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Master's Thesis of Economics

Demand for three major protein
sources in Korea: Focusing on
terrestrial, seafood, and plant protein

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Abstract

Despite recent dramatic growth in seafood consumption worldwide, knowledge about seafood protein demand is limited relative to other protein sources. The present study models demand across three major protein categories (i.e., terrestrial protein, seafood protein, and plant protein) in South Korea to fill this research gap. In the first essay, household panel data is used to model a quadratic almost ideal demand system (QUAIDS). The study takes this one step further by modeling demand within four seafood protein categories (i.e., fish, cephalopods, shellfish, and crustaceans). Sociodemographic variables, including health-related factors, are incorporated in the demand models. The results indicate that seafood protein is in a complementary relationship with terrestrial protein while substituting for plant protein. All four seafood categories are a substitute for each other. Individuals who take their health seriously are likely to consume more seafood, particularly fish. In the second essay, the study investigates the factors influencing the success of protein-based ready meals in online grocery retail. Furthermore, it explores how the relationship between these factors and ready meal dollar sales performance varies based on the protein source of the ready meal. As a result of the study, it is found that the sales of protein-based ready meals are significantly higher when the product is stored at a freezing temperature, is a restaurant collaborated product, or is a private label product. In addition, in the case of protein-based ready meals, the results indicate that the higher the concentration of the category to which the product belongs, the higher the sales performance.

Keywords: Terrestrial protein, seafood protein, plant protein, QUAIDS, random effect panel regression, ready meal

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Preface

A move away from animal protein toward plant protein is becoming a global agenda. Food provision has a significant impact on the natural systems on which socioeconomic development depends, an effect that can be primarily attributed to the amount of protein consumed as well as the proportion of different protein sources consumed (de Boer & Aiking, 2019). Thus, research is needed to understand the demand for major protein sources.

While the literature on sustainable diets strongly supports a switch from animal protein consumption toward plant protein consumption, it is much less explicit about the role of seafood protein consumption in diets (Irz et al., 2018). Moreover, in most previous research on consumer protein demand, seafood protein has been either excluded or combined with all terrestrial protein (e.g., beef, pork, and chicken). This inappropriate aggregation of different types of animal protein can lead to biases in the estimations of price elasticities and associated specification problems concerning the identification of substitutes (Salvanes & Devoretz, 1997). To fill the above research gaps, the present study focuses on South Korean households' demand for protein sources. In the first essay, the study models the consumer demand for three major pre-processed proteins. Next, it moves on to investigate the demand for processed protein, namely protein-based ready meal products. The sales performance of these protein-based ready meals is assessed from the retailer's perspective.

In the first essay, the study estimates two demand models. First, the demand for three major protein sources (terrestrial, seafood, and plant protein) are estimated. Next, a model of the demand for seafood protein is estimated by disaggregating seafood into the broad taxonomic groups of fish, cephalopods, shellfish, and crustaceans. In addition, the study identifies sociodemographic and health-related

factors affecting protein demand. The results show that terrestrial protein and seafood protein are complementary, while plant protein can be seen as a substitute for both animal proteins.

In the second essay, the sales performance of ready meals on an online grocery channel is modelled according to the protein source through random effect panel regression analyses. As with the first essay, the first model considers the entire ready meal samples (including all protein sources) to estimate a panel regression model and determine which protein-based product sales performance is relatively better. Further, this study divides the dataset according to the protein source (i.e., terrestrial protein, seafood protein, and plant protein) to identify the factors that influence the success of each type of ready meal.

The results of this study will provide marketers and retailers with practical implications regarding the type of value proposition that can raise product sales in modern society, where the importance of sustainable protein consumption is emphasized. Furthermore, this study intends to provide implications for policymakers regarding the drivers of a demand shift from animal protein to plant protein. From an academic perspective, several previous studies have been conducted on the relationship between animal protein and plant protein. Meanwhile, the current study goes beyond the dichotomous division of protein and further subdivides the animal protein sources typically perceived by consumers as heterogeneous. From a practical perspective, studying the relative status of processed protein compared to pre-processed protein in the market and further researching the success factors of processed protein products according to their source suggests significant implications for new protein-based product development and product assortment strategy.

Table of Contents

I. Essay 1: Modelling the demand across three major protein sources: focusing on seafood protein	1
Chapter 1. Introduction	1
Chapter 2. Previous literature	4
Chapter 3. The QUAIDS framework.....	5
Chapter 4. Data and empirical specification	8
4.1. Demand system estimation in the absence of price data9	
4.2. Incorporating sociodemographic factors.....	13
4.3. Locating seasonal cycles	15
4.4. Handling endogeneity	19
Chapter 5. Empirical results	22
5.1. Demand for three major protein sources	24
5.2. Demand for disaggregated seafood protein categories	27
Chapter 6. Discussions and conclusions.....	30
 II. Essay 2: Success factors of protein based–ready meals.....	33
Chapter 1. Introduction	33
Chapter 2. Data	35
Chapter 3. Model formulation.....	36
3.1. Dependent variable.....	39
3.2. Independent variable	39
3.2.1. Product–level characteristics.....	39
3.2.2. Category–level characteristics.....	41
3.3. Control variables	45
Chapter 4. Results	48
4.1. Main study	48

4.2. Follow-up study	51
Chapter 5. Discussions and conclusions.....	54
5.1. Theoretical implications.....	54
5.2. Practical implications	55
5.3. Limitations and future research	57
Bibilography.....	59
Appendix A.....	70
Table A1. Descriptive statistics of variables.....	70
Table A2. Definitions of sociodemographic variables and average monthly expenditure for each consumer segment	71
Figure A1. Aggregated prices of four seafood categories over the data period	72
Figure A2. Shares of four seafood categories in overall seafood expenditures over the data period	72
Appendix B.....	73
Table B1. Description of product categories	73
Table B2. Random effects of estimation results	74
Reference in Korean	73

List of Figures

Figure 1. Aggregated prices of the three protein sources over the data period.....	17
Figure 2. Shares of the three protein sources in the total protein expenditures over the data period.	17

List of Tables

Table 1. Descriptive statistics of unit prices.....	12
Table 2. Variables and their descriptive statistics.....	21

Table 3. Goodness-of-fit statistics of M1 and M2	23
Table 4. Hausman specification tests for M1 and M2	24
Table 5. Estimation results of the QUAIDS from M1	25
Table 6. Expenditure elasticities and price elasticities from M1	27
Table 7. Estimation results of the QUAIDS from M2.....	28
Table 8. Expenditure Elasticities and price elasticities from M2	30
Table 9. Category size and concentration descriptive statistics.	44
Table 10. Description of variables	46
Table 11. Descriptive statistics of variables	47
Table 12. Random effects of estimation results.....	50
Table 13. Random effects of estimation results.....	53

I. Essay 1: Modelling the demand across three major protein sources: focusing on seafood protein

Chapter 1. Introduction

The worldwide consumption of seafood had been slowly increasing until the early 2010s¹. However, surprisingly, the consumption increased by 21% from 2015 to 2016, where per capita consumption, in particular, grew faster in Asia and Oceania compared to the other continents (OECD–FAO, 2016). Such rapid growth is driven by two factors: a change in supply and/or demand (Kidane & Brækkan, 2021)².

Demand growth plays a critical role in global seafood consumption. Even if there is no productivity growth, the demand growth can raise the market price, which, in turn, quantity supplied and consumed to increase (Kidane & Brækkan, 2021). Therefore, research on demand growth is essential, with previous studies having highlighted this importance (e.g., Asche et al., 2011; Brækkan et al., 2018; Kidane & Brækkan, 2021). However, due to the methodological complexity required, the demand side of seafood research has not received as much attention as its supply side.

¹ The average annual per capita consumption of seafood has increased by roughly 10kg, from 9.9kg in the 1960s to 19.2kg in 2012 (FAO, 2014)

² On the supply side, the expansion of aquaculture production and technological innovation have led to an increase in seafood supply (Asche, 2008; Garlock et al., 2020; Kobayashi et al., 2015; Tveterås et al., 2012). Aquaculture production is increasing rapidly, representing 52% of the seafood supply for human consumption in 2018 (Garlock et al., 2020). Furthermore, innovations in alternative feed and selective breeding have led to production cost-savings and the decline of the market place (Asche, 2008; Guttormsen, 2002).

A multitude of factors complicate seafood demand estimation. In particular, consumer heterogeneity in relation to health is a key factor influencing consumer demand for seafood (Kaabia et al., 2001; Mintert et al., 2001; Torrissen & Onozaka, 2017). It is also important to understand seafood demand relative to the substitute protein sources. However, knowledge regarding the role of seafood demand in the demand literature remains rather limited (Irz et al., 2018). In the previous studies on consumer demand for meat, seafood has been either excluded or combined with all other types of meat (e.g., beef, pork, and chicken). Even when seafood protein has been included as a research subject and compared with terrestrial protein, researchers have failed to compare demand between animal and plant-based protein. The inappropriate aggregation of different types of protein can lead to biases in the estimations of price elasticities and associated specification problems when attempting to identify substitutes (Salvanes & Devoretz, 1997).

To fill the above research gaps, the present study focuses on South Korean households' demand for protein sources in terms of the following three main objectives: (1) to examine the demand interrelationships among terrestrial meat, seafood, and plant protein; (2) to investigate the demand interrelationships within specific seafood protein categories; and (3) to identify sociodemographic factors, including health-related factors, that affect protein consumption.

To achieve these research objectives, this study estimates two demand systems. In the first demand system (M1 henceforth), the demand for three major protein sources (terrestrial, seafood, and plant protein) is modelled, while, in the second (M2), seafood is disaggregated into the broad taxonomic groups of fish, cephalopods, shellfish, and crustaceans. Terrestrial protein includes fresh and frozen red meat (beef and pork) and white meat (chicken) in various cuts. Seafood protein consists of all fresh and frozen fish, cephalopods, shellfish, and crustaceans. Plant protein includes tofu

and legumes. Our rationale for analysing the demand relationships among these categories is as follows: (1) they are the major protein categories consumed by South Korean households; (2) there is a scarcity in the literature regarding consumer preferences for them; (3) it is plausible that the factors driving consumer demand for each respective category differ; and (4) hence, each category can be expected to provide different types of utility. Finally, it should be noted that the subject of the analyses is limited to uncooked protein.

This study conducts its empirical analyses using unique household panel data collected by South Korea's Rural Development Administration (RDA). The dataset includes information on grocery purchases by consumer panels, and the current study uses the dataset to analyse protein consumption at the household level. This study specifies the demand systems for major protein sources by applying the quadratic almost ideal demand system (QUAIDS) model proposed by Banks et al. (1997). As QUAIDS can also incorporate sociodemographic demand shifters, this study specifically examines the effect of the presence of children, age, body mass index (BMI), and degree of health concern on expenditure shares of each protein sources. The results have both economic and marketing implications for which strategies could be adopted to influence seafood consumption.

The remainder of this paper is as follows. The next section explains the pertinent literature on seafood demand. In the following section, QUAIDS framework is described. The subsequent section introduces the data and empirical specifications of the estimated demand model. The paper then presents and discusses the empirical results. In the final section, a summary is provided along with some concluding remarks.

Chapter 2. Previous literature

Several previous studies have addressed the demand for seafood (e.g. Bronnmann, 2016; Bronnmann et al., 2016; Buason & Agnarsson, 2020; Huang, 2015; Schrobback et al., 2019; Surathkal et al., 2017; Tabarestani et al., 2017; Toufique et al., 2018). The meta-analysis by Gallet (2009) showed that the majority of demand specifications are based on the almost ideal system (AIDS) of Deaton and Muellbauer (1980). In addition to these AIDS specifications, previous studies have estimated the demand for seafood using functional forms such as double-log, semi-log, Rotterdam, Translog, and S-Branch (Gallet, 2009).

Focusing on recent studies that used AIDS models, Bronnmann (2016) addressed the demand for wild and aquaculture whitefish on the German market by using a general form of AIDS with linear approximation (LA-AIDS). The results indicated that the demand for aquaculture whitefish is relatively elastic and that pangasius is a substitute for wild-caught species, namely cod, pollock, and Alaska pollock. Surathkal et al. (2017) modelled frozen seafood in the United States using LA-AIDS to estimate the demand relationships among three aggregate frozen seafood categories (breaded, entrees, and unbreaded), as well as these relationships when disaggregated as finfish and shellfish. The results revealed that finfish and shellfish are mutual substitutes. Buason and Agnarsson (2020) examined French household demand for fresh salmon, frozen Salmonidae, fresh cod, frozen whitefish, and other seafood by estimating a two-regime infrequency of purchase model (IPM) and frequency-adjusted AIDS model. The results showed significant relationships between sociodemographic factors (e.g., family size, age, region, and BMI) and demand for different seafood categories.

