d X_{it}^{d} + \beta_{DD}\mathrm{DD_{it}} + \theta_t + \lambda_g + \mu_{gt} + \varepsilon_{igt} \tag{8}$$

where $\mathrm{lnP_{igt}}$ is the log transformation of sales price for pork cut *i* in group *g* at time *t*, X_{it}^{d} indicate dummy variables respectively, and $\mathrm{DD_{it}}$ represents a dummy variable that is interacted with the dummy for the time periods the policy has been in place and a dummy for each treatment group; θ_t represents a set of time dummy variables that capture any trends in sales prices over time; and λ_g is a spatial fixed effect that absorbs differences that do not vary over time between markets. The terms β_0, β_d, and β_{DD} are individual or vectors of coefficients to be estimated. μ_{gt} and ε_{igt} represents region and individual levels of error components, respectively.

The coefficient of interest, β_{DD}, is the difference in difference estimator for the periods that the policy has been operated. More specifically:

$$\hat{\beta}_{DD} = \left(ln\overline{P}_{treat,policy=1} - ln\overline{P}_{treat,policy=0}\right) - \left(ln\overline{P}_{control,policy=1} - ln\overline{P}_{control,policy=0}\right) \tag{9}$$

where $\overline{P}_{treat}$ represents the average sale price of low-fat pork cuts, $\overline{P}_{control}$ is average sale price of high-fat pork cuts. The first term in Equation (9) is the average price difference due to the implementation of the policy with respect to low-fat pork cuts and the second is on average price difference attributed to the policy for high-fat pork cuts. Thus, the parameter $\hat{\beta}_{DD}$ captures the difference of these two terms.

Following Kennedy [43] the average percentage change (APC) in price of low-fat pork cuts due to the policy corresponding to Equation (8) is:

$$\mathrm{APC} = \{\exp(\beta_{DD} - 0.5\, V(\beta_{DD})) - 1\} \times 100 \tag{10}$$

where $V(\beta_{DD})$ is an estimate of the variance of β_{DD}.

5.2. *Difference-in-Difference-in-Difference Estimation*

Bertrand, Duflo and Mullainathan [44] argued that DD frameworks may have a potential problem regarding endogeneity of the policy effect itself. To address this issue, a few studies extended DD analysis to a difference-in-difference-in-difference (DDD) analysis. This DDD approach can be extended from the DD analysis by involving other sales observations which took place in a similar but different market. Our DD analysis assumed that in the absence of the policy the price time paths for high-fat pork cuts and low-fat pork cuts within the Seoul would move in tandem with those in an associated market. However, since it is possible that other factors unrelated to the policy could influence the values of high-fat pork cuts, the assumption is not likely to be assured.

To gain more accurate estimates of the impact of the policy for promoting low-fat pork consumption on its sale price, we use DDD approach extended from DD by using integrated information from the three (regional) markets. In our DDD analysis, it is assumed that factors causing disparate changes in sales prices of different pork cuts (high-fat pork cuts versus low-fat pork cuts) are universal to the three markets. In other words, the DDD estimator is specified to correct for possible bewildering trends, such as changes in low-fat pork cut values, across the three markets, which is not likely to connect to the government intervention. Another point of the DDD analysis is to control for the changes in values of all pork cuts within Seoul which could be influenced by region-specific factors.

Similar to the DD model, in the DDD analysis, we applied a region fixed effect model where each pork cut was placed into one of nine regional groups: southern Seoul, northern Seoul, western Seoul, southeast Gyeonggi-do, northeast Gyeonggi-do, southwest Gyeonggi-do, northwest Gyeonggi-do, central Gyeonggi-do, and Incheon. It is obvious that the sample divided up into smaller group could be further effective with regard to curbing more factors. In doing so, however, there is less probability of generating powerful estimates. This is because it is required to be adequate within-group variation in each explanatory variable for triumphant estimation acquisition. Extension of the range of region-fixed effects, however, is likely to be vulnerable to high probability of omitted variables bias [11].

