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AGGREGATION BIAS FOUND IN KOREAN DEMAND FOR IMPORTED BEEF

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Key words
aggregation bias, beef, import demand

Abstract
The purpose of this paper is to analyze whether the aggregation problem really matters in estimating the Korean demand for imported beef. This paper incorporates the aggregation bias in the demand system and tests whether the aggregation bias is statistically significant with two models: an unrestricted model with aggregation bias variables and a restricted model without the bias variables. The impact of the aggregation bias is also analyzed by comparing the elasticities of the two models. According to the Wald test, the hypothesis of no aggregation bias is rejected and the LR (Likelihood Ratio) test shows that the unrestricted model is statistically better than the restricted model. However, the impact of the aggregation bias on the demand system for imported beef is not so severe in that the elasticities of the two models are not so different and the elasticities of aggregation bias variables are insignificant. This paper utilizes imported beef data of two types (frozen and non-frozen) from USA, Canada, Australia and Rest of World. The aggregation bias is decomposed into country effect, product effect and interaction effect.

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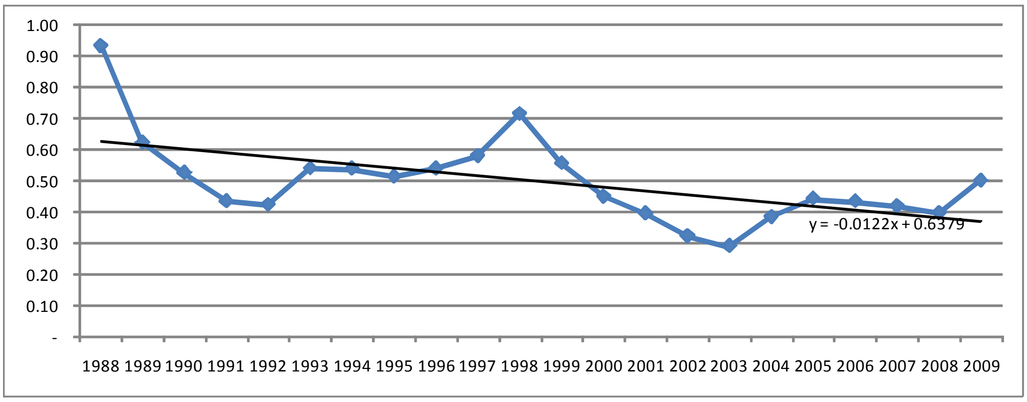
I. Introduction

The market share of domestic beef in the Korean beef market has been on a decreasing trend. The average market share of the Korean domestic beef from 2000 to 2009 was 40.3%, meaning that imported beef occupied more than a half share. The major exporting countries of beef to Korea were traditionally Australia, USA, and Canada, but the beef from Canada has not been imported since 2006.

FIGURE 1. The Share of Korean Domestic Beef



Source: Ministry for Food, Agriculture, Forestry and Fisheries(MIFAFF), Korea.
Note: The linear line is a trend line.

The Korean beef market has been traditionally analyzed in a two-market framework: domestic beef vs. imported beef, i.e. Korean beef vs. foreign beef. In this framework, there is no differentiation among imported beef in terms of country of origin. The two-market framework is implicitly based on a strong assumption that the imported products are homogeneous regardless of where they come from and they are perfectly substitutable to each other (Davis 1997). However, the aggregation based on the strong assumption can be easily exposed to the aggregation bias problem in which small fallacy in valid aggregation leads to large mistakes in elasticity and welfare estimates (Lewbel, 1996). Davis (1997) regards the aggregation bias problem as ‘omitted variables problem’ which causes the OLS estimator to be biased and inconsistent. This aggregation bias problem is often caused by the strong assumption for convenience to address specific research objectives without an empirical evidence for consistent aggregation (Shumway and Davis, 2001).

A few scholars such as Aw and Roberts (1986), Davis and Hewitt (1996), and Davis (1997) directly tackled the aggregation bias problem in footwear and tobacco import demand. The usage of aggregate unit-value for the true import price was regarded as a main source of the aggregation bias. Aw and Roberts (1986) suggested the Tornqvist partial index to measure the aggregation bias described as 'quality change' in footwear import demand. Davis and Hewitt (1996) differentiated quality and quality change and showed how the index theory can be applied to measure them (quality and quality change). Davis (1997) showed a theoretic and empirical background to incorporate the aggregation bias in specifying the demand system, where USA tobacco import demand is very sensitive to the aggregation bias.