Concerning previous studies conducted using QUAIDS model, Bronnmann et al. (2016) used a two-step procedure to study

German household demand for six frozen seafood products: farmed and wild salmon, farmed and wild shrimp, redfish, and cultured pangasius. The results indicated that German seafood consumers are generally price-sensitive to salmon and shrimp, implying that the German seafood industry's revenue could rise if the supply increases. Toufique et al. (2018) estimated demand for fish categorized by their origin (inland capture, marine capture, and aquaculture) in Bangladesh by employing the QUAIDS model. The results indicated that the income elasticities for fish from all sources are positive and that the demand for fish from all sources becomes elastic depending on the household income level. The implications of these results are in line with the results from the study by Bronnmann et al. (2016). Increasing supply at aquaculture and inland capture fisheries is crucial for food security.

This study presents a novel perspective of seafood demand that differs from the aforementioned literature. Given the previous literature on seafood demand, this study proposes using QUAIDS model to specify the demand systems of three major protein sources and four seafood protein categories to derive the expenditure, own-price, and cross-price elasticities. Overall, the subject of our analyses as well as the protein classification can be considered more representative of current protein consumption contexts.

Chapter 3. The QUAIDS framework

The QUAIDS model is an extension of the AIDS model developed by Deaton and Muellbauer (1980). Following criticisms of the AIDS approach for yielding biased and inconsistent estimates (Asche & Wessells, 1997), Banks et al. (1997) improved the AIDS model by adding a quadratic expenditure term, resulting in the QUAIDS model. QUAIDS is an acknowledged model in fishery demand studies (e.g., Bronnmann, 2016; Bronnmann et al., 2016; Dey et al., 2011; Toufique

et al., 2018) and is calculated as follows (for notational simplicity, this study omits the subscript for household and time):

$$w_i = \alpha_{i0} + \sum_{j=1}^n \gamma_{ij} \ln(p_j) + \beta_i \ln\left\{\frac{E}{a(p)}\right\} + \frac{\theta_i}{b(p)} \ln\left\{\frac{E}{a(p)}\right\}^2 + \varepsilon_i. \quad (1)$$

Here, w_i denotes the expenditure share of the i^{th} protein category, resulting in three expenditure share equations for M1 and four expenditure share equations for M2. E indicates the total expenditure of the protein categories in each demand model (M1 and M2). α_{i0} , γ_{ij} , β_i , and θ_i are the parameters to be estimated. β_i measures the linear income effect, γ_{ij} measures the non-linear income effect, and ε_i is an error term. $\ln(p_i)$ is calculated as the logarithm of the price. $a(p)$ and $b(p)$ are non-linear price aggregators. $\ln a(p)$ has a transcendental logarithm form, and $b(p)$ is a Cobb-Douglas price aggregator:

$$\ln a(p) = \alpha_0 + \sum_{i=1}^n \alpha_i \ln(p_i) + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \ln(p_i) \ln(p_j) \quad (2)$$

$$b(p) = \prod_{i=1}^n p_i^{(\theta_i)}. \quad (3)$$

The present study imposes three sets of theoretical restrictions: adding up, homogeneity, and symmetry. Adding up requires that the budget shares sum up to unity, implying the following:

$$\sum_{i=1}^n \alpha_i = 1, \sum_{i=1}^n \beta_i = 0, \sum_{i=1}^n \gamma_{ij} = 0. \quad (4)$$

The homogeneity of degree zero in prices and total expenditure assures that if all prices and income are multiplied by a positive constant, the quantity demanded must remain unchanged and requires:

$$\sum_{j=1}^n \gamma_{ij} = 0, \sum_{j=1}^n \theta_i = 0, \forall i. \quad (5)$$

Slutsky symmetry deals with the substitution effect between goods and restricts the matrix of substitution effects to be symmetric. To illustrate, the coefficient of the price of the i^{th} good ($\ln(p_i)$) has the same value in the budget share equation of the j^{th} good as the coefficient of $\ln(p_j)$ (Deaton & Muellbauer, 1980). The symmetry restriction is satisfied by:

$$\gamma_{ij} = \gamma_{ji}, \forall i \neq j. \quad (6)$$

The present study derives expenditure elasticities, e_i , uncompensated price elasticities, eu_{ij} , and compensated price elasticities, ec_{ij} , following Banks et al. (1997). Differentiating Equation (1) with respect to $\ln E$ and $\ln(p_j)$, respectively, yields:

$$\mu_i \equiv \frac{\partial w_i}{\partial \ln m} = \beta_i + \frac{2\theta_i}{b(p)} \left[\ln \left\{ \frac{E}{a(p)} \right\} \right] \quad (7)$$

$$\mu_{ij} \equiv \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i (\alpha_j + \sum_k \gamma_{jk} \ln p_k) - \frac{\lambda_i \beta_j}{b(p)} \left[\ln \left\{ \frac{E}{a(p)} \right\} \right]^2. \quad (8)$$

The expenditure elasticities, e_i , are given by³

$$e_i = \frac{\mu_i}{w_i} + 1. \quad (10)$$

The uncompensated (Marshallian) price elasticity, eu_{ij} , takes the income effect and substitution effect into account and is calculated by:

³ It must be noted that the expenditure elasticity is based on expenditure on protein sources as in the QUAIDS model and does not directly reflect the consumer responses to total expenditures.

$$eu_{ij} = \frac{\mu_{ij}}{w_i} - \delta_{ij} \text{ where } \delta_{ij} = \begin{cases} 1 & \text{if } i = j \\ 0 & \text{if } i \neq j \end{cases} \quad (11)$$

The compensated (Hicksian) price elasticity ec_{ij} , capturing the pure substitution effect of the price change, is computed by:

$$ec_{ij} = eu_{ij} + e_i w_j. \quad (12)$$

Elasticities are a function of the parameter estimates of the demand system and expenditure shares. This study uses the sample means of the shares to calculate the elasticities.

Chapter 4. Data and empirical specification

In the empirical analyses, the current study used household panel data collected by the RDA. The dataset was collected from a randomly selected consumer panel using a stratified sampling method. The respondents attached all their daily food purchase receipts to the housekeeping book and recorded the information, including purchase frequency from January 2015 to November 2019.

In addition to the purchase information, the dataset incorporates multiple sociodemographic variables. The choice of variables was determined following the previous literature (e.g., Buason & Agnarsson, 2020; Dey et al., 2011) but was also dictated by the availability of variables in the data. The dataset includes a dummy variable for the presence of children, an ordinal variable for the age of the household head, and a logarithm of household income. To account for the health-related factors of the respondents, this study merged the dataset with supplemental questionnaire data on the respondents' health concerns (HCs) and BMIs, which were distributed in 2015.

The following procedures describe how the merged dataset was prepared for econometric analysis. First, household panel data from a total of 835 households were collected. During the process, unusable observations containing missing values (two households) were removed from the dataset. Respondents who did not respond to the supplemental questionnaire were removed from the sample, yielding a total of 634 household samples for M1. For M2, three households without seafood purchase history from January 2015 to November 2019 were removed from the sample, yielding a total of 631 household samples. In summary, the final dataset consisted of 634 households with 35,654 observations for M1 and 631 households with 22,643 observations for M2.

Expenditures were aggregated into monthly figures for further matching with the price data. Since there was no price variable in the dataset, the price variable was created using expenditure shares and the Consumer Price Index (CPI). The final model included sociodemographic and seasonality variables, with endogeneity handled by utilizing a logarithm of income. In the following sections, the data management process and QUAIDS model specification are given in detail.

4.1. Demand system estimation in the absence of price data

Previous studies have used several approaches to compensate for a lack of price data (Castellón et al., 2015). Some consumer expenditure surveys have collected data on purchase quantities and expenditures, allowing for the calculation of unit values (i.e., expenditure divided by quantities), which are used as proxies for prices (e.g., Cox & Wohlgemant, 1986; Deaton, 1988). Another common approach has been incorporating external sources of price variability, such as the CPI, to account for missing prices (e.g., Bronnmann et al., 2016; Kastens & Brester, 1996; Kim et al., 2019;

Seale Jr. et al., 2003). However, studies conducted by Slesnick (2005) and Hoderlein and Mihaleva (2008) have found this approach problematic, as it does not account for household variability. Considering this criticism expressed in previous literature, in this study, the price variables were generated using both the CPI and unit values.

First, the CPI⁴ was used to account for the price fluctuations of each category. The study deflated the unit values for January 2015 by the monthly CPI (base year =2015) as of January 2015 to yield the final price data. To match the category of protein sources provided by the CPI, first, the expenditures on proteins were grouped into 16 subgroups: domestic beef, imported beef, pork, chicken, mackerel, hairtail, croaker, pollock, squid, small octopus, abalone, oyster, clam, crab, tofu, and legumes. Despite the unavailability of shrimp' s CPI, the category was added to the analyses⁵ since it occupies a significant portion of South Korean seafood consumption. This resulted in a total of 17 subgroups.

This study generated its unit values by dividing the monthly expenditure by the monthly quantities of each good purchased on each shopping trip. This approach has been used in other demand studies, including the studies of Allais et al. (2010) and Bertail and Caillavet (2008). This approach not only accounts for household variability but also for cross-product differences. Before generating the unit values, all quantity observations in the upper 5% and lower 5% were dropped, since the data on the purchased quantity included a few outliers, which were probably due to errors in data recording. Then, the unit values of January 2015 were deflated by the monthly

⁴ The CPI is managed by South Korea and is calculated monthly by an actual price survey of items. The categories of interest satisfy the following; first, the average household spending per capita of national households is greater than a certain percentage; second, items represent the price of the same species group; and third, items are continuously priced in the market.

⁵ The CPI of shrimp is included in the survey from 2020.

CPI (base year =2015) as of January 2015 to yield the final price data.

Table 1 presents the descriptive statistics of the unit prices of each protein subgroup averaged over the years from January 2015 to November 2019. It can be seen that domestic beef has the highest unit price at about US\$37/kg among subgroups of terrestrial meat, followed by chicken at about US\$7/kg. Among the categories of seafood protein, abalone exhibits the highest unit price at about US\$47/kg, followed by shrimp at about US\$18/kg. Croaker records the lowest unit price among the categories of seafood protein; the average unit price for this species is about US\$7/kg. The unit price of tofu is US\$4/kg, which is the lowest price among all the protein subgroups.

Table 1. Descriptive statistics of unit prices.

		Unit Price (US\$/kg) ^a	
		<i>Mean</i>	<i>Std.Dev.</i>
Terrestrial protein			
	Beef		
	Domestic beef	37.055	2.400
	Imported beef	19.856	0.720
	Pork	12.690	0.782
	Chicken	6.505	0.286
Seafood protein			
	Fish		
	Mackerel	12.680	0.636
	Hairtail	10.649	0.908
	Croaker	7.494	0.260
	Pollock	6.700	0.135
	Cephalopods		
	Squid	10.062	2.773
	Small octopus	13.954	2.100
	Shellfish		
	Abalone	47.483	4.236
	Oyster	12.426	1.048
	Clam	7.193	0.393
	Crustaceans		
	Crab	12.772	1.462
	Shrimp	18.471	2.170
Plant protein			
	Tofu	4.080	0.049
	Legumes	7.604	1.436

^aAugust 3, 2021 Exchange Rate: 1 US\$ = 1,149 Won (South Korean currency).

Finally, the Stone price index approach developed by Deaton and Muellbauer (1980) was implemented for the construction of three prices for M1 (terrestrial, seafood, and plant protein) and four prices for M2 (fish, cephalopods, shellfish, and crustaceans). $\ln(p_i)$ is the Stone price index (Stone, 1954) of protein computed as:

$$p_{kt} = p_{k,2015} \cdot cpi_{kt}, \quad (13)$$

$$\ln(p_{it}) = \sum_{k \in i} w_{kt} \ln(p_{kt}),$$

where $i =$

$$\begin{cases} \text{terrestrial meat, seafood, plant-based protein for M1} \\ \text{fish, cephalopods, molluscs, crustaceans for M2} \end{cases}. \quad (14)$$

where $p_{k,2015}$ are the unit values from January 2015 for subgroup k , and cpi_{kt} and w_{kt} are the CPI and expenditure shares for subgroup k and period t , respectively.

4.2. Incorporating sociodemographic factors

The demand for a particular good also depends on sociodemographic factors (Toufique et al., 2018). Accounting for sociodemographic factors when estimating a demand model is common with household data and can be found in several studies assessing seafood demand (e.g., Bronnmann et al., 2016; Buason & Agnarsson, 2020; Dey et al., 2011; Salvanes & Devoretz, 1997; Surathkal et al., 2017; Toufique et al., 2018). In this study, the presence of children, the household head's age, and respondents' health-related factors, (namely BMI and HC), were included in the analyses.

BMI is an important indicator of health status (Braha et al., 2017) and has been widely used to indicate obesity (Kim et al., 2019;

Romero–Corral et al., 2008). Individuals with a BMI less than 18.5 are considered underweight⁶, while, those with a BMI in the range of 18.5–24.9 are of a normal weight. Those with a BMI in the range of 25.0–29.9 are considered overweight and otherwise obese ($\text{BMI} \geq 30$).

