Vol.35, No.1, pp.74-90, 2023

Journal of Agricultural, Life and Environmental Sciences

RESEARCH ARTICLE

pISSN 2233-8322, eISSN 2508-870X
https://doi.org/10.22698/jales.20230006

Can Rice Replace Wheat? Evidence from Korean Consumers

Hyun Ju Park[1], **Sang Hyeon Lee**[2*]

[1]Graduate Student, Food and Resource Economics, Korea University, Seoul 02841, Korea
[2]Associate Professor, Food and Resource Economics, Korea University, Seoul 02841, Korea

***Corresponding author:** Sang Hyeon Lee (E-mail: lsh21c@korea.ac.kr)

Received: 7 March 2023
Revised: 10 March 2023
Accepted: 12 March 2023

ABSTRACT

This study aims to investigate the demand for wheat and rice processed food in South Korea to assess the feasibility of the Korean government's ‘Measures to vitalize the rice processing industry’ policy. This policy was proposed in response to the decline in rice consumption and the country's high dependency on imported wheat. However, the empirical research on consumer demand for rice processed food and its ability to replace wheat is limited. This study aims to address two main questions: the extent to which consumers consider wheat and rice processed food as substitutes, and the potential impact on rice consumption if the rice processing industry expands. The study used household account book data from 2010-2021 and a survey of 1,550 households to estimate the demand system, using the Source Differentiated Almost Ideal Demand System (SDAIDS) method. The results suggested that despite the substitutability of rice and wheat processed foods, rice-processed foods may also substitute for white rice consumption. Therefore, the expected increase in total rice consumption via rice processing may be overestimated.

Keywords: Grain processed food, Rice demand, Rice processing industry, SDAIDS

Introduction

One of the paramount concerns facing many Asian countries is the steady decrease in per capita rice consumption while high dependency on imported wheat deepens. Due to a steady decline in consumption of this staple food and improved productivity of farmers, rice supply in domestic markets exceeds demand annually, and the carryover amount is steadily increasing (FIS, 2020), causing its governments huge monetary burdens. Meanwhile, the volatility of international wheat prices, driven by factors such as international politics and climate change, has had a considerable impact on countries with a high dependency on imported wheat, one of which is South Korea (RDA, 2022). In 2020, South Korea’s self-sufficiency rate for wheat was a mere 0.8%, leaving the economy vulnerable to fluctuations in international grain prices.

In an effort to address these issues, the Ministry of Agriculture, Food and Rural Affairs (MAFRA) of South Korea announced in June 2022 a set of ‘Measures to vitalize the rice processing industry using powdered rice’. Powdered rice is a new type of rice developed by the Rural Development Administration (RDA) in 2016 that has similar starch structure to wheat and has the advantage of lower processing costs than regular rice. The objective of these measures is to resolve the oversupply of rice by actively consuming powdered rice in the processed food industry, and simultaneously reduce dependency on wheat imports. The target was set to supply 200,000 tons of powdered rice by 2027, replacing 10% of the annual wheat flour demand (about 2 million tons) in Korea. In addition, the rice processed food industry which is worth KRW 7.3 trillion (USD 6.3 billion) as of 2020, is expected to be nurtured to KRW 10 trillion (USD 7.5 billion) by 2027(MAFRA, 2022).

Recent consumption trends suggest that the policy is on the right path. According to Yoon et al. (2015), the proportion of rice consumption within the household sector is estimated to be 50 − 55% , 30 − 35% within the eating out sector, and 10 − 15% within the processing sector in Korea. This indicates that the rice consumption within the processing sector is not substantial yet. However, according to '2021 Grain Consumption Survey' conducted by Statistics Korea, per capita rice consumption in the household sector (56.9 kg) decreased by 1.4% (0.8 kg) compared to the previous year, while the rice consumption in the processing sector (68,157 tons) increased by 4.6% (3,135.2 tons). Among them, rice cake sector consumed 26%, and the meal-ready food sector consumed 16.7%, which also experienced 16.2% increase in consumption compared to the previous year. Such trends root for the potential of rice processing industry. Jang et al. (2017) also pointed out that the rice processing industry is moving from a means of managing rice supply/stocks to a future food industry that reflects new consumption values such as convenience and well-being. These studies and statistics support the government's efforts to activate the rice processed food industry in order to consume more rice.

However, there are also conflicting perspectives on the feasibility of the government's goal of replacing 10% of wheat imports with powdered rice. Efforts to replace wheat consumption with rice flour have been ongoing for over a decade, but have not been successful (It is not Korea's first attempt to increase rice consumption. South Korea recognized the decline in rice consumption in the 1980s and began to establish a response strategy. In the 1990s, along with various deregulations, a support system for the rice processing industry was introduced, and an inventory depletion policy was initiated which included methods such as food aid to North Korea. In 2011, the Act on Promotion of Rice Processing Industry and Rice Utilization was promulgated, and a basic plan has been established and implemented every five years (Jang et al., 2017)). There are concerns that the current government's strategy is not sufficiently differentiated from previous attempts and may also fail to achieve its goals (http://www.amnews.co.kr/news/articleView.html?idxno=50683, last searched date : 2023.01.30.). Despite its importance, little empirical research has focused on the replaceability of wheat and rice processed food in terms of consumer demand, especially because rice processed food industry has emerged recently and still on its climb (FIS, 2020).

Therefore this paper investigates the demand system of wheat and rice processed food in order to provide evidence for/against the feasibility of the policy. Two main research questions are raised for this purpose : (1) Do consumers view wheat and rice processed food as substitutes, as the policy claims? If not, governmental efforts to replace wheat with powdered rice will not align with market demand. (2) Even if the rice processing industry expands, would the actual rice consumption increase accordingly? It is plausible that the strategic powdered rice production will contribute to the expansion of rice processing industry. However it may not lead to substantial increase in total rice consumption because rice processed foods may replace raw rice, instead of wheat flour. Therefore it is critical to answer these two questions to fully comprehend the market situation and evaluate the Korean government's new approach, furthermore to develop an efficient strategy.