However, in the estimation of the Korean demand for imported beef, most papers did not properly deal with the aggregation bias issue. They used aggregated data without analyzing the aggregation bias. Lee et al (1999) used aggregated import beef to estimate Korean domestic demand with OLS, and KREI (2003) also used the aggregated import of various meats such as beef, pork, and chicken with the demand system by regarding the imported meats as homogeneous regardless of the import sources. Capps et al (1994) used aggregated meat of Japan, Taiwan and Korea respectively to estimate each country's import demand with a Rotterdam model by regarding each country's meat as homogeneous regardless of the kinds of meat.

Therefore, the purpose of this paper is to analyze whether or not the aggregation problem really matters in estimating the Korean demand for imported beef. This paper follows Davis (1997) to deal with the aggregation bias issue in the Korean demand for imported beef. Specifically, this paper incorporates aggregation bias variables in an import demand system and tests statistical significances of the variables as Davis (1997) did. In the Korean demand for imported beef, the aggregation bias is decomposed into country effect, product effect and interaction effect between country and product. This paper also analyzes the impacts of the bias variables on two models[1], i.e., a restricted

[1] The unrestricted model is a model with aggregation bias variables while the restricted model is a model without aggregation bias variables because the restriction is that there is no aggregation bias.

model and an unrestricted model by comparing elasticities of the two models.

This paper is composed of a theoretical background of the aggregation bias, an empirical model to estimate the Korean demand for imported beef, data, the estimation procedure and results with implication and conclusion. This paper will provide empirical implication to researchers and policy makers who are interested in the Korean beef market.

II. Theoretical Background

Aggregation theory is utilized to measure and test aggregation bias. Superlative quantity and price indices are theoretically consistent aggregates, but the total quantity and unit-value price are not theoretically consistent aggregates (Diewert and Nakamura, 1993; Davis, 1997). So the aggregation bias can be defined as the difference between the theoretically consistent aggregates and the theoretically inconsistent aggregates (Davis, 1997). This paper adopts the definition of the aggregation bias. Product aggregation theory gives a following relation.

(1) $Q^T{}_i P^T{}_i = E_i = P^u{}_i Q^u{}_i, \qquad i =$ d, f, R

, where E_i is total expenditure on all products within *i*th aggregate, $Q^T{}_i$, $P^T{}_i$ are 'true(theoretically consistent)' aggregates, and $P^u{}_i$, $Q^u{}_i$ are 'untrue(theoretically inconsistent)' aggregates. The subscripts are as follows; d= domestic, f= foreign, R= rest of world. Utilizing a scaling function or distance function (B_i) that makes the scaled correct aggregator function equal to the incorrect aggregator function, i.e., $Q^T{}_i = B_i Q^u{}_i$, change of aggregation bias, $d\ln B_i$,is obtained by total differentiation of equation(1)[2].

(2) $d\ln B_i = d\ln Q^T{}_i - d\ln Q^u{}_i = d\ln P^u{}_i - d\ln P^T{}_i, \qquad i =$ d, f, R

2 The equation (2) is easily calculated by 1) taking log on right and left side of equation (1), 2) utilizing the relation $Q^T{}_i = B_i Q^u{}_i$ and 3) total differentiating. For a reference, the relation $Q^T{}_i = B_i Q^u{}_i$ is transformed into $\ln B_i = \ln Q^T{}_i - \ln Q^u{}_i$ through taking log on the relation.

Because continuous Divisia quantity and price indices are exact for $d\ln Q^T{}_i$ and $d\ln P^T{}_i$ if consistent product aggregation condition is satisfied (Hulten 1973), the equation (2) can be approximated in a discrete form by Tornqvist quantity and price indices yielding equation (3) (Davis 1997)[3].

(3) $$DB_{it} = DQ^T{}_{it} - DQ^u{}_{it} = DP^u{}_{it} - DP^T{}_{it}, \qquad i = \text{d, f, R}$$

, where DB_{it} is log change of aggregation bias from t-1 to t, $DQ^T{}_{it}$, $DP^T{}_{it}$ are log change of Tornqvist quantity and price indices from t-1 to t, and $DQ^u{}_{it}$, $DP^u{}_{it}$ are log change of ith aggregate total quantity and unit-value price from t-1 to t. From the above equality, if DB_{it} >0, then total quantity change underestimates the true change while unit-value change overestimates it.