To assess HC, the scale of Kähkönen et al. (1996) was used. This scale has been used in several studies (e.g., Apaolaza et al., 2018; Kähkönen & Tuorila, 1999; Sun, 2008). HC captures respondents' concerns regarding health-related issues. In this study, it was determined by asking the respondents a set of eight questions, using a 5-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

Confirmatory factor analysis (CFA) is conducted on a set of HC items (Nunnally, 1994). It generates factor loadings of HC, which can be used as a single index. The Cronbach's α and composite reliability values for the HC construct for both models were robust and above the lower limit of 0.6, supporting the reliability for both models (internal consistency). Bartlett's sphericity tests were significant for both models ($p < 0.01$), indicating that the data was sufficiently correlated. The Kaiser–Meyer–Olkin (KMO) values of M1 and M2 suggest adequate suitability for factor analysis (Cerny & Kaiser, 1977). This study omitted HC5 and HC7, the factor loadings of which fell below 0.5, to maintain content validity but ensure convergent validity. The standardized factor loadings of the remaining items were significant ($p < 0.01$). The average variance extracted (AVE) of the HC constructs of M1 and M2 exceeded the minimum criterion of 0.5, indicating that the measures share more than 50% of their variation with the latent variable. Descriptions of the HC items and CFA results are provided in Table A1 in the Appendix.

⁶ Although these BMI categories are widely used, they may need to be adjusted upward in the near future to accommodate for population-based changes in height and weight (e.g., Nuttall, 2015).

In QUAIDS model, the sociodemographic variables of the households enter the demand system through the intercept. Following Pollak and Wales (1981), this study modelled the intercept as linear combinations of a set of sociodemographic variables observed in the data. This translating approach allows for the level of demand to depend upon sociodemographic variables and preserves the conditional linearity of the model (Lecocq & Robin, 2015). The equation to be estimated with the sociodemographic variables incorporated is then given as:

$$w_i = \alpha_{i0} + \sum_{j=1}^n \gamma_{ij} \ln(p_j) + \beta_i \ln\left\{\frac{E}{a(p)}\right\} + \frac{\theta_i}{b(p)} \ln\left\{\frac{E}{a(p)}\right\}^2 + \sum_h \delta_{ih} demo_h + \varepsilon_i, \quad (15)$$

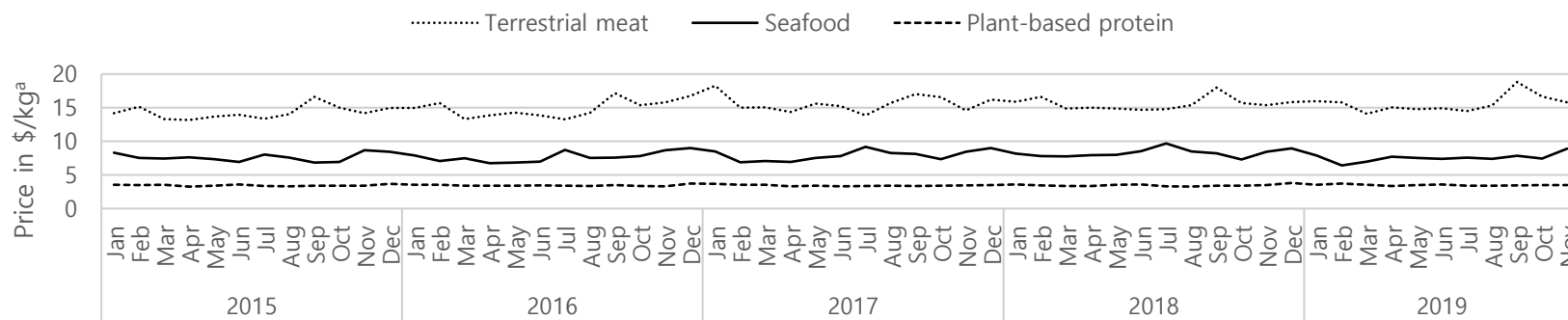
where $demo_h$ is the h^{th} sociodemographic variable, of which there are four: the presence of children, the age of the household head, BMI, and HC. Table A2 provides definitions of the sociodemographic variables and average monthly expenditure shares for each consumer segment of M1 and M2, respectively.

4.3. Locating seasonal cycles

The availability of seafood may act as a barrier to seafood protein consumption. If there is a lack of products available for the desired species, other available species can be a weak substitute for the preferred species (Torrissen & Onozaka, 2017). The availability of perishable agricultural products can be affected by seasonal production cycles (Arnade et al., 2004). Thus, the seasonal structure must be accounted for and isolated to improve the accuracy of demand analysis for the fresh seafood industry (Arnade et al., 2004).

Figures 1 and 2 respectively demonstrate the development of the monthly average expenditure shares and aggregated monthly prices

of the three protein sources. There are seasonality patterns in the expenditure shares and prices of the protein sources; these were found to differ upon comparison. Previous studies have shown the seasonality of seafood consumption and price, depicting an inverse relationship between the two (e.g., Dey et al., 2011). However, the relationship between seafood consumption and price is systematic, yet too complex to be viewed simply as an inverse relationship. To illustrate this point, the expenditure shares of seafood in the dataset generally peak every November (ranging from 24% to 26%), and hit bottoms every July (ranging from 17% to 20%) (Figure 1). On the other hand, aggregated prices of seafood show higher values in November (US\$8.4/kg–US\$9.0/kg), and September (US\$6.9/kg–US\$8.2/kg) (Figure 2). Likewise, each seafood category in M2 exhibits different seasonality patterns, and it should be noted that their prices cannot simply explain their expenditure shares.



^aAugust 3rd, 2021 Exchange Rate: 1 US\$ = 1,149 Won (South Korean currency)

Figure 1. Aggregated prices of the three protein sources over the data period.

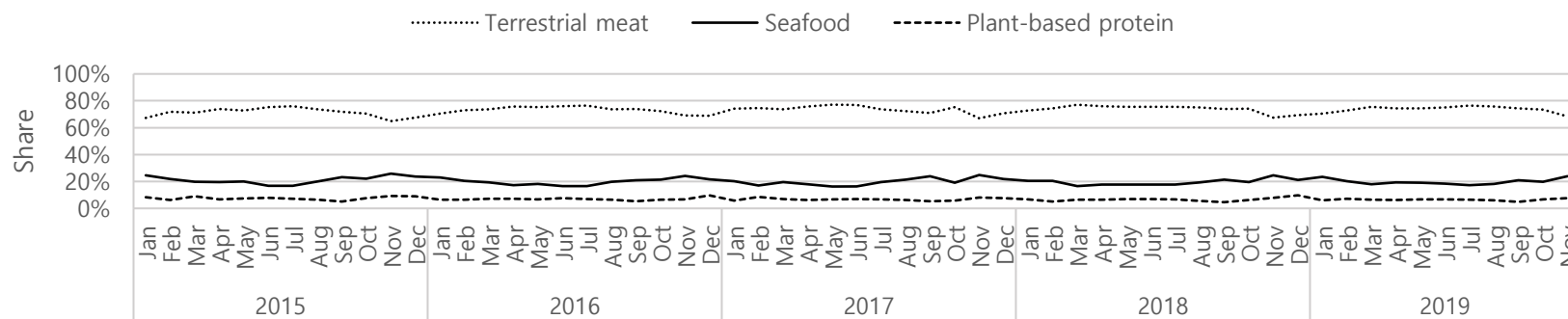


Figure 2. Shares of the three protein sources in the total protein expenditures over the data period.

The monthly average expenditure shares and aggregated monthly prices of four seafood categories are depicted in Figures A1 and A2 in the Appendix.

When there are seasonal effects, and seasonal consumption is not explained solely by the price, the most common approach to account for seasonality has been the use of deterministic seasonal dummy variables (e.g., Bronnmann et al., 2016; Buason & Agnarsson, 2020; Tabarestani et al., 2017). However, previous studies (i.e., Arnade & Pick, 1998; Fraser & Moosa, 2002) have questioned the use of such an approach, pointing to the possibility of biased estimates. Since the introduction of different varieties and sources of supply and demand can affect the seasonal structure over time in unknown ways, it is crucial to control for the seasonal structure of demand models (Arnade et al., 2004).

To locate the seasonal cycle, the present study assumed that the demand follows a one-year cycle (Arnade et al., 2004). The intercept and demand equation for estimation with the seasonal trigonometric variables are then modified as:

$$w_i = \alpha_{i0} + \sum_{j=1}^n \gamma_{ij} \ln(p_j) + \beta_i \ln\left\{\frac{E}{a(p)}\right\} + \frac{\theta_i}{b(p)} \ln\left\{\frac{E}{a(p)}\right\}^2 + \sum_h \delta_{ih} demo_h + \sum_s \tau_{is} season_s + \varepsilon_i, \quad (16)$$

where $season_s$ is the s^{th} seasonality variable, of which there are three: $season_1 = t$, $season_2 = \cos((2f/m)\pi t)$, and $season_3 = \sin((2f/m)\pi t)$. Here, t is the observation number. The value of f corresponds to the seasonal frequencies of the data. In this paper, it is assumed that there is one cycle per year, $f = 1$. The coefficients (τ_{i2}, τ_{i3}) represent the contribution of each cycle to the seasonal process m . Since we use monthly data, $m = 12$ (Arnade & Pick,

1998)⁷.

4.4. Handling endogeneity

The present study used the seemingly unrelated regression (SUR) procedure for its estimation. The SUR procedure takes the optimization process underlying the demand system through an adjustment for cross-equation contemporaneous correlation. However, it generally did not provide consistent estimators for Equation (16) due to the potential endogeneity of some of the right-hand side variables. In each share equation, the error term, ε_i , can be correlated with the log of the total budget variable $\ln E$. The correlation, a source of potential bias, can be accounted for with instrumental variables (IVs) (Hausman, 1978; Holly & Sargan, 1982).

In this study, it was assumed that the total expenditure is endogenous, leading to the creation of a logarithm of income as the identifying IV. Potential endogeneity in expenditure was accounted for by estimating a model for the total expenditure in each household and then incorporating the residuals of the model as an additional control variable. ε_i in Equation (16) was augmented with the residual vector $\hat{\mathbf{v}}$ so that:

$$\varepsilon_i = \rho_i \hat{\mathbf{v}} + u_i. \quad (17)$$

The residual vector $\hat{\mathbf{v}}$ is gained from the first-stage IV regression. Here, the dependent variable is the log of the total expenditure, and the independent variables are all exogenous variables entering the model and the identifying IV. From the first regression, residuals,

⁷ . For a more complete explanation of the trigonometric specification, see Arnade and Pick (1998), Arnade et al. (2004), and Canova and Hansen (1995).

namely, \hat{v} , are included as a new variable in the final specification of the demand system:

$$w_i = \alpha_{i0} + \sum_{j=1}^n \gamma_{ij} \ln(p_j) + \beta_i \ln\left\{\frac{E}{a(p)}\right\} + \frac{\theta_i}{b(p)} \ln\left\{\frac{E}{a(p)}\right\}^2 \\ + \sum_h \delta_{ih} demo_h + \sum_t \tau_{it} season_t + \rho_i \hat{v} + u_i, \quad (18)$$

where ρ_i is the coefficient for \hat{v} of i^{th} goods, and u_i is an error term.

The descriptive statistics for the variables estimated and interpreted through the analyses are summarized in Table 2. In M1, the price of terrestrial protein ranges in the upper price segment, averaging about US\$15/kg. As expected, the price of plant protein ranges in the lower price segment (US\$3/kg). Among the seafood protein categories (M2), shellfish are in the upper price segment (US\$7/kg), and cephalopods are in the lower price segment (US\$4/kg). Most of the protein budget is spent on terrestrial protein with just over 20% of the total expenditure on protein is spent on seafood. Moreover, fish accounted for the highest expenditure share (42%), followed by shellfish (35%). Regarding the sociodemographic variables, about 70% of the households raise children. The average household head in the sample is 56 years old. The BMI and HC estimates indicate that the average household heads are of a normal weight and have moderate health concerns.

Table 2. Variables and their descriptive statistics.

			M1		M2	
Variable			Mean	Std. Dev.	Mean	Std. Dev.
<hr/>						
Terrestrial protein		Price (\$/kg)	15.192	8.644	—	—
		Expenditure share	0.669	0.305	—	—
<hr/>						
Seafood protein		Price (\$/kg)	7.818	7.820	—	—
		Expenditure share	0.203	0.247	—	—
	Fish	Price (\$/kg)	—	—	6.427	5.315
		Expenditure share	—	—	0.420	0.408
	Cephalopods	Price (\$/kg)	—	—	3.768	5.234
		Expenditure share	—	—	0.192	0.319
	Shellfish	Price (\$/kg)	—	—	6.892	11.814
		Expenditure share	—	—	0.249	0.353
	Crustaceans	Price (\$/kg)	—	—	4.171	7.411
		Expenditure share	—	—	0.139	0.286
<hr/>						
Plant protein		Price (\$/kg)	3.454	1.884	—	—
		Expenditure share	0.129	0.221	—	—
<hr/>						
Real expenditure						

Sociodemo- graphic variables	Total protein sources	64.157	54.964	–	–
	Total Seafood	–	–	20.443	21.908
	Presence of children ^a	0.721	0.449	0.724	0.447
	Age ^b	55.956	9.824	56.025	9.789
	BMI ^c	22.321	2.629	22.333	2.618
	HC ^d	3.718	0.720	3.725	0.712
Number of observations		35,654		22,643	
Number of households		634		631	

^a Dummy variable, 1 = have kids.