Literatures analyzing close substitutes of rice include Gao et al. (1994), who developed a synthetic demand system of rice with its complex carbohydrate substitutes : potatoes, bread, and pasta, using household survey data in the United States. Following Gao et al.'s segmentation of complex carbohydrates and applying the categorization based on Korean culinary culture (We assume that the wide/middle/detail food categorization provided by Rural Development Agency (RDA) of South Korea to reflect the general culinary culture of the population. More explanation about RDA dataset and its categories are mentioned in page 13), we select Rice Processed Foods, Wheat Processed Foods and Whole Grains as complex carbohydrate substitutes to be included in the model.

This article is organized as follows. The next section justifies the use of SDAIDS and Separability testing. Econometrical specifications of these methods are presented in the following section. Then the empirical results are presented. The final section provides conclusions.

Materials and Methods

Model Consideration

In the literature of demand analysis, Deaton and Muellbauer's Almost Ideal Demand System (AIDS) has been widely used for its flexibility, plausibility and convenience. Although there are other models such as Armington trade model, this model suffers from various restrictive assumptions (Alston et al., 1990; Winters, 1984; Yang and Koo, 1993). General framework of AIDS model assumes (1) product aggregation, under which the demand system does not differentiate products under same good (Following the terminology defined by Armington (1969), goods are consisted of products with same ingredient) (Hayes et al., 1990) or (2) block separability among goods, which allows the model to consist only of share equations for products under one good only (Alston et al., 1990). This means for example modeling only the rice processed foods demand independently of wheat processed foods or grain demand. However, in our analysis of rice and wheat processed foods and grains, product aggregation is counter-intuitive since each product under the same good (i.e. rice processed foods, wheat processed foods and grains) has distinctive characteristics in Korean dietary culture as displayed in Table 1.

On the other hand, the proposed policy directly opposes the block separability assumption because it relies on the substituting relationship between the two goods. Among many literatures investigating consumer behavior of different rice processed foods (Kang and Kang, 2017; Piao et al., 2020; Han and Gouk, 2014; Yoon et al., 2015), only Ha et al. (2019) considers wheat processed food expenditure as an explanatory variable for rice processed food expenditure. Therefore, it is worthwhile to test block separability assumption in order to evaluate whether or not rice and wheat processed food demands are related to each other. If the block separability assumption among the

Table 1. Product descriptions

Goods	Products	Items
Rice Processed Foods	(1) Cooked Rice	Instant cooking rice/Instant intaking Gimbap, Instant intaking Sushi/Instant cooking or intaking rice mixed with vegetables or with toppings, Fried rice etc.
	(2) Congee	Instant cooking Congee, Instant intaking Congee, Instant intaking soup
	(3) Rice Cake	Garaetteok (Joraeng rice cake etc.), Potato cake, Puffy rice-cake with stuffing, Baekseolgi, Songpyeon, Sorghum rice cake, Mugwort rice cake, Yaksik, Injeolmi, Jeolpyeon, Others (Mochi, Sugar-filled Korean Pancake etc.)
	(4) Rice Snack	Korean traditional snack (Hangwa, Sanza, Yakgwa, Jeonbyung, Byunggwa, Yugwa, Sangwam Gangjeong etc.), General snack (Biscuit, Monaka, Hardtack, Flake, Chips etc.), puffed snack (puffed rice, puffed rice cake etc.), Scorched rice
	(5) Rice Bread	Sweet rice doughnut, Twisted sweet rice bread, stick sweet rice bread, Bread/Toast, Pie/Pastry, Bean steamed bun, Rice pizza, Rolled rice cake, Other sweet rice or rice bread (Some rice is added to bread)
	(6) Rice Noodles	Noodle, Ramen, Jajangmyeon, Sujebi, Udon, Pasta
Wheat Processed Foods	(7) Snack	Chips, cookies, biscuits etc.
	(8) Bread	Doughnut, bakeries, Pie/Pastry, pizza, cake, etc.
	(9) Noodles	Noodle, Ramen, Jajangmyeon, Sujebi, Udon, Pasta
Grains	(10) White Rice	Whole grain white rice
	(11) Other Grains	Glutinous rice, brown rice, mixed grains, barley, corn, beans etc.

Source : Edited by the author based on Yoon et al., 2015.

goods are valid, then the demand systems of rice and wheat processed foods can be separated, which weakens the grounds of the policy goals. If the block separability assumption is rejected, it means that the demand system of the abovementioned goods must be analyzed simultaneously. In this case, we utilize the specifications of Source Differentiated AIDS model developed by Yang and Koo (1994) in order to incorporate product differentiated AIDS without imposing block separability.

Separability Test

The main purpose of using the separability assumption in demand studies is to reveal the preference system between goods and to obtain more accurate parameter estimates. The separability assumption satisfies the condition that the demand parameters of a certain group of goods should be linked to other demand parameters in the entire demand system in a consistent manner (Lee and Choi, 2000).

There are three main ways to test for separability using the AIDS model (Lee et al., 1992). The first is to include an additional price variable in the model and test for separability using the t-value for this variable (Alston et al., 1990). The second is when constraints based on the direct utility function are used to test for separability (Eales and Unnevehr, 1988). The third is when a cost function is used to test for separability (Hayes et al., 1990). Each definition requires different parametric restrictions, but Pudney (1981) shows that the various definitions do not differ in empirical results. In this analysis, we follow the second approach and use a constraint based on the direct utility function to test for separability.