As Aw and Roberts(1986) and Davis (1997) decomposed product aggregation bias into country effect, product effect and interaction effect between country and product, the aggregation bias in the Korean demand for imported beef may be caused by different country sources and different types of product.

By using the partial Tornqvist price index, the country effect and product effect are defined as follows.

(4) $$Db_{ijt} = DP^u{}_{it} - DP^T{}_{ijt}, \qquad i = \text{d, f, R} \quad j = \text{c, r (c=country, r = product)}$$

, where $DP^T{}_{ijt}$ is a partial Tornqvist price index. Specifically, a country effect, Db_{ict}, is derived by regarding all product types as homogeneous within each country (domestic, foreign, rest of world) while a product effect, Db_{irt}, is derived by regarding all countries homogeneous within a product type (frozen and non-frozen). The interaction effect is defined as the rest left after subtracting country effect and product effect from DB_{it}.

(5) $$Db_{icrt} = DB_{it} - Db_{ict} - Db_{irt}, \qquad i = \text{d, f, R}$$

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3 Divisia index is superlative index that can exactly track a second order approximation to a linearly homogeneous aggregate function. For details, see Davis (1997) and Diewert and Nakamura(1993).

By using the equations (3) to (5) the Tornqvist price index comes out as in equation (6).

(6) $DP^{T}{}_{it} = DP^{u}{}_{it} - Db_{ict} - Db_{irt} - Db_{icrt}$, $i =$ d, f, R

While, the Tornqvist quantity index comes out by using equations (3) and (6).

(7) $DQ^{T}{}_{it} = DQ^{u}{}_{it} + Db_{ict} + Db_{irt} + Db_{icrt}$, $i=$ d, f, R

III. Empirical Model

To incorporate and statistically test product aggregation bias in demand system, a model with log differential form is required. The model should be also consistent with product aggregation theory. This paper uses a Rotterdam demand model which has log differential form and theoretical consistency with product aggregation theory (Deaton and Muellbauer 1980, Davis 1997).

(8) $w_{it} DQ^{T}{}_{it} = \sum_{j=d}^{R} c_{ij} DP^{T}{}_{jt} + b_i DQ_t$, $i =$ d, f, R

, where $DQ^{T}{}_{it}$, $DP^{T}{}_{it}$ are Tornqvist ith quantity and price index, DQ_t is Divisia volume index, c_{ij} is Slustky price parameter(= $w_i \eta^{*}_{ij}$, η^{*}_{ij} is Hicksian price elasticities), and b_i is marginal propensity to spend on the ith good(= $w_i \eta_{im}$, η_{im} is expenditure elasticity)[4]. In addition, intercept terms were added in the above Rotterdam model to allow for other variables' effect including gradual change in tastes than price and expenditure as Barten did (Deaton and Muellbauer 1980).

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[4] The fact that continuous Divisia quantity and price index are exact for $d \ln Q^{T}{}_{i}$ and $d \ln P^{T}{}_{i}$, and they are also approximated in discrete form by Tornqvist index was applied to the following Rotterdam model. $w_i d \ln q_{it} = \sum_{j=d}^{R} c_{ij} d \ln p_j + b_i DQ_t$

In estimating the above demand system, since domestic country is a single country (Korea), there is no aggregation bias from the country sources and furthermore an assumption that there is no aggregation bias from product types in the domestic country is also adopted, i.e. $DB_{dt} = 0 \, (Q^{T}{}_{d} = Q^{u}{}_{d})$ due to the data limitation. Because it is difficult to obtain the data of frozen and non-frozen beef, this paper uses the quantity and price data at wholesale stage in domestic country (Korea) with assumption of no aggregation bias[5] from product types.