^b The variable is converted into an ordinal variable: coded as 1 if age \leq 30; 2 if $30 < \text{age} \leq 40$; 3 if $40 < \text{age} \leq 50$; 4 if $50 < \text{age} \leq 60$; 5 if $60 < \text{age} \leq 70$; and 5 if age > 70 .

^c The variable is converted into an ordinal variable: coded as 1 if BMI < 18.5 ; 2 if $18.5 \leq \text{BMI} < 25$; 3 if $25 \leq \text{BMI} < 30$; and 4 if BMI ≥ 30 .

^d The variable is converted into a latent variable score. The table shows the average of the HC items.

Chapter 5. Empirical results

The goodness-of-fit statistics, and their associated p -values in the demand estimations for M1 and M2 are presented in Table 3. The explanatory power of the equations in M1 ranges from 56% to 65% of the variance. The R^2 values of the equations in M2 are relatively higher than those of the equations in M1, ranging from 76% to 83%. Thus, each equation in both M1 and M2 describes a considerable amount of variability in each dependent variable.

Table 3. Goodness-of-fit statistics of M1 and M2.

Model	Equation	RMSE	R^2	p -value
M1	Terrestrial protein	0.173	0.680	0.000
	Seafood protein	0.163	0.562	0.000
	Plant protein	0.131	0.651	0.000
M2	Fish	0.168	0.831	0.000
	Cephalopods	0.155	0.766	0.000
	Shellfish	0.164	0.785	0.000
	Crustaceans	0.135	0.778	0.000

The current study tested the exogeneity of expenditures in the whole demand system of M1 and M2 using the procedure developed by (Hausman, 1978). To apply a Hausman specification test, Wald tests for the parameters of each residual variable and the joint parameters were conducted. The Wald tests for M1 and M2 indicated that all expenditures are endogenous except the fish expenditure variables. These results are presented in Table 4.

Table 4. Hausman specification tests for M1 and M2.

Model	Category	Test	χ^2	$\Pr > \chi^2$	Label
M1	Terrestrial protein	Wald	252.799	0.000	$\rho_1 = 0$
	Seafood protein	Wald	90.909	0.000	$\rho_2 = 0$
	Plant protein	Wald	62.785	0.000	$\rho_3 = 0$
	Joint test for two categories (excludes plant protein)	Wald	260.410	0.000	$\rho_1, \rho_2 = 0$
M2	Fish	Wald	0.342	0.559	$\rho_1 = 0$
	Cephalopods	Wald	142.289	0.000	$\rho_2 = 0$
	Shellfish	Wald	104.308	0.000	$\rho_3 = 0$
	Crustaceans	Wald	629.235	0.000	$\rho_4 = 0$
	Joint test for three categories (excludes cephalopods)	Wald	721.106	0.000	$\rho_1, \rho_3, \rho_4 = 0$

5.1. Demand for three major protein sources

The estimated parameters of M1 are presented in Table 5. People who purchase more terrestrial meat than the average consumer are relatively younger and have children. The BMI parameter is positive, which indicates that these consumers are not as healthy as those who are more likely to consume other protein sources. Those consuming more seafood protein are typically older, healthier individuals with no children. Those who consume the most plant protein are generally older, healthier, and more health-conscious individuals with children.

Table 5. Estimation results of the QUAIDS from M1.

		Terrestrial protein	Seafood protein	Plant protein
Intercept	α_{i0}	5.123*** (0.052)	1.896*** (0.062)	-6.019*** (0.018)
ln Expenditure	β_i	0.046*** (0.001)	0.017*** (0.001)	-0.063*** (0.000)
ln Price of terrestrial protein	γ_{i1}	-0.011*** (0.002)	-0.052*** (0.002)	0.063*** (0.003)
ln Price of seafood protein	γ_{i2}	-0.052*** (0.003)	0.027*** (0.001)	0.025*** (0.004)
ln Price of plant protein	γ_{i3}	0.063*** (0.002)	0.025*** (0.001)	-0.088*** (0.001)
Presence of children	δ_{i1}	0.047*** (0.002)	-0.031*** (0.002)	-0.016*** (0.002)
Age	δ_{i2}	-0.024*** (0.001)	0.017*** (0.001)	0.008*** (0.001)
BMI	δ_{i3}	0.015*** (0.002)	-0.009*** (0.002)	-0.006*** (0.002)
Health Concern	δ_{i4}	-0.000 (0.001)	-0.001 (0.001)	0.002** (0.001)
t	τ_{1i}	-0.000 (0.000)	0.000*** (0.000)	-0.000 (0.000)
cos ^a	τ_{2i}	-0.007*** (0.001)	0.006*** (0.001)	0.002 (0.001)
sin ^a	τ_{3i}	0.007*** (0.001)	-0.005*** (0.001)	-0.002 (0.001)
Residuals	ρ_i	0.021*** (0.001)	-0.013*** (0.001)	-0.008*** (0.001)
Observations				35,654
Adj. R^2				0.520

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Standard errors are in parentheses.

^a cos denotes $season_2 = \cos((k/Z) \pi t)$ and sin denotes $season_3 = \sin((k/Z) \pi t)$.

To address the economic interpretation of the estimated parameters in M1, this study derived expenditure, uncompensated, and compensated price elasticities. Table 6 shows the elasticity estimates. Statistically, all elasticities are significant.

Both animal proteins, terrestrial and seafood protein, demonstrate strongly elastic expenditure responsiveness and are luxuries. In particular, seafood protein shows more elastic expenditure responsiveness than terrestrial protein. Expenditure elasticities for the plant protein category imply that it is a necessity. Thus, holding all other factors constant, seafood protein would attract higher expenditures than its protein substitutes if the expenditure on proteins increases. Considering the current expenditure share of seafood protein relative to other protein sources, its higher expenditure elasticity, and the prospects for increased seafood consumption (OECD–FAO, 2016), seafood protein has strong potential for further demand growth.

The uncompensated and compensated own–price elasticity estimates reveal a negative relationship between prices of normal goods and their demand. Comparing the uncompensated elasticities with the corresponding compensated values thus show the role of the two effects of price change on demand. All compensated own–price elasticities are smaller in absolute value than the corresponding uncompensated values. The results imply that the price responsiveness of the different protein sources is dependent on income; when income is held constant (i.e., it is not a constraint in the decision process), consumers tend to be less responsive to the price of the protein categories. The own–price elasticity of seafood protein is found to be relatively inelastic in comparison with the other two protein categories.

The compensated cross–price elasticities show that the plant protein categories are mutual substitutes with terrestrial and seafood protein. The degree of substitutability has increased compared with

the corresponding uncompensated elasticities. On the other hand, the terrestrial and seafood proteins are found to be mutual complements.

Table 6. Expenditure elasticities and price elasticities from M1.

	Terrestrial protein	Seafood protein	Plant protein
Expenditure elasticities	1.168*** (0.005)	1.274*** (0.034)	0.906*** (0.000)
Uncompensated (Marshallian) price elasticities			
Terrestrial protein	-1.900*** (0.027)	-0.495*** (0.012)	1.226*** (0.035)
Seafood protein	-2.268*** (0.267)	-1.040*** (0.027)	2.034*** (0.260)
Plant protein	0.576*** (0.001)	0.207*** (0.000)	-1.689*** (0.001)
Compensated (Hicksian) price elasticities			
Terrestrial protein	-1.580*** (0.001)	-0.424*** (0.006)	2.004*** (0.037)
Seafood protein	-1.919*** (0.252)	-0.963*** (0.032)	2.882*** (0.294)
Plant protein	0.824*** (0.004)	0.264*** (0.005)	-1.086*** (0.002)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. All elasticities are computed at the mean of the data. Standard errors are in parentheses.

5.2. Demand for disaggregated seafood protein categories

The estimated parameters of M2 are presented in Table 7. The results indicate that individuals who purchase more fish than the average consumer are older and more health-conscious. Those consuming more cephalopods are typically older and less health-conscious. Moreover, the individuals who consume the most crustaceans have children.

Table 7. Estimation results of the QUAIDS from M2.

		Fish	Cephalopods	Shellfish	Crustaceans
Intercept	α_{i0}	-0.149*** (0.030)	0.278*** (0.027)	-0.089*** (0.029)	0.960*** (0.025)
ln Expenditure	β_i	0.012*** (0.001)	-0.001 (0.001)	0.010*** (0.001)	-0.022*** (0.001)
ln Price of fish	γ_{i1}	0.059*** (0.001)	-0.022*** (0.000)	-0.027*** (0.000)	-0.011*** (0.001)
ln Price of cephalopods	γ_{i2}	-0.022*** (0.000)	0.052*** (0.000)	-0.015*** (0.000)	-0.015*** (0.001)
ln Price of shellfish	γ_{i3}	-0.027*** (0.000)	-0.015*** (0.000)	0.052*** (0.001)	-0.009*** (0.001)
ln Price of crustaceans	γ_{i4}	-0.011*** (0.001)	-0.015*** (0.001)	-0.009*** (0.001)	0.035*** (0.001)
Presence of Children	δ_{i1}	-0.004 (0.003)	-0.000 (0.003)	0.001 (0.003)	0.004* (0.002)
Age	δ_{i2}	0.005*** (0.001)	-0.004*** (0.001)	-0.000 (0.001)	-0.001 (0.001)
BMI	δ_{i3}	-0.003 (0.002)	0.001 (0.002)	0.002 (0.002)	-0.000 (0.001)
Health Concern	δ_{i4}	0.003*** (0.001)	-0.002* (0.001)	-0.001 (0.001)	0.001 (0.001)
t	τ_{1i}	-0.000** (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
cos ^a	τ_{2i}	-0.010*** (0.002)	-0.007*** (0.002)	0.009*** (0.002)	0.007*** (0.001)
sin ^a	τ_{3i}	-0.002 (0.002)	0.004** (0.001)	0.003* (0.002)	-0.004*** (0.001)
Residuals	ρ_i	0.001 (0.002)	-0.019*** (0.002)	-0.018*** (0.002)	0.036*** (0.001)
Observations					22,643
Adj. R ²					0.439

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Standard errors are in parentheses.

^a cos denotes $season_2 = \cos((k/Z) \pi t)$ and sin denotes $season_3 = \sin((k/Z) \pi t)$.

Table 8 provides the demand elasticities of M2. All elasticity estimates are statistically significant. The expenditure elasticities for the four seafood protein categories are positive. Among the seafood protein categories, fish and shellfish are luxuries, while cephalopods and crustaceans are necessities. The results indicate that, as the expenditure on seafood increases, shellfish would attract a more proportionate increase in expenditure, thereby further increasing its share.

Both the uncompensated and compensated own-price elasticities indicate a negative relationship between the price of a normal good and its demand. The demand for all seafood protein categories are found to be inelastic. The demand for crustaceans shows the least responsiveness to price changes. Hence, a uniform decrease in price across all the seafood protein categories would decrease the share of crustaceans in favour of more elastic categories. When comparing the uncompensated elasticities with the compensated elasticities, a large income effect of price change can be seen for the own-price- and cross-price elasticities of seafood protein categories: The own-price effects become more inelastic after ignoring the income effect. In contrast, the cross-price effects show gross complementarity but net substitution. The most considerable income effect of price change can be seen for fish.

Seafood protein categories compete in the same market if the goods are substitutable for the consumer. The identification of potential substitutes or complements is based on the signs of the compensated price elasticities. In the current study, all the uncompensated cross-price elasticities are positive, indicating substitution relationships across all seafood protein categories. The weakest relationship is found between crustaceans and shellfish.

Table 8. Expenditure elasticities and price elasticities from M2.

	Fish	Cephalopods	Shellfish	Crustaceans
Expenditure elasticities	1.028*** (0.002)	0.996*** (0.004)	1.036*** (0.003)	0.761*** (0.012)
Uncompensated (Marshallian) price elasticities				
Fish	-0.867*** (0.001)	-0.054*** (0.001)	-0.058*** (0.001)	-0.049*** (0.001)
Cephalopods	-0.113*** (0.001)	-0.728*** (0.004)	-0.081*** (0.001)	-0.074*** (0.001)
Shellfish	-0.099*** (0.001)	-0.064*** (0.001)	-0.806*** (0.002)	-0.067*** (0.001)
Crustaceans	-0.122*** (0.002)	-0.111*** (0.002)	-0.126*** (0.002)	-0.402*** (0.013)
Compensated (Hicksian) Price Elasticities				
Fish	-0.407*** (0.002)	0.142*** (0.002)	0.221*** (0.002)	0.044*** (0.002)
Cephalopods	0.333*** (0.002)	-0.538*** (0.001)	0.189*** (0.002)	0.016*** (0.002)
Shellfish	0.365*** (0.002)	0.133*** (0.002)	-0.525*** (0.001)	0.027*** (0.002)
Crustaceans	0.220*** (0.005)	0.034*** (0.003)	0.080*** (0.004)	-0.333*** (0.010)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. All elasticities are computed at the mean of the data. Standard errors are in parentheses.