Let $Q = (q_1, \cdots q_n)$ be the vector of n consumer goods, $P = (p_1, \cdots p_n)$ the corresponding nominal price vector, and E the total expenditure on n goods, and if the n goods are separated into S separable groups, then the utility function U(Q) is expressed as in Eq. (1).

$$U(Q) = U^0[U^1(Q^1), \ldots, U^S(Q^S)] \tag{1}$$

$U^0(\bullet), U^S(\bullet)$: Conditions on utility functions such as strong monotonicity, strict quasi-concavity, differentiability are assumed to be satisfied.

Separable utility structures impose many constraints on the substitutability of goods from different groups. If $h_i(P,u)$ is a i th order hicksian (compensated) demand function and V(P, E) is an indirect utility function that is pairwise related to U(Q), Goldman and Uzawa (1964) showed that the Slutsky substitutability between two goods in different groups is proportional to the income impact of the two goods.

$$\frac{\partial h_i(P, V(P,E))}{\partial p_k} = \mu_{gs}(P,E)\frac{\partial q_i(P,E)}{\partial E}\frac{\partial q_k(P,E)}{\partial E} \tag{2}$$

$i \in I_g,\ k \in I_s,\ g \neq s$

Equation (2) is a necessary and sufficient condition for the weakly separable utility structure of equation (1). In other words, equation (2) implies constraints on the separable structure of equation (1) and can be used to test for separability.

Asymmetric separability assumes weaker conditions on the utility function. Letting I_s be a group of some goods and I^c be a set of other goods, the utility function is shown in Eq. (3).

$$U(Q) = U^0[Q^c, U^s(Q^s)] \tag{3}$$

Blackorby et al. (1991) provide a necessary and sufficient condition for asymmetric weak separability. According to Blackorby, Davidson and Schworm, the following equations (4) and (5) hold.

$$\frac{\partial h_i(P,u)}{\partial p_k} = \lceil (P,u)\frac{\partial \equiv (P,u)}{\partial p_i}\frac{\partial \equiv (P,u)}{\partial p_k} \tag{4}$$

$$\frac{\partial h_i(P,u)}{\partial u} = \lceil (P,u) \frac{\partial \equiv (P,u)}{\partial p_i} \frac{\partial \equiv (P,u)}{\partial u} \tag{5}$$

$i \in I_s,\ k \in I^c,\ \lceil(\bullet), \equiv(\bullet)$: Properly defined function types

If $c(p,u)$ is a cost function that switches $V(p,E)$, then the identity $q_i(P,c(P,u)) \equiv h_i(P,u)$ holds, resulting in $\partial h_i/\partial u = (\partial q_i/\partial E)(\partial c/\partial u)$. Using expression (5), the constraint expression is transformed into expression (6).

$$\frac{\partial h_i(p, V(p,E))}{\partial p_k} = \mu_k(p,E) \frac{\partial q_i(p,E)}{\partial E} \frac{\partial q_k(p,E)}{\partial E} \tag{6}$$

$$\mu_k = [(\partial \Xi/\partial p_k)(\partial C/\partial u)^2 [(\partial \Xi/\partial u)(\partial h_k/\partial u)]^{-1}$$

If (i, j) belongs to group s and the other goods are k, then the separability-satisfying case is given by equation (7), which is expressed in terms of price and income elasticities as equation (8).

$$\frac{\dfrac{\partial h_i(p, V(p,E))}{\partial p_k}}{\dfrac{\partial h_j(p, V(p,E))}{\partial p_k}} = \frac{\dfrac{\partial q_i(p,E)}{\partial E}}{\dfrac{\partial q_j(p,E)}{\partial E}} \tag{7}$$

$$\frac{\sigma_{ik}}{\sigma_{jk}} = \frac{\epsilon_i}{\epsilon_j} \tag{8}$$

Substituting Chalfant’s (1987) elasticity formula for price elasticity and the formula for income elasticity, we derive equation (9). Equation (9) is the necessary and sufficient condition for the separability we want to test in this analysis.

$$\frac{(\gamma_{ik} - \beta_i w_k)}{(\gamma_{jk} - \beta_j w_k)} = \frac{(w_i + \beta_i)}{(w_j + \beta_j)} \tag{9}$$

Also, expression (10) is derived from expression (9) at the mean point.

$$\frac{(\gamma_{ik} - \beta_i \alpha_k)}{(\gamma_{jk} - \beta_j \alpha_k)} = \frac{(\alpha_i + \beta_i)}{(\alpha_j + \beta_j)} \tag{10}$$

When the number of goods is n and the number of separable groups is S, the number of constraints to be analyzed is equal to (11).

$$n_R = \frac{1}{2}\left[n(n-1) - \sum_{s=1}^{S} n_s(n_s - 1) - S(S-1)\right] \tag{11}$$

n_R: Number of constraints, n_s: Number of products in group s

Eq. (11) was then tested with the Wald test.

Source Differentiated AIDS Model

SDAIDS model was originally built to differentiate the origin (or source) within each meat kind when specifying the demand system for meats, but it has been applied frequently in differentiating other qualities of goods. For example, Ji et al. (2019) estimates the demand system of processed foods differentiated by its usage. In this paper we apply the same specifications to differentiate various types of products within each grain kind(i.e. products made with common ingredients such as wheat/rice/other grains). The derivation of the AIDS model starts with an expenditure function, representing the Price Independent Generalized Logarithmic (PIGLOG) preference (Deaton and Muellbauer, 1980). For the SDAIDS model, the expenditure function is rewritten to approximate consumers' behavior that differentiates products within each good. The expenditure function given utility u is

$$\ln[E(p,u)] = (1-u) \bullet \ln[a(p)] + u \bullet \ln[b(p)] \tag{12}$$

where

$$\ln[a(p)] = \alpha_0 + \sum_i \sum_h \ln(p_{i_h}) + \frac{1}{2}\sum_i \sum_j \sum_h \sum_k \gamma^*_{i_h j_k} \ln(p_{i_h}) \ln(p_{j_k}) \tag{13}$$

and

$$\ln[n(p)] = \ln[a(p)] + \beta_0 \prod_i \prod_h p_{i_h}^{\beta_{in}}, \tag{14}$$

where α, β, and γ^* are parameters. The subscripts i and j denote goods $(i, j = 1, \ldots, N)$, and h and k denote products. The numbers of products are not necessarily the same for all goods. Good i may be consisted of m different products, while good j may have n products (when $i \neq j$, $h = 1, \ldots, m$, and $k = 1, \ldots, n$).