Consequently by substituting $DQ^{T}{}_{dt}, DP^{T}{}_{dt}, DQ^{T}{}_{ft}, DP^{T}{}_{ft}$ from equations (6) and (7) into equation (8), domestic and import aggregate beef demand equations come as follow.

$$(9.1) \quad w_{dt} DQ^{T}{}_{dt} = c_{dd} DP^{T}{}_{dt} + c_{df} DP^{u}{}_{ft} - c_{df} (g_{fc} Db_{fct} + g_{fr} Db_{frt} + g_{fcr} Db_{fcrt}) + c_{dR} DP^{T}{}_{Rt} + b_{d} DQ_{t}$$

$$(9.2) \quad w_{ft} DQ^{u}{}_{ft} = c_{fd} DP^{T}{}_{dt} + c_{ff} DP^{u}{}_{ft} - c_{ff} (g_{fc} Db_{fct} + g_{fr} Db_{frt} + g_{fcr} Db_{fcrt}) + c_{fR} DP^{T}{}_{Rt} + b_{f} DQ_{t} - w_{ft} (g_{fc} Db_{fct} + g_{fr} Db_{frt} + g_{fcr} Db_{fcrt})$$

The g's are coefficients to test aggregation bias and used to get elasticities of aggregation bias variables. Estimating system (9) gives useful information about g's to check the aggregation bias by testing if all g's are zero. If all g's are zero, then the system is free of aggregation bias from product types and country sources. The likelihood ratio test can be used to check which of the two models, the unrestricted model with aggregation bias variables and the restricted model without aggregation bias variables, is better.

IV. Data

The data in this paper are annual beef import data, import quantity and total value from 1988 to 2002[6] of leading beef import source countries such as

[5] Generally the slaughtered meat is quantified and priced first at the stage of wholesale and then distributed to next stage in frozen and non-frozen forms.

[6] Because of several data issues, the data period was intentionally set-up from 1988

Australia, Canada, USA including Korean domestic beef production and wholesale price. The imported beef data of import source countries were obtained from the Korea International Trade Association (KITA). The imported beef data consist of two types of products, frozen and non-frozen beef that are given according to the HS classification code. Korean domestic beef production and wholesale price data are from the Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF, Korea). The frozen data are continuous over the whole period but the non-frozen data are not because the non-frozen began to be imported recently.

This paper is dealing with a system of three equations for domestic (Korea), foreign, and rest of world. To avoid singularity, the last equation was dropped. Foreign data under estimation is composed of Australia, Canada and USA, and the rest of world data is obtained by subtracting foreign data from total imported frozen and non-frozen quantity and value. Import unit-value of each country is obtained by dividing the value by quantity. Price data including unit-value are deflated by the consumer price index given by Bank of Korea.

Data unit of quantity and imported value is kg and US dollar respectively[7]. The average Korean domestic beef production is 157,780,000kg with a standard deviation of 55,522,000, and a range of 90,051,000 to 264,070,000. The average frozen imported quantity of Australia is 13,482,000kg with a standard deviation of 8,577,600, and a range of 121,310 to 28,052,000. The average frozen imported quantity of USA is 70,468,000kg with a standard deviation of 45,828,000, and a range of 14,228,000 to 191,930,000. The average frozen imported quantity of Canada is 4,783,700kg with a standard deviation of 5,460,100, and a range of 98,667 to 18,617,000. The average non-frozen imported quantity of Australia is 512,220kg with a standard deviation of 1,344,900, and a range of 0 to 5,201,100. The average non-frozen imported

to 2002. For example, non-frozen beef of USA was not imported in 2005 and frozen beef of USA was not imported in 2006 while non-frozen beef of Canada was not imported in 2004 while both frozen beef and non-frozen beef of Canada were not imported since 2006. Therefore, the period of data was intentionally selected to avoid the empty data of the variables. However, the problems from the limited sample such as low degrees of freedom were addressed by applying the 'symmetry' and 'homogeneity' condition to the demand system to save the degrees of freedom as Davis (1997) did.

[7] However, the unit of the wholesale price of Korean domestic beef is US dollar/kg.

quantity of USA is 1,343,800kg with a standard deviation of 2,696,400, and a range of 0 to 9,196,200. The average non-frozen imported quantity of Canada is 24,978kg with a standard deviation of 50,953, and a range of 0 to 144,660.