The model structure of our DDD estimation is expressed as follows:

$$\begin{aligned} \ln P_{igt} = \ & \beta_0 + \beta_d X_{it}^{d} + \beta_{seoul \times policy}\, \mathrm{Seoul}_{igt} \times \mathrm{Policy}_t \\ & + \beta_{treatment \times policy} \mathrm{Treatment}_{it} \times \mathrm{Policy}_t + \beta_{DDD} \mathrm{DDD}_{igt} + \theta_t \\ & + \lambda_g + \mu_{gt} + \varepsilon_{igt} \end{aligned} \tag{11}$$

where $\ln P_{igt}$ is the log transformation of sales price for pork cut *i* in group *g* at time *t* and X_{it}^{d} are the same variables defined as in Equation (8). Seoul_{igt} is a dummy variable for pork cuts sold in Seoul, $\mathrm{Treatment}_{it}$ is a dummy variable for those observations which are low-fat pork cuts in samples from Seoul, Incheon and Gyeonggi-do, Policy_t indicates a dummy for the implementation of the policy from May 2013 to November 2014. $\mathrm{Seoul}_{igt} \times \mathrm{Policy}_t$ term represents an additional dummy variable for the pork cuts sold in Seoul after implementing the policy. In the same manner, $\mathrm{Treatment}_{it} \times \mathrm{Policy}_t$ is a dummy variable equivalent to one for those observations which are low-fat pork cuts sold in Seoul, Incheon, and Gyeonggi-do after the implementation of the policy. Finally, DDD_{igt} represents the product between Seoul_{igt}, $\mathrm{Treatment}_{it}$, and Policy_{it} and is identical to one only if a pork type is low-fat pork cuts sold in Seoul after the policy intervention and 0 otherwise. As characterized in Equation (8),

θ_t is a set of time dummies and λ_g is a group fixed effect. The coefficient of interest, β_{DDD}, is the difference in difference in difference estimator of the following expression:

$$\begin{aligned}\hat{\beta}_{DDD} = &\left(ln\overline{P}_{Seoul,treat,policy=1} - ln\overline{P}_{Seoul,treat,policy=0}\right)\\ &- \left(ln\overline{P}_{other,treat,\ policy=1} - ln\overline{P}_{other,\ treat,policy=0}\right)\\ &- \left(ln\overline{P}_{Seoul,control,policy=1} - ln\overline{P}_{Seoul,control,policy=0}\right)\end{aligned} \quad (12)$$

where the first term in Equation (12) is construed as the average sales price difference caused by the implementation of the policy in terms of low-fat pork cuts in Seoul. The second term is, on the other hand, taken as the average sales price difference arising from the government policy in connection to low-fat pork cuts in other regions: Incheon and Gyeonggi-do. The last term is interpreted as the price difference resulting from the policy for high-fat pork cuts in Seoul. Note that if this second term is removed, then β_{DDD} will collapse into the DD estimate [14].

6. Results and Discussion

Table 3 shows the estimation results for the DD and DDD models. To verify the validity of regional group-fixed effects, we conducted a test of the null hypothesis that all group fixed effects are zero. The hypothesis was, as a result, rejected in favor of regional group-fixed effects. For the presence of the multicollinearity, we confirmed that our empirical models exhibit very less collinearity since the average variance inflation factors (The variance inflation factor (VIF) quantifies the severity of multicollinearity in an ordinary least squares regression. It provides an index that measures how much the variance (the square of the estimates' standard deviation) of an estimated regression coefficient is increased because of collinearity.) (VIF) were below 2 or 3.

Table 3. Parameter estimates for difference-in-difference (DD) and difference-in-difference-in-difference (DDD) models.

Variable	DD Model		DDD Model	
	Coefficient	Std. Err.	Coefficient	Std. Err.
constant	7.3915 *	0.0023	7.3548 *	0.0241
foreleg	−0.4119 *	0.0030	−0.4144 *	0.0160
hindleg	−0.6683 *	0.0034	−0.6462 *	0.0292
rib	−0.4188 *	0.0028	−0.4004 *	0.0205
shin	−0.5150 *	0.0029	−0.4761 *	0.0159
shoulder	0.0230 *	0.0026	0.0157	0.0103
sirloin	−0.2845 *	0.0035	−0.2716 *	0.0142
special	0.4206 *	0.0043	0.3730 *	0.0269
tenderloin	−0.3900 *	0.0034	−0.3867 *	0.0103
belly	reference		reference	
holiday	0.0180 *	0.0025	−0.0033	0.0113
DD	0.0444 *	0.0025		
seoul × policy			0.0029	0.0121
treatment × policy			−0.0084	0.0109
DDD			0.0391 **	0.0131
year12	−0.0233 *	0.0025	−0.0172	0.0292
year13	−0.1345 *	0.0021	−0.1137 *	0.0188
year14	reference		reference	
F test	85.27 *		202.52 *	
Mean VIF	1.86		2.09	
N	82,513		218,656	
Adj R^2	0.66		0.65	

Note: Standard errors were clustered at the level of spatial fixed effects to control for potential heteroscedasticity.
* significant at 0.01 level; ** significant at 0.05 level.