By substituting equations (13) and (14) into (12), the expenditure function can be rewritten as

$$\ln[E(p,u)] = \alpha_0 + \sum_i \sum_h \alpha_{i_h} \ln(p_{i_h}) + \frac{1}{2} \sum_i \sum_h \sum_j \sum_k \gamma^*_{h_h j_k} \ln(p_{i_h}) \ln(p_{j_k}) + \beta_0 u \prod_i \prod_h p_{i_h}^{\beta_{ih}} \tag{15}$$

By Shephard's lemma, the budget share of product h in good i can be obtained by differentiating $\ln[E(p,u)]$ with respect to $\ln(p_{i_h})$. Thus, the budget share (w_{i_h}) is a function of prices and utility as

$$w_{i_h} = \alpha_{i_h} + \sum_i \sum_k \gamma_{i_h j_k} \ln(p_{i_k}) + \beta_{i_h} u \beta_0 \prod_i \prod_h p_{i_h}^{\beta_{i_h}}, \tag{16}$$

where $\gamma_{i_h j_k} = 1/2(\gamma^*_{i_h j_k} + \gamma^*_{j_k i_h})$. Solving equation (15) with respect to u and substituting this into equation (16) results in the SDAIDS in expenditure share form :

$$w_{i_h} = \alpha_{i_h} + \sum_j \sum_k \gamma_{i_h j_k} \ln(p_{j_k}) + \beta_{i_h} \ln\left(\frac{E}{P^*}\right), \tag{17}$$

where

$$\ln(P^*) = \alpha_0 + \sum_i \sum_h \alpha_{i_h} \ln(p_{i_h}) + \frac{1}{2} \sum_i \sum_h \sum_j \sum_k \gamma^*_{i_h j_k} \ln(p_{i_h}) \ln(p_{j_k}) \tag{18}$$

Since the price index (P^*) in the share equation (17) is nonlinear and provides difficulties in estimation as displayed in equation (18), Stone's index is used as a linear approximation (Deaton and Muellbauer, 1980). Stone's index in this extension is $\ln(P) = \sum_i \sum_h w_{i_h} \ln(p_{i_h})$. However, this index causes a simultaneity problem since the expenditure share in the index, w_{i_h}, is also the dependent variable. To avoid this, the lagged share (Eales and Unnevehr, 1988) or the average share (Haden, 1990) has been used. This paper utilizes the latter.

In order to reduce the number of parameters and preserve degrees of freedom, Yang and Koo (1994) introduces the following assumption :

$$\gamma_{i_h j_k} = \gamma_{i_h j}, \quad \forall\, k \in j \neq i. \tag{19}$$

In other words, equation (19) assumes that cross-price effects of products in good j on the demand for product h in good i are the same for all products in good j (we call this "block substitutability"). The block substitutability assumption enables the SDAIDS model to be rewritten as

$$w_{i_h} = \alpha_{i_h} + \sum_k \gamma_{i_{hk}} \ln(p_{i_k}) + \sum_{j \neq i} \gamma_{i_h j} \ln(p_j) + \beta_{i_h} \ln\left(\frac{E}{P}\right), \tag{20}$$

where $\ln(p_j) = \sum_k w_{jk} \ln(p_{jk})$ in equation (20). In general, the RSDAIDS model has M+(N-1)+2 parameters, while the SDAIDS model has MN+2 parameters in each equation if all goods(N) have the same number of products(M).

With this restriction, the general demand conditions are rewritten as

Adding-up: $\sum_i \sum_h \alpha_{i_h} = 1;\ \sum_h \gamma_{i_{hk}} = 0;\ \sum_i \sum_h \gamma_{i_h j} = 0;\ \sum_i \sum_h \beta_{i_h} = 0;$

Homogeneity: $\sum_k \gamma_{i_{hk}} + \sum_{j \neq i} \gamma_{i_{hj}} = 0;$

Symmetry: $\gamma_{i_{hk}} = \gamma_{i_{kh}}$.

Marshallian price elasticities of the RSDAIDS model are

$$\epsilon_{i_h i_h} = -1 + \frac{\gamma_{i_{hh}}}{w_{i_h}} = \beta_{i_h}, \tag{21}$$

$$\epsilon_{i_h i_k} = \frac{\gamma_{i_{hk}}}{w_{i_h}} - \beta_{i_h}\left(\frac{w_{i_k}}{w_{i_h}}\right), \tag{22}$$

$$\epsilon_{i_h j} = \frac{\gamma_{i_h j}}{w_{i_h}} - \beta_{i_h}\left(\frac{w_j}{w_{i_h}}\right). \tag{23}$$

where equation (21) is own-price elasticity, (22) cross-price elasticity within one good, and equation (23) cross-price elasticity between a product in good i and good j. Expenditure elasticity is displayed in equation (24) below.

$$\eta_{i_h} = 1 + \frac{\beta_{i_h}}{w_{i_h}} \tag{24}$$

Hicksian elasticities which excludes the income effect from Marshallian elasticities are expressed in equations (25) below.