Chapter 6. Discussions and conclusions

This study uses household panel data from the RDA from January 2015 to November 2019 to analyze the demand for major protein sources in South Korea. Two QUAIDS models are estimated to obtain the demand structure for three major protein sources: terrestrial protein, seafood protein, and plant protein, as well as disaggregated

seafood protein categories. QUAIDS models incorporate the four sociodemographic variables: the presence of children as well as the age, BMI, and HCs of the household head. To understand the demand relationships, the uncompensated and compensated expenditure, own-price, and cross-price elasticities are obtained.

The present study takes one step further from the previous literature, which has thus far only compared animal protein and plant protein dichotomously or omitted plant-based protein entirely, when estimating seafood demand. The results of the present study justify analysing the demand for terrestrial protein, seafood protein, and plant protein within the broader category of protein. By considering the relationship between seafood protein and the other two proteins, the position of seafood protein within the protein market is identified in detail.

The complementarity between terrestrial protein and seafood protein shows that the two proteins are not competing goods in the same market and that consumers perceive them differently in many ways. The parameter estimates of this study show the heterogeneity of distinct consumer segments for terrestrial protein and seafood protein. The results indicate that terrestrial protein consumers are younger and less healthy (in terms of weight) individuals, while seafood protein consumers are older and healthier. Surprisingly, plant protein is found to be a substitute for both animal proteins. The recent trend towards sustainability suggests that consumers perceive plant protein as a sustainable alternative to animal proteins. This is supported by the present study's discovery, indicating that consumers who are significantly more health-conscious have a higher expenditure share in plant protein. Overall, the results demonstrate the importance of market segment information when attempting to increase seafood protein consumption. For instance, a potential marketing strategy aimed at attracting more seafood consumers could involve advertising seafood protein as lean protein

as well as specifically targeting the elderly and single-person households.

Furthermore, this study addresses the demand structure within four seafood protein categories (i.e., fish, cephalopods, shellfish, and crustaceans). The cross-price elasticity estimates show that these four seafood protein categories are substitutes for each other. This implies that the seafood protein categories are not homogenous in the market. Thus, the findings of this study highlight the potential for growth in the South Korean seafood market.

II. Essay 2: Success factors of protein based-ready meals

Chapter 1. Introduction

A protein transition in diets, replacing animal protein with alternative protein sources, is necessary for sustainable protein consumption (Chollet et al., 2022; Paloviita, 2021). Animal-based diets have raised concerns regarding their detrimental effect on the environment (de Boer & Aiking, 2018; Paloviita, 2021). However, the way in which to implement this shift from animal protein to alternative protein sources remains an unsolved problem, as animal products play a significant role in protein provision (Chollet et al., 2022; Jallinoja et al., 2016; Melendrez-Ruiz et al., 2019; Tziva et al., 2020).

In regard to this protein transition, the development of ready meal products has been suggested as a potential way to decrease animal-based protein consumption through the protein transition (Chollet et al., 2022). A ready meal is a type of convenience food found in precooked, partially cooked, uncooked, frozen, or preserved form that is consumed as sold or after minimal cooking (Aviles et al., 2020; Bumbudsanpharoke & Ko, 2022). According to the previous literature, the consumption barrier to plant protein is alleviated or disregarded when plant protein is given in the processed form (Chollet et al., 2022). This process dimension of ready meals overshadows the origin of protein (Chollet et al., 2022). Ready meals offer consumers the opportunity to quickly prepare and enjoy dishes, similar in quality to those of gourmet restaurants in their own homes (Cho et al., 2020). Their functional properties are so anchored that they overshadow the origin dimension (Chollet et al., 2022).

The market size of the ready meal is gradually increasing worldwide (Bumbudsanpharoke & Ko, 2022).⁸ In particular, the annual sale of ready meal in South Korea was estimated to be approximately US \$3.4 billion in 2020, up from approximately US \$ 3.0 billion in 2019, due to changing consumer lifestyles, an increased middle-class population, and many producers launching various ready meals (Bumbudsanpharoke & Ko, 2022; Statista, 2021).

The ready meal is a food category to which retailers have paid great attention, having grown considerably in volume and diversity (Dawson, 2013). Through new product development efforts, ready meal manufacturers and retailers offer customers a broader range of different ethnic cuisines. These category innovation efforts have positive effects on margins, driving the sales growth of grocery retailers (Dawson, 2013; Richards & Hamilton, 2012). Ready meals are available to consumers via various retail channels, including online grocery retailing, which has been experiencing explosive growth in recent years (Anshu, 2022; Bumbudsanpharoke & Ko, 2022; Yoon et al., 2022; Singh, 2019; Laato et al., 2020).

In light of this, this study focuses on answering the following questions: (1) What drives the success of ready meals in an online grocery channel? For example, which product-level characteristics and category-level characteristics influence the sales performance of ready meals? (2) How does the influence of these product- and category-level characteristics on sales performance vary between ready meals with different major protein sources? To answer these research questions, this study models the sales performance of ready meals in an online grocery channel in South Korea based on their protein source using random effect panel regression analyses.

⁸ The global ready meal market is expected to expand at a compound annual growth rate (CAGR) of roughly 7% from 2019 to 2025 and is estimated to be valued at about US \$157 billion by the end of 2025 (Bumbudsanpharoke & Ko, 2022; Research and Markets, 2020).

This research is conducted in two phases. First, the entire dataset of ready meals is used to estimate a panel regression model and determine which protein-based ready meal sales perform relatively better. Then, the dataset is divided according to the protein source (i.e., terrestrial protein, seafood protein, and plant protein) to individually identify the factors influencing the success of the different types of ready meals. In the analyses, product-level characteristics (e.g., preservation method, restaurant collaboration, private label) and category-level characteristics (e.g., category size, category concentration) that can affect ready meal sales performance in the online retail context were incorporated. The results from both analyses provide strategic insights into and rationale for potential product assortment strategies to market protein-based ready meals.

The remainder of the paper is organized as follows. In the next section, an overview of the data is provided. In Section 3, the model is presented. In Section 4, the model estimates and main findings are presented. Finally, the findings as well as conclusions for practice and future research are discussed.

Chapter 2. Data

A unique dataset is provided by a leading South Korean online grocery retail company covering actual sales data on ready meal products. This data include monthly sales and product- and brand-level characteristics for individual ready meals from January 2017 to August 2021. The sales data are unbalanced panel data lacking observations prior to the product launch in the store. The product categories selected are appetizer (30% of all ready meals); followed by entrée (22%); cooked rice (17%); stew (12%); noodle (9%); salad (6%); and soup (4%)⁹.

⁹ A description of the categories is presented in Table B2 in Appendix B.

The raw form of the data includes the quantity of each product sold and its price¹⁰ for the individual ready meals. In the main study, the relationship between the ready meal sales and product- and brand-level characteristics are estimated. In total, there are 52,941 observations of 3,300 ready meals are used in the main study. In the follow-up study, the ready meals are categorized according to the three major protein sources (e.g., terrestrial protein, seafood protein, and plant protein). The terrestrial protein dataset consists of 31,273 observations of 1,933 ready meals; the seafood protein dataset consists of 11,165 observations of 712 ready meals; and, the plant protein dataset consists of 2,778 observations of 198 ready meals. The remaining 8,570 observations of 457 ready meals lacks protein sources and are thus not included in the follow-up study.

The main study allows exploring for which the product- and category-level characteristics (e.g., preservation method, restaurant collaboration, private label, category size, and category concentration) that contribute to the sales performance of ready meals in an online grocery retail channel. The follow-up study further explores how the relationships between sales and the product- and category-level characteristics of ready meals differ according to the major protein source of the ready meal.

Chapter 3. Model formulation

The independent variables used in this study include both time-invariant and time-variant product-related characteristics of ready meals. The fixed-effect model omits important time-invariant variables (Bollen & Brand, 2010). On the other hand, fixed-effect estimators are highly inefficient in terms of their degree of freedom, since the number of ready meals in the datasets (3,300 ready meals

¹⁰ The price at the time the product was last sold by the retailer are used in the research.

in total) is greater than the time period (56 months). Therefore, a random-effect panel model is employed to analyse the impact of both the time-variant and time-invariant variables on ready meal sales.

This study applies the Breusch-Pagan Lagrange Multiplier (LM) test and Wooldridge test for random effects to select the best model. The LM test (Breusch & Pagan, 1979) indicates that random-effect estimators are preferable to pooled ordinary least squares (pooled OLS) estimators. The current study adopts generalized least squares (GLS) random-effects with AR(1) disturbances to address a first-order serial correlation issue in the dataset, revealed through the Wooldridge test (Wooldridge, 2010).

The main study applies a stepwise method to the GLS random-effects model to identify key variables influencing the sales performance of the ready meals ((19)–(22)). The subscripts used in these equations are: i (product), c (category), and t (month). First, the control variables are introduced in the main-effect model (Equation (19)), followed by the product- (Equation (20)) and category-level characteristics (Equation (21)). Finally, the major protein source is interacted with the category concentration variable (HHI_{ct}) to test whether the category concentration moderates the dollar sales performance of each protein-based ready meal (Equation 22). The variables are sequentially added to the model according to their relative importance in terms of the explanatory power of the model. The robustness of the results is confirmed by comparing the changes in the coefficients of the variables in each model.

$$\textbf{Step1: } \ln(\text{Sales}_{it}) = \alpha_0 + \beta_1 \text{Unit price}_i + \sum_c \beta_c \text{Category}_i^c + T_t + \varepsilon_{it} \quad (19)$$

$$\begin{aligned} \textbf{Step2: } \ln(\text{Sales}_{it}) = & \alpha_0 + \sum_p \beta_p \text{Protein}_i^p + \sum_s \beta_s \text{Preserve}_i^s + \\ & \beta_2 \text{Restaurant}_i + \beta_3 \text{PL}_i + \beta_1 \text{Unit price}_i + \sum_c \beta_c \text{Category}_i^c + T_t + \varepsilon_{it} \quad (20) \end{aligned}$$

$$\begin{aligned} \textbf{Step3: } \ln(\text{Sales}_{it}) = & \alpha_0 + \sum_p \beta_p \text{Protein}_i^p + \sum_s \beta_s \text{Preserve}_i^s + \\ & \beta_2 \text{Restaurant}_i + \beta_3 \text{PL}_i + \beta_4 \ln(\text{SKU}_{ct}) + \beta_5 \text{HHI}_{ct} + \beta_1 \text{Unit price}_i + \\ & \sum_c \beta_c \text{Category}_i^c + T_t + \varepsilon_{it} \end{aligned} \quad (21)$$

$$\begin{aligned} \textbf{Step4: } \ln(\text{Sales}_{it}) = & \alpha_0 + \sum_p \beta_p \text{Protein}_i^p + \sum_s \beta_s \text{Preserve}_i^s + \\ & \beta_2 \text{Restaurant}_i + \beta_3 \text{PL}_i + \beta_4 \ln(\text{SKU}_{ct}) + \beta_5 \text{HHI}_{ct} + \beta_1 \text{Unit price}_i + \\ & \sum_h \beta_h \text{Protein}_i * \text{HHI}_{ct} + \sum_c \beta_c \text{Category}_i^c + T_t + \varepsilon_{it} \end{aligned} \quad (22)$$

The follow-up study explores how the relationship between the ready meal sales and category- and product-characteristics varies depending on the protein source. Individual regressions for each protein-based ready meal group (e.g., terrestrial meat, seafood protein, plant-based protein) are conducted. As in the main study, a stepwise method is applied: First, the control variables are first introduced in the main-effect model, followed by the category- and product-level characteristics. The final regression model is specified as follows (Equation (23)).

$$\begin{aligned} \ln(\text{Sales}_{it}) = & \alpha_0 + \sum_s \beta_s \text{Preserve}_i^s + \beta_2 \text{Restaurant}_i + \beta_3 \text{PL}_i + \\ & \beta_4 \ln(\text{SKU}_{ct}) + \beta_5 \text{HHI}_{ct} + \beta_1 \text{Unit price}_i + \sum_c \beta_c \text{Category}_i^c + T_t + \varepsilon_{it} \end{aligned} \quad (23)$$

A significance level of 10% is considered for all statistical tests. All statistical analyses are performed using STATA 16.0 software. In the following section, the variables used in the research are described in detail.

3.1. Dependent variable

The dependent variable of interest is the dollar sales, a logarithm of dollar sales $\ln(\text{Sales}_{it})$. The dollar sales are generated by multiplying the number of products sold by their price. This study employs a logarithmic transformation of the dollar sales to address the non-linear relationship between the independent and dependent variables (Benoit, 2011).

3.2. Independent variable

3.2.1. Product-level characteristics

To determine which protein sources affect the ready meal sales performance, the ready meals are classified into four categories according to the main ingredient indicated in their respective product labels: terrestrial protein, seafood protein, plant protein, and no protein. The terrestrial protein category includes fresh and frozen red meat (beef and pork) and white meat (chicken) in various cuts. The seafood protein category consists of fresh and frozen fish, cephalopods, shellfish, and crustaceans. The plant protein category includes legumes and other plant-based alternative proteins. Following this classification, the protein source (Protein_i^p) variable of the ready meal is incorporated in the model of the main study¹¹. Protein_i^p is expanded into four dummy variables: terrestrial protein, seafood protein, plant protein, and no protein (reference). Besides the major protein source of the ready meal, this study considers three product-level characteristics as independent variables: preservation method (Preserve_i^s), restaurant collaboration (Restaurant_i), and private label (PL_i).