Most of the variables in the DD models are statistically significant at the 1 or 5% level corresponding to our expectation of the signs of parameters. In terms of polychotomous binary variables, the coefficients for all variables can be explained as compared with the reference category variable while controlling for the other explanatory variables. The coefficient on *foreleg*, for example, indicates that holding other factors constant the sale prices of *foreleg* is around 33.8% lower than that of *belly*. While *shoulder* and *special* have around 2.3% and 52.3% higher prices respectively in comparison to *belly, hindleg*, *rib*, *shin*, *sirloin* and *tenderloin* have 48.79%, 34.2%, 40.3%, 24.8% and 32.3% lower prices individually. The time dummies (*year 12 to year 13*) can be interpreted in an analogous way. The *holiday* variable is statistically significant and has a positive effect on sales prices of pork.

The coefficient on the single DD variable indicates the % change in sales prices of low-fat pork cuts due to the government policy. Since this coefficient is positive and statistically significant we find evidence that the policy implementation had a positive and significant impact on the sales prices of low-fat pork cuts sold in Seoul. Using the formula described in Equation (10), the *DD* parameter shows that the policy aimed at increasing the consumption of low-fat pork cuts led to around a 4.5% increase in values for low-fat pork cuts in Seoul.

Similar to the result of DD model, DDD model result proves that there is also region fixed effects and no concern about the multicollinearity problems. In comparison to the result of the DD model, it is confirmed that *shoulder*, *holiday*, and *year12* variables are not statistically significant any more. The *seoul* $\times$ *policy* variable indicates that after the policy implementation the sales prices of both the high- and the low-fat pork cuts are averagely different from their corresponding base categories. However, this variable is not statistically significant. The *treatment* $\times$ *policy* variable which indicates the sales prices of low-fat pork cuts sold in Seoul, Incheon and Gyeonggi-do after the implementation of the policy, describes the difference in the mean sales prices compared to the base category. Similarly, this variable is also statistically insignificant. This implies, in other words, that the change in sales prices of low-fat pork cuts sold in the three regions is not different from those of pork cuts belonging to the base category.

The coefficient on the DDD variable describes the % change in prices of low-fat pork cuts sold in Seoul after the policy enforcement. Similar to the result from the DD model, it is confirmed that the government policy has a positive impact on the sale price of the low-fat pork cuts. However, the magnitude of the coefficient on the DDD variable is less than that of the DD variable which means the effect of the policy on the sale price of low-fat pork cuts is also smaller. Applying the formula specified in Equation (10), the sale price of the low-fat pork cuts sold in Seoul due to the policy implementation rises by around 4.0% on average.

The assumption about the parallel trend of the outcomes between treatment and control group in the absence of policy implementation is crucial to verify the validity of the DD models. To verify this, the mean prices of both a control group (high-fat pork cuts) and a treatment group (low-fat pork cuts) before policy implementation are shown in Figure 1. It is verified that before the implementation of the policy the trends in the sales prices of two groups are quite similar, which implies the assumption is likely to be satisfied.