$$\epsilon^*_{i_h i_h} = \epsilon_{i_h i_h} + \eta_{i_h} w_{i_h};\ \epsilon^*_{i_h i_k} = \epsilon_{i_h i_k} + \eta_{i_h} w_{i_k};\ \epsilon^*_{i_h j} = \epsilon_{i_h j} + \eta_{i_h} w_j \tag{25}$$

Estimation Method

The demand equations of the demand system model have common explanatory variables and their coefficients are determined simultaneously. As a result, the error terms are correlated with each other. Therefore, estimating the demand system model with methods such as SUR (Seemingly Unrelated Regression) or 3SLS (3-Stage Least Squares) is necessary. Also, one equation should be excluded arbitrarily while the remaining equations are simultaneously estimated. The parameters of the excluded equation are then calculated later based on the restrictions. This study employs SUR method by assuming that the prices are exogenous. Last equation of the demand system (Other Grains) was excluded in the estimation and calculated afterwards.

Data Description

The data utilized in this study is obtained from household panel data collected by RDA. The sample is selected through a stratified random sampling method, with an initial sample size of 1,000 metropolitan residents in 2009. 1,500 and 2,050 households were added in 2015 and 2017 each, and additional 1,000 participants were included in April 2021. The respondents are required to provide receipts for their daily food purchases, which are collected on a monthly basis. The survey includes demographic information, as well as purchase behavior, including details such as agricultural food product names, place of purchase, quantity and amount of purchase, household characteristics, housing type, and income.

In this study, data from April 2021 to December 2021 was used in order to control for the differences incurred by newly added panels in April 2021. Therefore, in total 2,235 panel households had complete purchase information for each month during the chosen period. In order to conduct the analysis, the data was transformed from daily account book data to cross-sectional data of total purchases during the period by each product type. This step was necessary as the purchase amount of some products were too small to conduct the analysis on a daily or monthly basis.

RDA dataset was originally classified into wide, middle, and detailed categories. The wide categories utilized in the analysis are 'Processed food' and 'Grains', and among the middle categories of 'Processed food' only 'Rice processed food' and 'Wheat processed food' were utilized. Thus the dataset reduced to three main categories of 'Rice processed food', 'Wheat processed food', and 'Grains'. Detailed categories of 'Rice processed food' were utilized without modification, which includes (1) Cooked Rice, (2) Congee (a.k.a. porridge), (3) Rice Cake, (4) Rice Snack, (5) Rice Bread, and (6) Rice Noodles. Rice flour, Seasonings, and Others were excluded as they have distinct uses in cooking and are less relevant to the study's focus on the replacement of rice and wheat processed foods. Detailed categories of 'Wheat processed food' were classified more specifically, such as Pizza and Pasta, which were grouped into broader products by the author : (7) Snack, (8) Bread, and (9) Noodles. Lastly, detailed categories of 'Grains' were modified into (10) White Rice and (11) Other Grains. Table 1 visualizes the categories and items within.

Table 2 shows the purchasing behaviors of 2,235 households in the sample. The data reveals that more than or

Table 2. Purchasing behaviors of each product

Goods	Products	# of Households		# of Purchases		Expenditure Shares	
		Freq.	Rate	Freq.	Rate	Mean	Std Dev.
Rice Processed Foods				**49,385**	**18%**	**0.209**	
	(1) Cooked Rice	1,975	88%	22,877	8%	0.104	0.099
	(2) Congee	1,048	47%	3,824	1%	0.017	0.036
	(3) Rice Cake	1,952	87%	14,107	5%	0.062	0.074
	(4) Rice Snack	1,320	59%	3,965	1%	0.012	0.023
	(5) Rice Bread	1,114	50%	3,086	1%	0.008	0.017
	(6) Rice Noodles	659	29%	1,526	1%	0.005	0.014
Wheat Processed Foods				**207,825**	**77%**	**0.584**	
	(7) Snack	2,176	97%	69,113	26%	0.132	0.096
	(8) Bread	2,207	99%	95,561	35%	0.334	0.174
	(9) Noodles	2,181	98%	43,151	16%	0.118	0.084
Grains				**12,019**	**4%**	**0.452**	
	(10) White Rice	1,660	74%	7,066	3%	0.161	0.176
	(11) Other Grains	1,434	64%	4,953	2%	0.047	0.088
Total		**2,235**		**269,229**			

equal to 50% of households had purchased Rice Processed Foods, with the exception of (6) Rice Noodles (29%). Additionally, a significant proportion of households also reported purchasing Wheat Processed Foods (above 97%) and Grains (above 64%). A total of 269,229 purchase records were analyzed, with 77% being the Wheat Processed Foods, 18% Rice Processed Foods, and 4% Grains. However, when considering the expenditure shares, households spent the most on wheat processed foods (58.4%), followed by grains (45.2%), and then rice processed foods (20.9%). These findings suggest that individual purchasing price of wheat and rice processed food is relatively low, while individual purchasing price for grains is relatively high. Notably, in the calculation of average expenditure shares, households with no purchase history in certain product were included as having spent 0.

In Table 3 the demographics of the sample is described. Total expenditure by income category revealed a steady increase in average total expenditure as income rises, but no further increase was observed for households with monthly income over 6 million KRW. Further examination of the sample, divided into 4 equal parts based on total expenditure, demonstrates that the larger the total expenditure, the smaller the variance. Additionally, the sample was divided according to the number of household members, with three-person households comprising the largest proportion at 26.4%, followed by two- and four-person households at 23.8%, and single-person households at 21%. The total expenditure was found to increase proportionately with the number of people in the household. Households without children accounted for 29.4% of households, while households with children made up the remaining 70.6%.