¹¹ In the follow-up study, the major protein source variable is not included in the model because the dataset is divided according to the major protein source and model estimation is performed using each dataset.

Preserve_i^s refers to the preservation method of the ready meal *i*, and is expanded into three dummy variables: frozen (reference), chilled, and ambient. Food preservation is one of the most critical tasks of producers and processors in food technology (Szymkowiak et al., 2020). One of the characteristics of grocery retail is the difference temperature requirements for preservation, depending on the food type (Eriksson et al., 2019). Grocery retailers manage products from three different temperature zones, including frozen, chilled, and ambient (Eriksson et al., 2019). The temperature requirements can be defined by law (e.g., for frozen products) or applied to increase the product quality (e.g., for products with a longer shelf life) (Ostermeier & Hübner, 2018).

The preservation method of a food product is interconnected with the shelf-life, ease of storage, and regeneration – in other words, bringing stored foods to a state of readiness for consumption (Costa et al., 2001). The type of preservation method also affects the nutritional value of the product (Mújica-Paz et al., 2011; Szymkowiak et al., 2020). Consumers have become increasingly familiarized with the labels of the food they buy in stores, searching for information regarding the nutritional value, shelf-life period, list of ingredients, and preservative content (Szymkowiak et al., 2020). Overall, the preservation method can implicitly signal this information to consumers and is thus considered an important factor influencing consumer purchase decisions for ready meals.

Restaurant_i indicates whether the ready meal, *i* is launched in collaboration with restaurants. The variable is coded as 1 if the product is a restaurant-collaborated ready meal and 0 otherwise. Grocery shoppers do not devote much time to decision-making (Anshu et al., 2022). Therefore, to differentiate themselves and make an impression on consumers, vendors should leverage the dining experience they can provide (Anshu et al., 2022; Palmer, 2010). In this regard, South Korean foodservice companies and well-known restaurants collaborate in launching restaurant-ready meals,

which are premium versions of already-existing ready meals. Restaurant ready meals are currently in the spotlight in the foodservice market, as they can offer consumers the experience of reproducing the popular menu of a famous restaurant at home through easy cooking at home (Kim & Lee, 2019). Regarding this current market trend, it is considered timely and thus essential to consider restaurant collaboration as a factor influencing the sales performance of ready meals.

PL_i indicates whether ready meal, i , is a private label (PL) brand product. The variable is coded as 1 if the product is a PL brand product and 0 otherwise. PLs differ from national brands (NBs) in that they are owned by the retailer and only distributed selectively in their stores (Bockholdt et al., 2020; Kumar, 2007). One of the most salient changes in the grocery environment is the success of PLs (Hökelekli et al., 2017). From a retailer's perspective, PLs are an attractive option as they provide higher margins on each product and, in turn, greater profitability (McNeill & Wyeth, 2011). Today, PLs exist in almost every product category, especially in the grocery sector (Beneke, 2010; Lamey et al., 2007; Porral & Levy-Mangin, 2016). Due to their lower prices and preferential retailer support PL brands have the potential to gain a higher market share (Hirche et al., 2021). Accordingly, there has been a global increase in private label brands' market share and penetration in the grocery sector, with retailers having achieved great success with their PLs (Lassoued & Hobbs, 2015). Thus, it is crucial to consider whether the individual ready meals in this study are PL products or NB products.

3.2.2. Category-level characteristics

Similar to the product-level characteristics, the category-level characteristics of the ready meals are also incorporated in the model. Specifically, in this study, two category-level characteristics are

considered as independent variables: category concentration (HHI_{ct}) and category size $\ln(SKU_{ct})$.

The category concentration refers to the sum of the squared market shares of all ready meals in each category. The Herfindahl Hirschman Index (HHI) is widely used for measuring market concentration (Çakır et al., 2020). Similarly, Noormann and Tillmanns (2017) measured the category concentration of the top three national brands in a given category in terms of the squared market share. A high HHI value suggests low category competition or high category concentration. When a product category is fragmented and its concentration is low, the degree of competition in that category is likely to be more intense (Ngobo et al., 2010). In such a case, consumers are more likely to be more price-sensitive, as they can find other substitutes (Ngobo et al., 2010). Conversely, consumers have fewer alternatives in a concentrated category, with the category leaders capturing most of the demand (Ngobo et al., 2010). It is likely that preferences for products are more established in concentrated categories – where consumers commonly purchase specific products (Osuna et al., 2016). Therefore, the role of category concentration is investigated in the present study. HHI is obtained by taking the sum of the squared market shares of all products in a ready meal category. Formally, the HHI in category c in month t is given as:

$$HHI_{ct} = \sum_{i \in c} (w_{ict})^2 \quad (24)$$

where w_{ict} is the market share of the ready meal i in category c in month t . The current study obtains the ready meal market shares from the sales data using:

$$w_{ict} = \frac{s_{ict}}{\sum_{i \in c} s_{ict}}, \quad (25)$$

where s_{ict} is the sales of ready meal i in category c . In the main study, HHI_{ct} is interacted with $Protein_i^p$ to assess whether category

concentration moderates the dollar sales performance of each protein-based ready meal.

In addition, a logarithm of the total number of ready meals in each category $\ln(SKU_{ct})$ is incorporated in the model to assess the relationship between the category size and sales performance of the ready meals. The category size $\ln(SKU_{ct})$ proposed by retailers is defined as the number of different items in a merchandise category (Lombart et al., 2018). Retailers consider category size one of the most critical elements of differentiation strategy and use it to satisfy consumers' needs and influence their decision-making (Broniarczyk & Hoyer, 2006; Kahn et al., 2014; Simonson, 1999). The previous literature supports the fact that consumers are drawn to stores that offer a higher number of product alternatives (Briesch et al., 2009; Iyengar & Lepper, 2000). Consequently, a large category size guarantees multiple options and appeals to broader and more diverse consumers (Betancourt & Gautschi, 1990; Fornari et al., 2021; Ho & Tang, 1998; Ngobo et al., 2010; Tanusondjaja et al., 2018; Wan et al., 2012). Large categories also further draw significant competition (Ngobo et al., 2010).

Several explanations for the expansion of category size have been suggested (Fox, 2018). Consumers have innate psychological needs to explore or seek novelty (i.e., variety seeking). They also tend to purchase multiple products for their future consumption, which vary in terms of brand, flavor and/or package size (i.e., multiple discreteness). Moreover, consumers tend to overestimate their propensity to satiate their need for their favorite products during future consumption, causing the simultaneous choosing of much more variety than that is effectively needed (i.e., diversification bias). Table 9 presents the category size and concentration descriptive statistics for each ready meal category of this study.

Table 9. Category size and concentration descriptive statistics.

Category	Monthly # SKUs				Monthly HHI				Monthly Market Share			
	<i>Avg</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>	<i>Avg</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>	<i>Avg</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
Appetizer	299.2	221.4	18	689	0.03	0.02	0.01	0.10	0.23	0.04	0.09	0.28
Entreeé	192.0	172.6	15	549	0.05	0.03	0.01	0.14	0.27	0.03	0.20	0.36
Noodles	70.2	59.3	2	204	0.13	0.18	0.02	0.85	0.05	0.03	0.01	0.16
Cooked rice	156.3	126.0	21	413	0.06	0.03	0.02	0.14	0.13	0.02	0.07	0.17
Salad	61.5	45.2	2	147	0.07	0.09	0.02	0.54	0.07	0.02	0.00	0.12
Soup	48.9	24.7	10	96	0.05	0.04	0.02	0.15	0.03	0.02	0.01	0.09
Stew	119.5	82.5	12	286	0.07	0.05	0.02	0.30	0.21	0.06	0.15	0.39
Total	135.13	108.85	11.57	338.14	0.07	0.06	0.02	0.28	0.14	0.00	0.14	0.17

3.3. Control variables

Control variables are also considered in the empirical analyses. Specifically, the unit price (*Unit price_i*), retail category (*Category_i^c*), and month (*T_t*) are used to eliminate bias from extraneous variables other than the independent variables that can influence the sales. Generally, higher prices decrease consumer demand, and increased quantity demand results in increasing prices (Hirche et al., 2021; Swait & Andrews, 2003). In particular, the unit price is an important factor for consumers in grocery retailing context in terms of the current trend in consumer packaged goods (CPGs), where retailers display a combination of the retail price and its unit price (Crown et al., 2016).

Category_i^c are included to test whether any subgroup (ready meal category) significantly affects the regression outcome. The ready meal categories control for a different number of products in the category (Loy et al., 2020; Vanhuele & Drèze, 2002). The impact of product marketing factors varies according to the categories perceived by consumers. For instance, consumer involvement may differ between product categories (Dens & De Pelsmacker, 2010; Laurent & Kapferer, 1985; Loy et al., 2020). In this study, the largest category – appetizers – is omitted from the regression as per the dummy–coding requirements.

Since the effect of the time–to–market on sales performance depends on the length of the product life cycle (Suomala, 2004), the month factor is expanded to 56 dummy variables to control for the effect of time, such as the seasonality of sales. The month1 (January 2017) variable is omitted from the regression in the same way the product category variables are omitted. Descriptions and the descriptive statistics of the variables are provided in Table 10 and 11, respectively. Since the monthly dummy variables are time–independent of the product, they are not summarized in the descriptive statistics table.

Table 10. Description of variables.

Variables		Description
ln(Sales _{it})		Logarithm transformation of the dollar sales amount of product i sold on month t
Month _t		Dummy variables indicating month t
Unit Price _i		Unit price (dollar price divided by product weight(g)) of product i
Preserve _i	Frozen	Reference category indicating if the product i is preserved in a frozen temperature
	Chilled	Dummy variable indicating if the product i is preserved in a chilling temperature
	Ambient	Dummy variable indicating if the product i is preserved in an ambient temperature
Category _i	Appetizer	Reference category indicating if the category type of product i is an appetizer
	Entree	Dummy variable indicating if the category type of product i is an entree
	Noodles	Dummy variable indicating if the category type of product i is noodles
	Cooked rice	Dummy variable indicating if the category type of product i is a cooked rice
	Salad	Dummy variable indicating if the category type of product i is a salad
	Soup	Dummy variable indicating if the category type of product i is a soup
	Stew	Dummy variable indicating if the category type of product i is a stew
	Protein _i	Non
Terrestrial protein		Dummy variable indicating if the product i is based on terrestrial protein
Seafood protein		Dummy variable indicating if the product i is based on seafood protein
Plant protein		Dummy variable indicating if the product i is based on plant-based protein
Restaurant _i		Dummy variable indicating if the product i is manufactured in collaboration with a restaurant
PL _i		Dummy variable indicating if the product i is a private label brand product
HHI _{ijt}		Herfindahl–Hirschman Index based on retail category j of the product i on month t
ln(SKU _{ijt})		Logarithm transformation of the number of SKUs based on retail category j of the product i on month t

Table 11. Descriptive statistics of variables.

Overall		Total		Terrestrial protein		Seafood protein		Plant protein	
Variables		<i>Mean</i>	<i>Std.Dev</i>	<i>Mean</i>	<i>Std.Dev</i>	<i>Mean</i>	<i>Std.Dev</i>	<i>Mean</i>	<i>Std.Dev</i>
$\ln(\text{Sales}_{it})$		8.388	1.342	8.531	1.332	8.380	1.356	8.123	1.185
Unit price _i		0.020	0.022	0.019	0.012	0.027	0.040	0.020	0.015
Preserve _i	Frozen	0.602	0.489	0.687	0.464	0.534	0.499	0.515	0.500
	Chilled	0.299	0.458	0.253	0.435	0.395	0.489	0.333	0.471
	Ambient	0.099	0.298	0.059	0.236	0.072	0.258	0.152	0.359
	Appetizers	0.296	0.456	0.259	0.438	0.459	0.498	0.300	0.457
	Entreés	0.225	0.417	0.329	0.470	0.087	0.282	0.141	0.348
	Noodles	0.086	0.281	0.057	0.233	0.084	0.278	0.061	0.239
	Cooked rice	0.167	0.373	0.145	0.352	0.154	0.361	0.172	0.377
	Salads	0.065	0.247	0.061	0.238	0.052	0.222	0.076	0.265
	Soups	0.039	0.194	0.019	0.137	0.039	0.194	0.071	0.256
	Stews	0.122	0.327	0.130	0.336	0.124	0.329	0.182	0.386
Protein _i	Non	0.138	0.345	—	—	—	—	—	—
	Terrestrial protein	0.586	0.493	—	—	—	—	—	—
	Seafood protein	0.216	0.411	—	—	—	—	—	—
	Plant protein	0.060	0.238	—	—	—	—	—	—
Restaurant _i		0.225	0.418	0.253	0.435	0.225	0.417	0.136	0.343
PL _i		0.220	0.414	0.235	0.424	0.213	0.410	0.258	0.437
HHI _{ijt}		0.054	0.071	0.085	0.102	0.173	0.200	0.303	0.237
$\ln(\text{SKU}_{ijt})$		4.655	1.181	4.205	1.220	3.248	1.388	1.696	1.130

Chapter 4. Results

4.1. Main study

Table 12 presents the random-effects panel estimation results for the model specifications in Equations (21) and (22) (M3 and M4, respectively). Both models feature an overall R^2 between 18% and 14% and significantly explain the dependent variable¹².