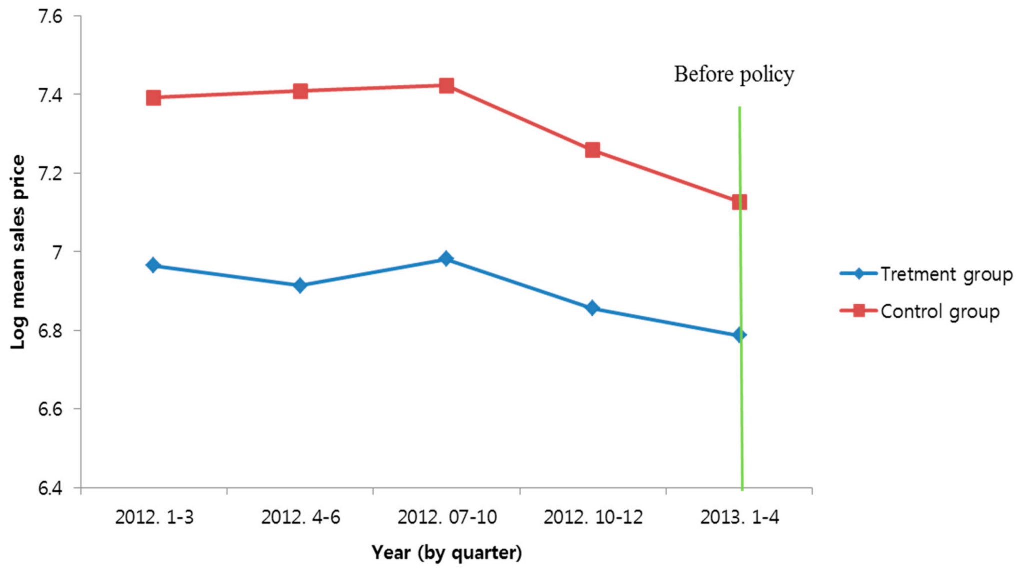

Figure 1. Mean sales price (2010 KRW) of pork cuts sold in Seoul before policy implementation.

6.1. Economic Effect of the Government Policy

The results from both DD and DDD models show that the government policy has a positive impact on improving sales prices of the low-fat pork cuts. We, thus, estimate the economic effect of the policy by using the mean and the median prices of the low-fat pork cuts sold in Seoul. The result is presented in Table 4.

Table 4. Economic impact estimation of low-fat pork cuts sold in Seoul due to the policy implementation.

Model		Sales Price (won/100 g)	% Increase	Price Increase (won/100 g)
DD	Mean	1039.59	4.5	47.15
	Median	1001.31	4.0	45.41
DDD	Mean	1039.59	4.5	41.37
	Median	1001.31	4.0	39.84

Note: the price expressed in Table 4 is in year 2010 KRW.

Based on the significant parameters related to the policy impact on the sale price of the low-fat pork cuts in the DD models, the economic impact (in year 2010 KRW) of the policy is estimated to be KRW 45.41 to 47.15 per 100 g. Based on DDD models it is estimated to be KRW 39.84 to 41.37 per 100 g. These figures can be interpreted as the economic values generated by government policy aiming at increasing consumption of low-fat pork cuts. As shown in Figure 2, the government policy can have potential implications for maintaining the sustainability of pork industry by improving the balance in pork consumption and the management of stocks, which can result in increasing the efficiency of pork distribution. Note that the total economic effect can be assessed by applying total amounts of low-fat pork cuts sold in Seoul after implementation of the policy (Unfortunately, no information regarding the amounts of low-fat pork cuts sold in Seoul is available so we are not able to derive the total economic impact of the policy.).