Since the data only provides expenditures and quantity information per each product, proxies of unit prices were calculated as expenditure divided by quantities. Such method has been applied in various studies (Cox and

Table 3. Food Expenditure by Demographics

Monthly Income **	N	N (%)	Mean*	SD*	Min*	Max*
< 200	202	9.0	381	251	15	1,597
200 – 300	313	14.0	461	293	25	1,418
300 – 400	363	16.2	603	382	29	2,138
400 – 500	334	14.9	691	421	52	2,770
500 – 600	304	13.6	722	406	64	2,742
600 – 700	222	9.9	803	446	101	2,500
700 – 800	186	8.3	740	434	96	2,983
800 <	311	13.9	780	476	7	3,125
Expenditure Level	N	N (%)	Mean*	SD*	Min*	Max*
1st Quantile	558	25.0	217	80	7	339
2nd Quantile	559	25.0	446	65	340	562
3rd Quantile	559	25.0	700	92	562	877
4th Quantile	559	25.0	1,228	340	879	3,125
# of houshold members	N	N (%)	Mean*	SD*	Min*	Max*
1	469	21.0	365	237	7	1,825
2	532	23.8	527	321	33	2,376
3	589	26.4	721	379	38	3,125
4	533	23.8	871	454	55	2,983
5	87	3.9	901	460	96	2,500
6 <	25	1.1	1,189	645	441	2,742
Child	N	N (%)	Mean*	SD*	Min*	Max*
No	1578	70.6	612	409	7	2,983
Yes	657	29.4	736	429	38	3,125
Total	**2235**	**100.0**	**648**	**418**	**7**	**3,125**

Note : Single asterisk (*) displays the values in 1,000 KRW unit.
Double asterisks (**) display the values in 10,000 KRW unit.

Wohlgenant, 1986; Deaton, 1988). The surveyed number of the quantity survey may be subjective, depending on the type of product and unit of measurement. This can lead to errors in accurately calculating unit prices. To address this issue, this study calculated unit prices using only the observations providing weight information in grams or kilograms, to determine an objective 'price per kg' unit. This unit was used to replace missing values. It should be noted that there may be a potential bias due to the difference between data that included weight information and data that did not, but no significant differences were observed upon comparing item components. However, it should be acknowledged that this study does not take into account the quality of each product, which is a limitation of the dataset. The dataset also contained various outliers in weight variable. Unrealistic values in lower and upper 5% of each wide category were dropped before the analysis (Processed Food : 0.06 < kg < 1.8, Grains : 0.5 < kg < 40 with exceptions considering the purchase amount of heavier products).

Table 4. Separability test results

Block Separability :
H0 : Rice Processed Foods are separable from Wheat Processed Foods and Grains.
• chi2(10) = 17.70*
Prob > chi2 = 0.0603
H0 : Wheat Processed Foods are separable from Rice Processed Foods and Grains.
• chi2(4) = 45.87***
Prob > chi2 = 0.0000
H0 : Grains are separable from Rice Processed Foods and Wheat Processed Foods.
• chi2(2) = 35.55***
Prob > chi2 = 0.0000

Note : Single and triple asterisks (*) denote significance at 10% and 1% levels, respectively.

Results

Separability Test Results

Hypothesis of block separability was tested with the Wald test. Table 4 summarizes the test results. The null hypothesis for each test states that the specific food is separable from all others. The first test, for processed food made from rice, yields a chi-squared value of 17.70 and a probability (Prob > chi2) of 0.0603. This suggests that the null hypothesis cannot be rejected under 5% but can be rejected under 10% significance level, indicating that processed food made from rice is not clearly separable from all others. The second test, for processed food made from wheat, yields a chi-squared value of 45.87 and a probability of 0.0000. This suggests that the null hypothesis can be rejected with high significance, indicating that processed food made from wheat is not separable from all others. The third test indicates the same with grains. In conclusion, even though rice processed food is the most distinguished good, which raises concerns for the replaceability of rice and wheat, the overall results support that processed food made from rice or wheat, and grains are not separable from each other. Therefore, this study constructs a SDAIDS model without assuming block separability to further analyze their relationship.

Elasticities from SDAIDS model

The primary objective of this research is to evaluate the substitutability of wheat and rice processed foods. To achieve this, Hicksian elasticities were calculated, which capture the pure substitution effect while excluding the income effect. The results presented in Table 7 indicate that the demand elasticities of Wheat Processed Foods in response to the price of Rice Processed Foods are all positive and statistically significant. This implies that reduction in the price of Rice Processed Foods through the implementation of powdered rice would result in a significant substitution of Wheat Processed Foods. However, the possibility remains that the total consumption of Rice Processed Foods may not increase because the rice processed products substitute each other. Fortunately the results in Table 5 suggest otherwise, as only Rice Bread and Rice Noodles exhibit substitution with Cooked Rice, but the impact is relatively small (0.065, 0.090 each). Although the impact of a price change in Cooked Rice on the

Table 5. Estimated compensated price and expenditure elasticities of rice processed foods

Goods	Rice Processed Foods						Wheat Processed Foods	Grains	Expenditure Elasticities
Products	(1)	(2)	(3)	(4)	(5)	(6)			
(1) Cooked Rice	-0.852***	-0.006	0.027	0.025	0.065*	0.090***	0.221*	0.459***	0.971***
(2) Congee	-0.038	-0.502	-0.365	0.166	-0.073	0.162	0.224	0.465*	0.962***
(3) Rice Cake	0.041	-0.092	-0.597***	-0.063	0.048	0.013	0.059	0.669***	0.922***
(4) Rice Snack	0.152	0.173	-0.26	-0.783***	0.173	-0.106	-0.185	0.991***	0.844***
(5) Rice Bread	0.621*	-0.118	0.303	0.268	-1.722***	-0.004	0.044	0.703**	0.903***
(6) Rice Noodles	1.525***	0.46	0.147	-0.289	-0.006	-2.487***	0.059	0.695*	0.897***

Note : Single, double and triple asterisks (*) denote significance at 10%, 5% and 1% levels, respectively.