The main effects of the product- and category-level ready meal characteristics are reported in the M3 column. In the current study, the main effects of the product characteristics are first assessed. Concerning the protein sources of the ready meals, the reference is non-protein-based ready meals. Compared with this reference group, the terrestrial meat-based group exhibits significantly higher levels of dollar sales. In regard to storage types, the reference is frozen ready meals. Compared with the frozen ready meals, the ready meals with ambient storage temperatures are associated with lower levels of dollar sales. The restaurant-ready meals generate significantly higher levels of dollar sales. Compared to NBs, PLs generate significantly higher levels of dollar sales. In terms of the category-level characteristics, the more concentrated the category is found to be, the more significantly lower the level of dollar sales. Moreover, the relationship between the size of category assortment and dollar sales of the ready meals is found to be positively significant.

Among the control variables, the unit price has a negative effect on the dollar sales of the ready meals. Of the ready meal categories, the reference is appetizers. Compared with this reference

¹² M1 is a base model with control variables. The independent variables are added based on the product- and category-related SKU characteristics' contribution to the models' explanatory power (M1 and M2). The stepwise regression results of M1 and M2 are reported in Table B2 in the Appendix B.

group, the entreé, noodle, cooked rice, salad, and stew categories individually exhibit higher levels of dollar sales.

Finally, the moderating effects of category concentration on the effects of the protein sources are tested (M4). When the interaction terms are added, the main effect of the seafood protein variable becomes insignificant, while the main effect of the plant protein variable becomes marginally significant. Both signs remain unchanged. For the interaction terms, all three are found to be significant. After accounting for the interaction terms, the results show that compared to the ready meals without protein, the protein-based ready meals exhibit higher dollar sales levels when the associated product category is concentrated.

Table 12. Random effects of estimation results.

Dependent variable		M3	M4
		ln(Sales)	
Independent variables			
Protein _i (Ref.=Non)	Terrestrial protein	0.232***	0.109*
	Seafood protein	0.167**	0.066
	Plant protein	-0.037	-0.159*
Preserve _i (Ref.=Frozen)	Chilled	0.026	0.028
	Ambient	-0.638***	-0.632***
Restaurant _i		0.580***	0.579***
PL _i		1.081***	1.089***
HHI _{ijt}		-0.772***	-3.695***
ln(SKU _{ijt})		0.113**	0.140***
Control variables ¹⁾			
Unit price(\$/g)		-1.967**	-2.007**
Category _i (Ref.=Appetizers)	Entree	0.249***	0.266***
	Noodles	0.603***	0.649***
	Cooked rice	0.226***	0.239***
	Salad	0.577***	0.622***
	Soup	-0.061	-0.013
	Stew	0.610***	0.627***
Interactions			
	HHI x Terrestrial protein		3.668***
	HHI x Seafood protein		2.850***
	HHI x Plant protein		3.609***
Constant		6.742***	6.763***
Number of observations		52,941	52,941
Number of products		3,300	3,300
R ² within		0.095	0.096
R ² between		0.192	0.195
R ² overall		0.182	0.182
Wald chi ²		3550.51	3593.15
Prob > chi ²		0.000	0.000

¹⁾Month variables are not reported in the table.

Significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Source: Own, based on sales data using STATA version 16 (StataCorp, 2015).

4.2. Follow-up study

The follow-up study focuses on the relationship between the dollar sales and product and category characteristics of the terrestrial protein-, seafood protein-, and plant protein-based ready meals. Table 5 presents the random-effects panel estimation results for the model specifications laid out in Equation (23). Three models feature an overall R^2 between 29% and 16% and significantly explain the dependent variable.

The results of the main-effect model of the terrestrial protein-based ready meals are reported in the Terrestrial protein column of Table 13. In terms of product characteristics, ready meals stored at a chill temperature perform better in dollar sales than those stored at a freezing temperature. On the other hand, ready meals stored at an ambient temperature perform worse compared to the reference category (freezing temperature). The restaurant-affiliated ready meals generate significantly higher levels of dollar sales. Additionally, compared to the NBs, the PLs generate significantly higher levels of dollar sales. In terms of the category characteristics, the more competitive the category is found to be, the more significantly higher the level of dollar sales. The category assortment variables are insignificant for the terrestrial protein-based ready meals. Compared with the appetizers group, the entrée, noodles, and stew categories exhibit higher levels of dollar sales.

Regarding the relationship between the product characteristics of the seafood protein-based ready meals, products stored at a chilling temperature exhibit lower levels of dollar sales compared to the products stored at a freezing temperature. As with the terrestrial protein-based ready meals, the products with an ambient storage temperature perform worse in terms of dollar sales compared to the products under the reference storage temperature. Moreover, restaurant-ready meals generate significantly higher levels of dollar sales. In terms of the category characteristics, the

more competitive the category is found to be, the more significantly higher the level of dollar sales. The category assortment variables are insignificant for the seafood protein-based ready meals. Concerning the control variables, the unit price has a negative effect on the dollar sales of the seafood protein-based ready meals. Compared with the appetizer category, all but the soup group has a significant positive impact on the dollar sales.

In terms of the relationship between the product characteristics of the plant protein-based ready meals, products with an ambient storage temperature perform worse in terms of dollar sales than those with the reference storage temperature and freezing temperature. The restaurant-collaborated ready meals generate significantly higher levels of dollar sales. In terms of the category characteristics, the more competitive the category is found to be, the higher the level of dollar sales is. Moreover, the larger the category size is found to be, the lower the sales level of the plant protein-based ready meals. Compared with the appetizer category, the entrée and cooked rice-ready meals have significant negative impacts on the dollar sales. Conversely, the salad category has positive impacts on dollar sales when compared to the appetizer category.

Table 13. Random effects of estimation results.

Dependent variable		Terrestrial protein	Seafood protein ln(Sales)	Plant protein
Independent variables				
Preservation method _i (Ref.=Frozen)	Chilled	0.159**	-0.177*	0.055
	Ambient	-0.773***	-1.097***	-0.498**
RMR _i		0.508***	0.619***	0.759***
PL _i		1.170***	0.545	0.478
HHI _{ijt}		-0.750***	-0.695***	-0.770***
ln(SKU _{ijt})		-0.076	0.063	-0.265***
Control variables				
Unit price (\$/g)		1.170	-1.835*	-4.915
Category _i (Ref.=Appetizers)	Entree	0.186***	0.427***	-0.815***
	Noodles	0.286**	0.899***	0.396
	Cooked rice	0.007	0.439***	-0.395*
	Salad	0.150	0.673***	0.640**
	Soup	-0.254	0.134	-0.267
	Stew	0.583***	0.413**	0.156
Constant		7.833***	7.272***	7.587***
Number of observations		31,273	11,165	2,778
Number of products		1,933	712	198
R ² within		0.097	0.082	0.153
R ² between		0.164	0.214	0.346
R ² overall		0.171	0.164	0.278
Wald chi ²		2146.69	761.08	350.02
Prob > chi ²		0.000	0.000	0.000

¹Month variables are not reported in the table.

Significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Source: Own, based on sales data using STATA version 16 (StataCorp, 2015).

Chapter 5. Discussions and conclusions

5.1. Theoretical implications

The present research contributes to the retailing research in several ways. First, the study clarifies the relationships between ready meal product- and category-level characteristics and sales performance in online grocery retailing. The dollar sales are found to be higher among the frozen, restaurant-affiliated, and PL ready meals. Overall, the sales performance of a ready meal is found to be greater in a large and competitive category. On the other hand, in terms of the protein-based ready meals, the category concentration interacts with the main effect of the protein sources in that the dollar sales performance is found to be greater as the category becomes more concentrated.

Second, this study fills the knowledge gap in the current research regarding the sales performance of protein-based ready meals in the online grocery retail context. It is revealed that the dollar sales performance of a terrestrial protein-based ready meal is greater than that of a ready meal without protein. More specifically, this study further examines how the product- and category-level ready meal characteristics vary across ready meals with different protein sources.

In the case of terrestrial protein-ready meals, chilled products performed significantly better than frozen products. In contrast, in the case of seafood protein-ready meals, frozen products performed significantly better than chilled products. These contradictory results may be due to consumers' concerns about seafood products' freshness or food safety issues. According to a previous study, consumers find it difficult to evaluate the quality of seafood, with concerns about freshness and a short shelf life seen as barriers to seafood consumption (Christenson et al., 2017). Currently, frozen seafood products are more diverse than ever, with retailers providing

a range of species, product forms, packaging – making the South Korean market quite interesting.

Regarding the PL variable, only in the case of terrestrial protein-based ready meals is the sales performance significantly better for PL products. Compared to other protein sources, the terrestrial protein market is more mature, and consumers easily accept terrestrial meat products. Hence, it can be assumed that consumers more easily trust and purchase the product even if it is not an NB product.

In terms of the category size, it is found that the smaller the category size, the better the sales performance of plant protein-based ready meals. These results are also assumed to be related to the degree of maturity of the vegan market. The vegan market is a relatively emerging market, and consumers lack knowledge regarding these products.

5.2. Practical implications

The results regarding product-level ready meal characteristics' effecting on the dollar sales of individual ready meals can contribute to the practical planning of optimizing investments in the marketing mix. Overall, the results from both the main and follow-up study show that the sales performance of frozen ready meals is significantly better compared to that of ready meals preserved at an ambient temperature. This result is in line with the current food industry trend. The frozen food industry is one of the fastest-growing industries in the world and is expected to continue to grow (Kennedy, 2000; Popescu et al., 2017). In recent years, the quality of frozen food products has improved due to advances in food processing technology (Kumar et al., 2020). As a result, consumers' perceptions of frozen food products have changed from viewing them as cheap junk food to convenient and high-quality, value-added food (Kennedy, 2000b). Accordingly, the demand for frozen food has

increased, and the variety of frozen food products has also expanded (Kumar et al., 2020a). In particular, the results of the follow-up study show that for seafood protein-based ready meals, frozen products perform better than products with other preservation methods.

Overall, the results of both the main study and follow-up study consistently show that the level of dollar sales for restaurant-ready meals are significantly higher than generic ready meals. These results represent the current trends in the South Korean food industry. The traditional industry boundaries between food manufacturing, retail, and restaurant franchise sectors are blurring more quickly than ever. Compared to the past when food manufacturers would produce food items to be sold through different distribution channels, food companies, retailers, and restaurants are now all offering ready meal options to consumers across the country. The present study results indicate that collaboration between ready meal manufacturers and restaurants can be utilized as an effective product differentiation strategy. Furthermore, considering the current trend of the South Korean ready meal market, it is suggested that ready meal manufacturing may be a viable business model for restaurants.

Furthermore, retailers can obtain important insights into the market dynamics of specific food product categories. Regarding the relationship between category size and ready meal sales performance, the results of this study indicate that online grocery retailers must consider a wider variety of products in their overall ready meal assortment planning activities. Retail managers should also consider whether information flow has reached a capacity point for consumers or is likely to continue growing. Strategies for presenting ready meals via promoting fluency and ease of processing can maximize positive category variety perceptions without overwhelming consumers (Townsend & Kahn, 2014). With varying sales distributions by product category, retailers that best adapt by

offering greater category variety and presenting this variety effectively will enjoy a competitive advantage in the marketplace.

The study results regarding category concentration indicate that retail managers need to determine whether niche products are positioned to increase in importance in the coming years or, alternatively, whether their potential has instead been achieved at this point. Regarding the results from the follow-up study, the dollar sales are significantly lower for ready meals in concentrated categories. From the results, it can be assumed that consumers are loyal to big players in concentrated categories, while the niche products are facing a double-jeopardy phenomenon (Ngobo, 2011).

Plant-based and animal-based ready meals share a large number of properties, and, thus, their substitution could represent a potential way to decrease meat consumption (Chollet et al., 2022). Based on nudge theory, a recent study encouraged meat substitutes sales by placing them in pairs of meat and meat substitutes with sensory characteristics similar to meat products rather than in separate sections of the grocery store (Vandenbroele et al., 2019; Chollet et al., 2022). Such an approach could increase the number of shared properties between meat products and their vegetarian counterparts (Chollet et al., 2022).