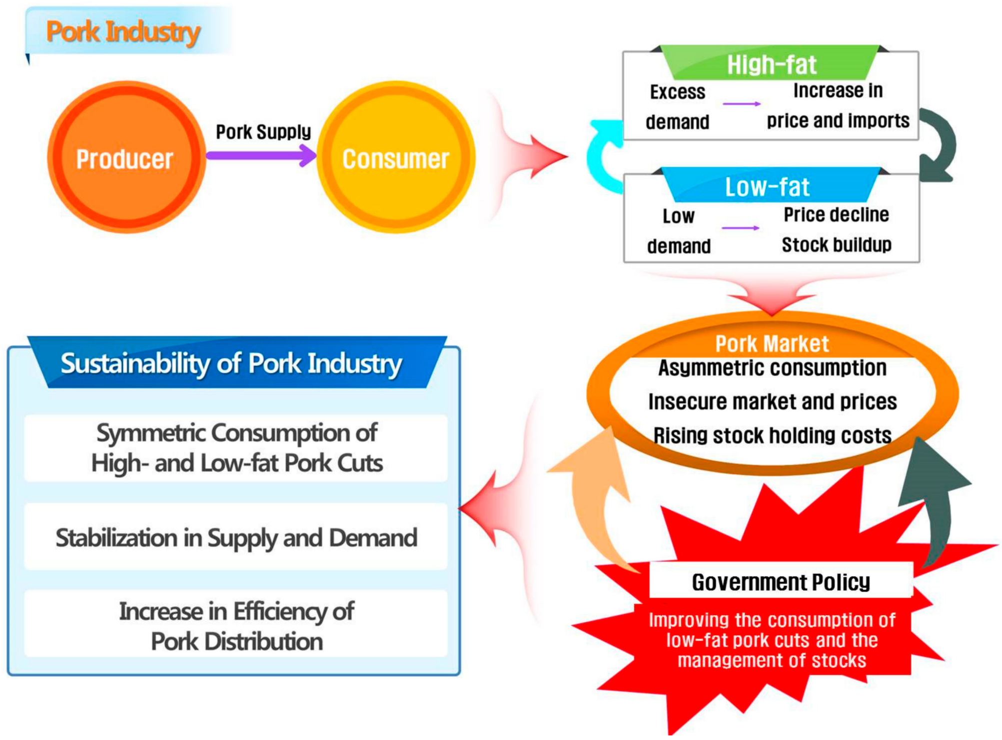

Figure 2. A graphical illustration of the effect of the government policy on the sustainability of pork industry.

6.2. Verification of Modeling Approach

In order to verify reliability of our model results, we conducted some sort of falsification tests. First, we estimated different DD models assuming that the policy has more influence on Incheon and Gyeonggi-do than Seoul using each regional sample. The results are presented in Table A1 in the Appendix A. The results indicate that the coefficient on the DD variable either in the Incheon or in the Gyeonggi-do model is not statistically significant. This can support our model specification that Seoul is affected most by the government policy compared to Incheon and Gyeonggi-do. In addition, this might imply the existence of market segmentation between three regions.

We, secondly, conducted a test of the null hypothesis that there is no difference in sales prices of low-fat pork cuts between three regions in order to confirm whether the mean sale prices of low-fat pork cuts in Seoul are different from those in Incheon and Gyeonggi-do. As a result, the null hypothesis is rejected implying there is a difference in sales prices of low-fat pork cuts between the three regions (see Table 5).

Table 5. Test on the difference in the mean sale price of low-fat pork cuts between groups.

Group	Observation	Mean	Std. Err.
Seoul	45,654	1039.59	1.327
Gyeonggi & Incheon	74,707	1002.31	0.925
Difference		37.28	1.573
Test	$t = 23.69$, p-value = 0.000		

Thirdly, we examined the annual average stocks of both pork groups before and after the implementation of the policy (Figure 3). Before the implementation of the policy there were similar trends in the annual average stocks between two groups. However, after implementing the policy, the stocks of low-fat pork cuts have decreased significantly while those of the high-fat pork cuts have remained unchanged.

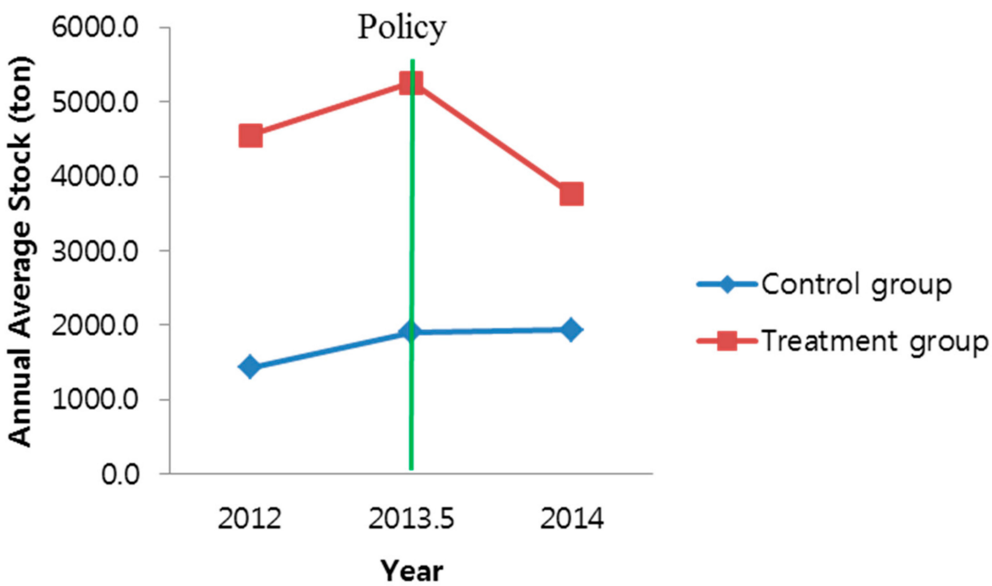

Figure 3. Annual average stock of high-fat pork cuts (control group) and low-fat pork cuts (treatment group) from 2012 to 2014.