Table 6. Estimated uncompensated price and expenditure elasticities of rice processed foods

Goods	Rice Processed Foods						Wheat Processed Foods	Grains	Expenditure Elasticities
Products	(1)	(2)	(3)	(4)	(5)	(6)			
(1) Cooked Rice	-1.009***	-0.033	-0.077	0	0.048	0.081***	-0.122	0.17	0.971***
(2) Congee	-0.194	-0.528*	-0.469*	0.141	-0.0895	0.153	-0.116	0.178	0.962***
(3) Rice Cake	-0.108	-0.118*	-0.696***	-0.0874*	0.032	0.004	-0.266*	0.394***	0.922***
(4) Rice Snack	0.016	0.15	-0.351*	-0.805***	0.159	-0.114	-0.482*	0.740***	0.844***
(5) Rice Bread	0.475	-0.142	0.206	0.244	-1.737***	-0.012	-0.274	0.434	0.903***
(6) Rice Noodles	1.380***	0.436	0.051	-0.312	-0.022	-2.496***	-0.257	0.428	0.897***

Note : Single, double and triple asterisks (*) denote significance at 10%, 5% and 1% levels, respectively.

demand for Rice Noodles appears large, this result is trivial given that Cooked Rice accounts for nearly half of the Rice Processed Foods expenditure share, while Rice Noodles accounts for 2.4%. Based on these findings, we can conclude that lowering the price of Rice Processed Foods is likely to contribute to the substitution of wheat.

It is important to note that all Rice Processed Foods products exhibit a significant substitution effect with Grains, as shown in Table 5. Additionally, the elasticity value 0.644 presented in Table 9 indicates that a decrease in the price of Rice Processed Foods will also lower the demand for White Rice significantly. This raises the second concern of this research: will the expansion of the rice processing industry through policy intervention actually lead to increased total rice consumption? To further address this concern, we turn to Marshallian elasticities, which incorporate both the substitution effect and the income effect. By considering these elasticities, a more realistic demand system can be analyzed. The overall results presented in Table 6, 8, 10 indicate that the substituting relationships become weaker when the income effect is taken into account. Furthermore, Table 6 shows that the elasticities of Rice Processed Foods in response to changes in the price of Wheat Processed Foods have become negative, suggesting that complementary relationship has appeared. Finally, the results in Table 10 indicate that the substitution between Rice Processed Foods and White Rice remains significant, implying that a decrease in the price of Rice Processed Foods will further accelerate the declining trend in the consumption of White Rice.

In conclusion, while consumers may view rice and wheat processed foods as substitutes, the actual substitution

Table 7. Estimated compensated price and expenditure elasticities of wheat processed foods

Goods	Wheat Processed Foods			Rice Processed Foods	Grains	Expenditure Elasticities
Products	(7)	(8)	(9)			
(7) Snack	-0.503***	-0.553***	0.409***	0.502***	0.072	1.073***
(8) Bread	-0.227***	-0.077	-0.344***	0.602***	-0.058	1.103***
(9) Noodles	0.428***	-0.876***	-0.200*	0.442***	0.148	1.056***

Note : Single, double and triple asterisks (*) denote significance at 10%, 5% and 1% levels, respectively.

Table 8. Estimated uncompensated price and expenditure elasticities of wheat processed foods

Goods	Wheat Processed Foods			Rice Processed Foods	Grains	Expenditure Elasticities
Products	(7)	(8)	(9)			
(7) Snack	-0.590***	-0.763***	0.327***	0.127	-0.248*	1.073***
(8) Bread	-0.316***	-0.293***	-0.428***	0.217**	-0.387***	1.103***
(9) Noodles	0.343***	-1.082***	-0.281***	0.0736	-0.167	1.056***

Note : Single, double and triple asterisks (*) denote significance at 10%, 5% and 1% levels, respectively.

Table 9. Estimated compensated price and expenditure elasticities of grains

Goods	Grains		Rice Processed Foods	Wheat Processed Foods	Expenditure Elasticities
Products	(10)	(11)			
(10) White Rice	-1.555***	-0.211***	0.644***	1.075***	1.047***
(11) Other Grains	2.176***	-0.163	-1.224***	-0.553	0.764***

Note : Single, double and triple asterisks (*) denote significance at 10%, 5% and 1% levels, respectively.

Table 10. Estimated uncompensated price and expenditure elasticities of grains

Goods	Grains		Rice Processed Foods	Wheat Processed Foods	Expenditure Elasticities
Products	(10)	(11)			
(10) White Rice	-1.779***	-0.299***	0.278*	0.705***	1.047***
(11) Other Grains	2.012***	-0.228*	-1.491***	-0.822**	0.764***

Note : Single, double and triple asterisks (*) denote significance at 10%, 5% and 1% levels, respectively.

may not occur due to the income effect. If the application of powdered rice can reduce the price level of Rice Processed Foods and therefore weaken the income effect, the substitution between rice and wheat processed foods may be realized in the market. However, it is crucial to consider that White Rice is also a significant substitute for Rice Processed Foods, which may result in an overestimation of the expected increase in total rice consumption.

Discussion and Conclusion

This research aimed to investigate the demand for wheat and rice processed food in South Korea in order to assess the feasibility of the Korean government's 'Measures to vitalize the rice processing industry'. Through the use of household accountbook survey of 1,550 households conducted in 2021, the study estimated the demand system of rice, wheat processed foods and whole grains using the Source Differentiated Almost Ideal Demand

System (SDAIDS) method. Separability test was conducted in order to justify the modelling. The results show that despite the substitutability of rice and wheat processed foods, rice processed foods may also substitute for white rice consumption. Therefore, the expected increase in total rice consumption through using powdered rice in food processing industry may be overestimated.