The average wholesale price of Korean domestic beef is US$10.4/kg with a standard deviation of 4.1, and a range of 4.0 to 16.6. The average frozen imported value of Australia is US$35,436,000 with a standard deviation of 23,296,000, and a range of 845,570 to 78,293,000. The average frozen imported value of USA is US$288,050,000 with a standard deviation of 126,160,000, and a range of 50,104,000 to 517,510,000. The average frozen imported value of Canada is US$16,048,000 with a standard deviation of 16,102,000, and a range of 576,580 to 61,308,000. The average non-frozen imported value of Australia is US$2,327,200 with a standard deviation of 5,513,100, and a range of 0 to 20,978,000. The average non-frozen imported value of USA is US$5,201,600 with a standard deviation of 10,449,000 and a range of 0 to 36,141,000. The average non-frozen imported value of Canada is US$99,183 with a standard deviation of 199,550, and a range of 0 to 554,000.

TABLE 1. Summary of Statistics

Unit: kg, US$

Name	Number	Mean	Standard deviation	Minimum	Maximum
Wholesale price of domestic beef	15	7.89	1.86	3.89	10
Domestic beef production	15	157,780,000	55,522,000	90,051,000	264,070,000
Value of frozen from Australia	15	29,087	18,526	449	64,435
Quantity of frozen from Australia	15	13,482,000	8,577,600	121,310	28,052,000
Value of frozen from USA	15	249,670	140,500	26,605	553,220
Quantity of frozen from USA	15	70,468,000	45,828,000	14,228,000	191,930,000
Value of frozen from Canada	15	14,703	16,284	384	61,308
Quantity of frozen from Canada	15	4,783,700	5,460,100	98,667	18,617,000
Value of frozen from rest of world	15	132,920	51,651	14,682	219,130
Quantity of frozen from rest of world	15	69,734,000	42,310,000	5,654,200	202,770,000
Value of non-frozen from Australia	15	2,395	5,897	0	22,425
Quantity of non-frozen from Australia	15	512,220	1,344,900	0	5,201,100
Value of non-frozen from USA	15	5,392	11,035	0	38,635
Quantity of non-frozen from USA	15	1,343,800	2,696,400	0	9,196,200
Value of non-frozen from Canada	15	102	207	0	587
Quantity of non-frozen from Canada	15	24,978	50,953	0	144,660
Value of non-frozen from rest of world	15	53	132	0	519
Quantity of non-frozen from rest of world	15	7,612	18,244	0	71,809

Note: the unit of the wholesale price of Korean domestic beef is US dollar/kg.

V. Estimation procedure/ results

Using the imported unit-value and quantity, the aggregate indices are calculated. This paper used SHAZAM, a statistics and econometrics software, in which the Divisia index is calculated out as level value. The Divisia index required in this paper is obtained by taking log and difference between two periods on the results[8] from SHAZAM. The correctness of the Divisia index can be checked through the equation (3) because according to the equation (3), the value of $DQ^T{}_{ft} - DQ^u{}_{ft}$ and the value of $DP^u{}_{ft} - DP^T{}_{ft}$ are supposed to be equal.

TABLE 2. Check for the Correctness of Divisia Index

Year	Index*		Expenditure	Aggregation Bias	
	Price($DP^T{}_{ft}$)	Quantity($DQ^T{}_{ft}$)		$DQ^T{}_{ft} - DQ^u{}_{ft}$	$DP^u{}_{ft} - DP^T{}_{ft}$
1988-89	-0.27953	1.29374	1.01421	1.07407	1.07407
1989-90	-1.43831	1.92821	0.48990	1.42300	1.42300
1990-91	-1.32980	1.95167	0.62186	1.28713	1.28713
1991-92	-1.18105	1.29721	0.11615	1.25614	1.25614
1992-93	-1.24218	1.02387	-0.21830	1.15193	1.15193
1993-94	-1.17466	1.54053	0.36587	1.17108	1.17108
1994-95	-1.05774	1.31958	0.26184	1.11804	1.11804
1995-96	-1.18634	1.12231	-0.06402	1.13370	1.13370
1996-97	-1.19256	1.10086	-0.09170	1.11724	1.11724
1997-98	-1.14045	0.56631	-0.57414	1.11026	1.11026
1998-99	-1.02817	1.54961	0.52144	1.00546	1.00546
1999-00	-0.89481	1.48390	0.58909	1.03181	1.03181
2000-01	-1.21410	0.75511	-0.45898	1.04610	1.04610
2001-02	-1.10199	1.72083	0.61884	1.05669	1.05669

Note: *the indices are theoretically consistent Divisia indices which are calculated through any statistics software.