Finally, we checked information disseminated via media on operating instant processing shops using low-fat pork cuts along with the creation of the meat instant sales processing industry in super supermarkets (SSM) after May 2013. It was confirmed that some SSMs such as E-mart, Homplus and Nonghyup run the meat instant processing shops mostly in Seoul [45]. This can be also another evidence of our study results verifying the positive effect on the value improvement of low-fat pork cuts sold in Seoul.

In an attempt to examine the consistency of our findings, we compared our results to other studies which used disparate approaches on examining the impacts of food policy implementation such as tax or subsidy on food consumption patterns [37–39]. These studies found that the government policy have an influence on change in the consumption patterns for particular foods.

7. Conclusions

Korean consumers have preferred high-fat pork cuts such as belly, shoulder, and ribs along with the influence of Western eating patterns and cultural formation of roasting meat, resulting in asymmetric consumption of pork cuts. To solve this disproportionate consumption pattern, the policy aimed at promoting the consumption of low-fat pork cuts such as foreleg, hind legs, tenderloin, sirloin etc. was implemented in May 2013. After the policy implementation, various public relations such as media reports, promotional and tasting events and so on. were operated. Based on these contexts, this study not only estimates the value of pork features, but also examines the effect of the policy on sales of low-fat pork cuts.

Based on time-series sales data from January 2012 to November 2014, our study estimates the economic effect of the policy implementation using DD and DDD approaches. The DD analysis result shows that only Seoul is influenced by the policy which might imply pork markets are segmented by regions. The DDD analysis result indicates that the size of the policy effect is smaller compared to the DD model. It is, however, confirmed that the policy implementation positively affects sales prices of low-fat pork cuts sold in Seoul. This result suggests that in order to achieve the goal and improve the efficacy of the government policy the institutional supports such as finance, manpower training, and investment in R&D should be extended to other regions. We conducted some tests to verify reliability of estimation results from the two models. Based on each model, the monetary values of the policy are estimated ranging from between KRW 39.84 and KRW 47.15 per 100 g.

There are a variety of attributes such as country of origin, brand, packing size, and so on, which can have an impact on the determination of sale prices of pork cuts. Due to the lack of data on these attributes, we estimated our empirical model without these attributes, which is the limitation of our study. However, our study contributes to presenting a very effective methodology for the ex-post economic valuation of government policy.

To conclude, while our study is associated with the policy aimed at increasing low-fat pork cuts and improving the balance the management of stocks in South Korea, the method utilized in this study can be also applied to evaluate the validity of policy or exogenous events in other cases. In addition, we believe that our study results would be of interest to policy makers or the meat industry involved in the management of food consumption/supply chain.

Acknowledgments: We would like to acknowledge the support from the research project (RE2018-19) of the Korea Environment Institute (KEI). This study was funded by the University of Bayreuth in the funding program Open Access Publishing, Germany.

Author Contributions: Hyun No Kim designed the experiments, analyzed the data, performed econometric analysis, and wrote main text. Ik-Chang Choi contributed literature reviews and data arrangement and gave inputs to logical flow in sustainability concepts.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A.

Table A1. The estimation results of another DD model specification (falsification tests).

Variable	Incheon Model		Gyeonggi-Do Model	
	Coef.	Std. Err.	Coef.	Std. Err.
constant	7.2802 *	0.0052	7.3897 *	0.0020
foreleg	−0.3442 *	0.0063	−0.4452 *	0.0024
hindleg	−0.5920 *	0.0068	−0.6551 *	0.0029
rib	−0.2925 *	0.0063	−0.4103 *	0.0028
shin	−0.4239 *	0.0066	−0.4726 *	0.0026
shoulder	0.0804 *	0.0061	−0.0036	0.0023
sirloin	−0.2115 *	0.0070	−0.2890 *	0.0027
special	0.4133 *	0.0074	0.3295 *	0.0029
tenderloin	−0.4056 *	0.0069	−0.3938 *	0.0027
belly	reference		Reference	
holiday	−0.0162 *	0.0037	−0.0187 *	0.0015
DD	0.0004	0.0058	0.0014	0.0021
year12	−0.0178 *	0.0049	−0.0502 *	0.0020
year13	−0.1133 *	0.0042	−0.1111 *	0.0016
year14	reference		reference	
F test	n/a		291.07 *	
Mean VIF	1.85		1.85	
N	23,844		112,299	
Adj R^2	0.58		0.66	

Note: Standard errors were clustered at the level of spatial fixed effects to control for potential heteroscedasticity.
* significant at 0.01 level.

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