The results of this research have important implications for the Korean government's efforts to increase the consumption of rice and reduce the dependency on imported wheat. The finding that rice processed foods may also substitute for white rice consumption raises questions about the government's strategy of increasing the consumption of rice through the expansion of the rice processing industry. The findings of this study suggest that expanding the supply of powdered rice as a substitute for wheat flour may not be an effective means of promoting overall rice consumption. In the long term, it appears that policies are needed to promote the consumption of both rice and rice-based products. This research highlights the need for further research to fully understand the consumer behavior and to develop an efficient strategy to meet the policy's target goals. The AIDS model used in this study has some limitations. The model assumes rigidity in consumer responses to price changes. However, in reality, consumer responses can vary. The model also does not consider interaction effects within product groups and assumes that products are purchased independently of each other. Therefore, further research is needed to fully understand the market situation and to develop an efficient strategy that aligns with consumer demand.

Acknowledgement

The data used in this study was supported by Agricultural Technology Management Research in 2021 (PJ015127) funded by the Rural Development Administration.

References

Alston, J. M., Carter, C. A., Green, R., Pick, D. (1990) Whither Armington trade models?. Am J Agric Econ 72:455-467.

Armington, P. S. (1969) A theory of demand for products distinguished by place of production. Staff Papers- IMF 159-178.

Blackorby, C., Davidson, R., Schworm, W. (1991) Implicit separability: Characterisation and implications for consumer demands. J Econ Theory 55:364-399.

Chalfant, J. A. (1987) A globally flexible, almost ideal demand system. J Bus Econ Stat 5:233-242.

Cox, T. L., Wohlgenant, M. K. (1986) Prices and quality effects in cross-sectional demand analysis. Am J Agric Econ 68:908-919.

Deaton, A. (1988) Quality, quantity, and spatial variation of price. Am Econ Rev 418-430.

Deaton, A., Muellbauer, J. (1980) An almost ideal demand system. Am Econ Rev 70:312-326.

Eales, J. S., Unnevehr, L. J. (1988) Demand for beef and chicken products: separability and structural change. Am J Agric Econ 70:521-532.

FIS (Food Industry Statistics) (2020) Processed Food Segment Market Status - Rice Processed Food. http://atfis.or.kr

(Retrieved: 2022.11.06.).

Gao, X. M., Wailes, E. J., Cramer, G. L. (1994) A synthetic demand system: an application to US consumer demand for rice and selected rice substitutes. Appl Econ Perspect Policy 16:27-38.

Goldman, S. M., Uzawa, H. (1964) A note on separability in demand analysis. J Econom 387-398.

Ha, J., Kim, S., Kim, T. (2019) An Analysis of Purchase Factors for Rice Processed Foods using Panel Tobit Model. KJFME 36:25-45.

Haden, K. (1990) The demand for cigarettes in Japan. Am J Agric Econ 72:446-450.

Han, J. H., Gouk, S. Y. (2014) Analysis on consumers' perceptions and preferred attributes toward the processed rice foods-Focusing on breads, biscuits, noodles. J Korean Food Mark 31:29-47.

Hayes, D. J., Wahl, T. I., Williams, G. W. (1990) Testing restrictions on a model of Japanese meat demand. Am J Agric Econ 72:556-566.

Jang, I., Kim, J. M., Koo, B. (2017) Diagnosis of rice processing industry status and measures to expand consumption of domestic raw rice (newly harvested rice). Food Sci Nutr 22:38-44.

Ji, J. H., Lee, K. I., Park, M. S., Kim, S. H., Lee, S. H. (2019) Analysis of processed food demand using a usage-differentiated AIDS model. J Rural Dev 42:31-54.

Kang, J. H., Kang, J. H. (2017) Effects of perceived value of rice cakes on attitudes and purchase intentions. IJTHR 31:217-232.

Lee, J. Y., Brown, M. G., Seale Jr, J. L. (1992) Demand relationships among fresh fruit and juices in Canada. Appl Econ Perspect Policy 14:255-262.

Lee, K., Choi, J. (2000) Analysis of substitutability and separability in meat demand. KJAE 41:45-60.

Piao, S. Y., Li, Z. R., Sun, Y. C., Lee, J. I., Amanor, Y. E. (2020) Analysis of the factors influencing consumers' preferences for rice: locally produced versus the imported in the Ga East municipality of the greater Accra region of Ghana. J Agri Life Environ Sci 32:177-192.

Pudney, S. E. (1981) An empirical method of approximating the separable structure of consumer preferences. Rev Econ Stud 48:561-577.

RDA (Rural Development Agency) (2022) Food Security is Our Future Increasing Soybean and Wheat Self-Sufficiency, 2022 Green Magazine, http://rda.go.kr/webzine/2022/06/sub1-2.html (Retrieved: 2022.11.06.).

Winters, L. (1984) Separability and the Specification of Foreign Trade Functions. J Internat Econ 17:239-63.

Yang, S. R., Koo, W. W. (1993) A Generalized Armington Trade Model: Respecification. Agr Econ 9:374-76.

Yang, S. R., Koo, W. W. (1994) Japanese meat import demand estimation with the source differentiated AIDS model. J Agric Resour Econ 396-408.

Yoon, S., Oh, S., Park, H., Woo, K., Choi, I., Jo, Y., Kim, W. (2015) Changing Consumption Patterns for Processed Rice Food Products in Metropolitan Household of Korea : 2010~2014. J Korean Soc Int Agric 27:631-638.