[8] The Divisia indices of price and quantity, i.e., $DP^T{}_{ft}$ and $DQ^T{}_{ft}$, can be calculated by any statistics software through a discrete approximation to the Divisia as follows. $\ln(D_t) - \ln(D_{t-1}) = \sum_{i=1}^{n} \frac{1}{2}[V_{it} + V_{it-1}][\ln(X_{it}) - \ln(X_{it-1})]$, where $V_{it} = P_{it}X_{it} / \sum_{j=1}^{n} P_{jt}X_{jt}$, P_{it} and X_{it} are price and quantity respectively. Also see Hulten (1973) for more details.

As the below table (table 3) shows, the aggregation bias of foreign imported beef which is the sum of country effect, product effect and interaction effect is positive for all years under estimation. This result means that the untrue aggregation of foreign import beef underestimates the true aggregation beef.

TABLE 3. Aggregation Bias in Foreign Imported Beef

Year	Country Effect (Db_{fct})	Product Effect(Db_{frt})	Interaction Effect(Db_{fcrt})	Aggregation Bias ($Db_{fct} + Db_{frt} + Db_{fcrt}$)
1988-89	0.01479	-0.00133	1.06060	1.07407
1989-90	0.00689	0.00060	1.41551	1.42300
1990-91	-0.03856	-0.00010	1.32578	1.28713
1991-92	0.03050	-0.00009	1.22573	1.25614
1992-93	-0.04844	0.00002	1.20035	1.15193
1993-94	0.00958	0.00017	1.16133	1.17108
1994-95	0.00751	0.00009	1.11045	1.11804
1995-96	0.01358	0.00069	1.11943	1.13370
1996-97	0.04278	0.00045	1.07401	1.11724
1997-98	0.03192	0.00212	1.07622	1.11026
1998-99	-0.00537	0.00272	1.00811	1.00546
1999-00	0.00064	0.00278	1.02839	1.03181
2000-01	0.00148	0.00276	1.04185	1.04610
2001-02	0.00059	0.00760	1.04851	1.05669

A nonlinear estimation method is used to estimate the demand system given in (9) and the Wald test is used to test the hypothesis that there is no aggregation bias effect, i.e., to check whether the coefficients of aggregation bias variables are all zero. Likelihood ratio test (LR test) is also done to see whether the unrestricted model is better than the restricted model. The LR test statistic[9] (=18.92) is larger than the critic value of even 1 percent level with degrees of freedom 3. So the unrestricted model is much better than the restricted model. Since the number of variable (=13) in system is large com-

[9] The LR statistic is calculated as $LR = -2(L_r - L_u)$, where L_r and L_u are the maximized value of the log likelihood function of the unrestricted and restricted regressions, respectively. The LR test shows that LR statistic: 18.92, Degrees of Freedom: 3, and P-value: 0.00287.

paratively to the number of observations (=14), this paper applies the symmetry ($c_{df} = c_{fd}$) and homogeneity ($c_{dd} + c_{df} + c_{dR}$ =0, $c_{fd} + c_{ff} + c_{fR}$ =0) condition to the system to save the degrees of freedom as Davis (1997) did.

TABLE 4. Estimation Result for Unrestricted and Restricted Model

Parameters	Unrestricted Model	Restricted Model
Intercept (Domestic)	-0.05 (-1.55)	-0.03 (-1.10)
b_d	0.66 (4.10)	0.66 (3.44)
c_{dd}	-0.30 (-2.09)	-0.27 (-2.24)
c_{df}	0.10 (1.12)	0.13 (1.74)
Intercept (Foreign)	0.02 (0.98)	0.03 (1.38)
b_f	0.38 (3.19)	0.33 (2.65)
c_{ff}	-0.17 (-3.52)	-0.22 (-3.50)
g_{fc}	17.14 (2.55)	
g_{fr}	2.97 (0.10)	
g_{fcr}	-0.30 (-1.89)	
Log-likelihood	53.94	44.48

Note: number in parenthesis is asymptotic t-ratio

To test whether there is no aggregation bias effect, the Wald test was done and its result is shown in Table 5. The hypothesis of no aggregation bias effect is rejected. This result implies that the unrestricted model is different from the restricted model and there exists statistically significant aggregation bias that may lead to different elasticity estimates. However, the impacts of the aggregation bias on the elasticities need to be checked.

TABLE 5. Hypothesis Test for No Aggregation Effect

Hypothesis	χ^2	Degrees of Freedom	Test Result
No aggregation Bias Effect ($g_{fc} = g_{fr} = g_{fcr} = 0$)	27.49932	3	Reject

The impacts of the aggregation bias on model specification can be checked by examining whether the aggregation bias really leads to significant change of the elasticities estimates, i.e., whether the elasticities of the two models, i.e., the unrestricted model and the restricted model, are significantly different when the aggregation bias is adjusted. From the Rotterdam demand system (8), (9), expenditure elasticity and price elasticities are given as $\eta_{im} = b_i / w_i$, $\eta_{ij}^* = c_{ij} / w_i$, $i =$ d, f, $j =$ d, f, R. The aggregation bias elasticities are $\pi_{dh} = -\eta_{df}^* * g_{fh}$, $h =$ c, r, cr for domestic beef, $\pi_{fh} = -(\eta_{ff}^* + 1) * g_{fh}$, $h =$ c, r, cr, for foreign beef. Table 6 shows the elasticity estimates when the elasticities are evaluated at the average expenditure share.

TABLE 6. Elasticity Estimates of Unrestricted and Restricted Models

		Expenditure Elasticity	Price Elasticities			Aggregation Bias Elasticities		
			Domestic	Foreign	ROW	Country	Product	Interaction
1.Unrestricted Model	Domestic	0.90 (-4.1)	-0.41 (-2.09)	0.13 (1.12)	0.28 (3.13)	-2.27 (-1.38)	-0.39 (-0.11)	-0.04 (1.27)
	Foreign	2.17 (3.19)	0.56 (1.12)	-0.96 (-3.52)	0.40 (1.45)	-0.64 (-0.13)	-0.11 (-0.07)	0.01 (0.13)
2.Restricted Model	Domestic	0.89 (3.44)	-0.37 (-2.24)	0.18 (1.74)	0.18 (2.25)			
	Foreign	1.89 (2.65)	0.77 (1.74)	-1.25 (-3.50)	0.47 (1.87)			

Note: ROW is for the rest of world. Expenditure share $w_d =$ 0.74, $w_f =$ 0.17. The number in parenthesis is asymptotic t-ratio.

Table 6 shows that domestic and foreign expenditure elasticities and own price elasticities of the unrestricted model and the restricted model are statistically significant, but cross price elasticities of domestic beef and foreign beef for the two models are not statistically significant. The aggregation bias elasticities in the unrestricted model can be utilized to check the sensitivity of the aggregation bias variables toward the domestic beef and foreign beef, but the elasticities are not statistically significant even though country effect elasticity to domestic beef quantity is very large (-2.27). However, the signs of elasticities show the relationships between domestic beef and foreign beef, between domestic beef and beef from rest of world, and between foreign beef and beef from rest of world. The domestic beef is a substitute to both foreign beef and beef from rest of world. The foreign beef and beef from rest of the world are complement to each other. These whole relationships hold at both models (the unrestricted and restricted model). In addition, because the elasticities of the two models are not so different in terms of size, the impact of the aggregation bias on the models seems to be not so severe.

VI. Implication and conclusion

This paper has decomposed the aggregation bias into country effect, product effect, and interaction effect between country and product. The product has two types of beef; frozen and non-frozen. The Wald test rejected the hypothesis of no aggregation bias and the LR test shows that the unrestricted model with aggregation bias variables is better than the restricted model without the variables. However, the size of the elasticities of the two models was not much different. Furthermore, the elasticities of aggregation bias variables were not statistically significant.

In these regards, the impact of aggregation bias on the Korean demand for imported beef is not big even though there is statistically significant aggregation bias in the demand system for imported beef. However, it should be considered that this paper has some technical shortcomings especially in terms of sample numbers and some missing variables. If the degrees of freedom are relatively low due to limited sample numbers, the estimates are more likely to be statistically insignificant due to thicker tails of the t-distribution than when the degrees of freedom are high. When the sample numbers are big enough and the missing variables such as pork and chicken, which are known as key substitutes to beef consumption, are incorporated in the models, the implication from the result may be clearer. These limitations are left as subjects of further research in the near future.

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