5.3. Limitations and future research

This study has some limitations, which can provide avenues for future research. First, while the study focuses on dollar sales of ready meals, indicating important demand-side outcomes, future research could incorporate cost-side information to assess the profitability impacts of product- and category-level ready meal characteristics of ready meals. Moreover, this study is conducted in the South Korean grocery retailing context, which prevents us from generalizing our findings. As the rapid expansion and significance of the ready meal market may be a distinct phenomenon in South Korea,

it is necessary to assess our research in an international context. Moreover, this study incorporates a dichotomous PL variable. Concerning the recent market trends of adopting a multi-tiered PL strategy (i.e., standard PLs, premium PLs), future research should subdivide the concept of PLs into sub-categories. Additional research could also consider new product- or category-level characteristics (e.g., organic, environmentally friendly, specialty, local) to add nuance to the current findings. Furthermore, incorporating individual consumer characteristics and behaviors may represent another interesting line of inquiry. Future research can also examine the roles of other marketing mix variables, such as promotions.

Bibliography

- Allais, O., Bertail, P., & Nichèle, V. (2010). The effects of a fat tax on French households' purchases: a nutritional approach. *American Journal of Agricultural Economics*, 92(1), 228–245.
- Anshu, K., Gaur, L., & Singh, G. (2022). Impact of customer experience on attitude and repurchase intention in online grocery retailing: A moderation mechanism of value Co-creation. *Journal of Retailing and Consumer Services*, 64, 102798.
- Apaolaza, V., Hartmann, P., D'Souza, C., & López, C. M. (2018). Eat organic-Feel good? The relationship between organic food consumption, health concern and subjective wellbeing. *Food Quality and Preference*, 63, 51–62.
- Arnade, C., & Pick, D. (1998). Seasonality and unit roots: the demand for fruits. *Agricultural Economics*, 18(1), 53–62.
- Arnade, C., Pick, D., & Gehlhar, M. (2004). Locating seasonal cycles in demand models. *Applied Economics Letters*, 11(9), 533–535.
- Asche, F. (2008). Farming the sea. *Marine Resource Economics*, 23(4), 527–547.
- Asche, F., Dahl, R. E., Gordon, D. V., Trollvik, T., & Aandahl, P. (2011). Demand growth for Atlantic salmon: The EU and French markets. *Marine Resource Economics*, 26(4), 255–265.
- Asche, F., & Wessells, C. R. (1997). On price indices in the almost ideal demand system. *American Journal of Agricultural Economics*, 79(4), 1182–1185.
- Aviles, M. V., Naef, E. F., Abalos, R. A., Lound, L. H., Olivera, D. F., & García-Segovia, P. (2020). Effect of familiarity of ready-to-eat animal-based meals on consumers' perception and consumption motivation. *International Journal of Gastronomy and Food Science*, 21, 100225.
- Banks, J., Blundell, R., & Lewbel, A. (1997). Quadratic Engel curves and consumer demand. *Review of Economics and statistics*, 79(4), 527–539.
- Beneke, J. (2010). Consumer perceptions of private label brands within the retail grocery sector of South Africa. *African Journal of Business Management*, 4(2), 203–220.

- Benoit, K. (2011). Linear regression models with logarithmic transformations. *London School of Economics*, London, 22(1), 23–36.
- Bertail, P., & Caillavet, F. (2008). Fruit and vegetable consumption patterns: a segmentation approach. *American Journal of Agricultural Economics*, 90(3), 827–842.
- Betancourt, R., & Gautschi, D. (1990). Demand complementarities, household production, and retail assortments. *Marketing Science*, 9(2), 146–161.
- Bockholdt, K., Kemper, J., & Brettel, M. (2020). Private label shoppers between fast fashion trends and status symbolism – A customer characteristics investigation. *Journal of Retailing and Consumer Services*, 52, 101883.
<https://doi.org/https://doi.org/10.1016/j.jretconser.2019.07.008>
- Bollen, K. A., & Brand, J. E. (2010). A general panel model with random and fixed effects: A structural equations approach. *Social Forces*, 89(1), 1–34.
- Braha, K., Cupák, A., Pokrivčák, J., Qineti, A., & Rizov, M. (2017). Economic analysis of the link between diet quality and health: Evidence from Kosovo. *Economics & Human Biology*, 27, 261–274.
- Brækkan, E. H., Thyholdt, S. B., Asche, F., & Myrland, Ø. (2018). The demands they are a–changin’ . *European Review of Agricultural Economics*, 45(4), 531–552.
- Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica: Journal of the econometric society*, 1287–1294.
- Briesch, R. A., Chintagunta, P. K., & Fox, E. J. (2009). How does assortment affect grocery store choice? *Journal of marketing research*, 46(2), 176–189.
- Broniarczyk, S. M., & Hoyer, W. D. (2006). Retail assortment: more ≠ better (Retailing in the 21st Century (pp. 225–238). Springer.
- Bronnmann, J. (2016). The German whitefish market: An application of the LA/AIDS model using retail–scanner–data. *Aquaculture Economics & Management*, 20(4), 330–341.
- Bronnmann, J., Loy, J.–P., & Schroeder, K. J. (2016). Characteristics of demand structure and preferences for wild and farmed seafood in Germany: an application of QUAIDS

- modeling with correction for sample selection. *Marine Resource Economics*, 31(3), 281–300.
- Buason, A., & Agnarsson, S. (2020). Fond of Fish? Count Data Analysis of Seafood Consumption in France. *Marine Resource Economics*, 35(2), 137–157.
- Bumbudsanpharoke, N., & Ko, S. (2022). Packaging technology for home meal replacement: Innovations and future prospective. *Food Control*, 132, 108470.
<https://doi.org/https://doi.org/10.1016/j.foodcont.2021.108470>
- Çakır, M., Kong, X., Cho, C., & Stevens, A. (2020). Rural Food Retailing and Independent Grocery Retailer Exits. *American Journal of Agricultural Economics*, 102(5), 1352–1367.
- Canova, F., & Hansen, B. E. (1995). Are seasonal patterns constant over time? A test for seasonal stability. *Journal of Business & Economic Statistics*, 13(3), 237–252.
- Castellón, C. E., Boonsaeng, T., & Carpio, C. E. (2015). Demand system estimation in the absence of price data: an application of Stone–Lewbel price indices. *Applied Economics*, 47(6), 553–568.
- Cerny, B. A., & Kaiser, H. F. (1977). A study of a measure of sampling adequacy for factor–analytic correlation matrices. *Multivariate behavioral research*, 12(1), 43–47.
- Cho, M., Bonn, M. A., Moon, S., & Chang, H. (2020). Home chef meal kits: Product attributes, perceived value and repurchasing intentions the moderating effects of household configuration. *Journal of Hospitality and Tourism Management*, 45, 192–202.
<https://doi.org/https://doi.org/10.1016/j.jhtm.2020.08.011>
- Chollet, S., Sénécal, C., Woelki, L., Cortesi, A., Fifi, V., Arvisenet, G., & Valentin, D. (2022). How protein containing foods are represented in memory? A categorization study. *Food Quality and Preference*, 96, 104381.
<https://doi.org/https://doi.org/10.1016/j.foodqual.2021.104381>
- Christenson, J. K., O'Kane, G. M., Farmery, A. K., & McManus, A. (2017). The barriers and drivers of seafood consumption in Australia: A narrative literature review [https://doi.org/10.1111/ijcs.12342]. *International Journal of Consumer Studies*, 41(3), 299–311.
<https://doi.org/https://doi.org/10.1111/ijcs.12342>

- Costa, A. I. d. A., Dekker, M., Beumer, R. R., Rombouts, F. M., & Jongen, W. M. (2001). A consumer-oriented classification system for home meal replacements. *Food Quality and Preference*, 12(4), 229–242.
- de Boer, J., Schösler, H., & Aiking, H. (2017). Towards a reduced meat diet: Mindset and motivation of young vegetarians, low, medium and high meat-eaters. *Appetite*, 113, 387–397.
- Cox, T. L., & Wohlgenant, M. K. (1986). Prices and quality effects in cross-sectional demand analysis. *American Journal of Agricultural Economics*, 68(4), 908–919.
- Crown, L. D., Sefcik, D. A., & Warfield, L. (2016). Uniform Laws and Regulations in the areas of legal metrology and engine fuel quality.
- Dawson, J. (2013). Retailer activity in shaping food choice. *Food Quality and Preference*, 28(1), 339–347.
- Deaton, A. (1988). Quality, quantity, and spatial variation of price. *The American Economic Review*, 418–430.
- Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review*, 70(3), 312–326.
- Dens, N., & De Pelsmacker, P. (2010). Consumer response to different advertising appeals for new products: The moderating influence of branding strategy and product category involvement. *Journal of Brand Management*, 18(1), 50–65.
- Dey, M. M., Alam, M. F., & Paraguas, F. J. (2011). A Multistage Budgeting Approach to the Analysis of Demand for Fish: An Application to Inland Areas of Bangladesh. *Marine Resource Economics*, 26(1), 35–58. <https://doi.org/10.5950/0738-1360-26.1.35>
- Eriksson, E., Norrman, A., & Kembro, J. (2019). Contextual adaptation of omni-channel grocery retailers' online fulfilment centres. *International Journal of Retail & Distribution Management*.
- FAO. (2014). *The state of world fisheries and agriculture (SOFIA): Opportunities and Challenges* (<http://www.fao.org/documents/card/en/c/097d8007-49a4-4d65-88cd-fcaf6a969776/>)
- Fornari, E., Fornari, D., Grandi, S., Ghezzi, A. I., & Menegatti, M. (2021). Taking advantage of the gluten-free opportunity: Assortment as the key driver for modern grocery retailers. *Journal of Retailing and Consumer Services*, 63, 102747.

- Fox, E. J. (2018). Choosing to choose: the dynamics of store, product, and consumption choices (*Handbook of Research on Retailing*. Edward Elgar Publishing.
- Fraser, I., & Moosa, I. A. (2002). Demand estimation in the presence of stochastic trend and seasonality: the case of meat demand in the United Kingdom. *American Journal of Agricultural Economics*, 84(1), 83–89.
- Gallet, C. A. (2009). The demand for fish: A meta-analysis of the own-price elasticity. *Aquaculture Economics & Management*, 13(3), 235–245.
- Garlock, T., Asche, F., Anderson, J., Bjørndal, T., Kumar, G., Lorenzen, K., Ropicki, A., Smith, M. D., & Tveterås, R. (2020). A global blue revolution: aquaculture growth across regions, species, and countries. *Reviews in Fisheries Science & Aquaculture*, 28(1), 107–116.
- Guttormsen, A. G. (2002). Input factor substitutability in salmon aquaculture. *Marine Resource Economics*, 17(2), 91–102.
- Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the Econometric Society*, 1251–1271.
- Hirche, M., Greenacre, L., Nenycz-Thiel, M., Loose, S., & Lockshin, L. (2021). SKU performance and distribution: A large-scale analysis of the role of product characteristics with store scanner data. *Journal of Retailing and Consumer Services*, 61, 102533.
<https://doi.org/https://doi.org/10.1016/j.jretconser.2021.102533>
- Ho, T.-H., & Tang, C. S. (1998). Product variety management: research advances (Vol. 10). *Springer Science & Business Media*.
- Hökelekli, G., Lamey, L., & Verboven, F. (2017). Private label line proliferation and private label tier pricing: A new dimension of competition between private labels and national brands. *Journal of Retailing and Consumer Services*, 36, 39–52.
<https://doi.org/https://doi.org/10.1016/j.jretconser.2016.12.014>
- Hoderlein, S., & Mihaleva, S. (2008). Increasing the price variation in a repeated cross section. *Journal of Econometrics*, 147(2), 316–325.

- Holly, A., & Sargan, D. (1982). Testing for exogeneity in a limited information framework. *Cahiers de Recherches Economiques*, No. 8204.
- Huang, P. (2015). An inverse demand system for the differentiated blue crab market in Chesapeake Bay. *Marine Resource Economics*, 30(2), 139–156.
- Iyengar, S. S., & Lepper, M. R. (2000). When choice is demotivating: Can one desire too much of a good thing? *Journal of personality and social psychology*, 79(6), 995.
- Irz, X., Leroy, P., Réquillart, V., & Soler, L.-G. (2018). Fish in Climate-Friendly and Healthy Diets. *Marine Resource Economics*, 33(4), 309–330.
- Jallinoja, P., Niva, M., & Latvala, T. (2016). Future of sustainable eating? Examining the potential for expanding bean eating in a meat-eating culture. *Futures*, 83, 4–14.
- Kaabia, M. B., Angulo, A. M., & Gil, J. M. (2001). Health information and the demand for meat in Spain. *European Review of Agricultural Economics*, 28(4), 499–517.
- Kähkönen, P., Tuorila, H., & Rita, H. (1996). How information enhances acceptability of a low-fat spread. *Food Quality and Preference*, 7(2), 87–94.
[https://doi.org/https://doi.org/10.1016/0950-3293\(95\)00040-2](https://doi.org/https://doi.org/10.1016/0950-3293(95)00040-2)
- Kahn, B. E., Chernev, A., Böckenholt, U., Bundorf, K., Draganska, M., Hamilton, R., Meyer, R. J., & Wertenbroch, K. (2014). Consumer and managerial goals in assortment choice and design. *Marketing Letters*, 25(3), 293–303.
- Kastens, T. L., & Brester, G. W. (1996). Model selection and forecasting ability of theory-constrained food demand systems. *American Journal of Agricultural Economics*, 78(2), 301–312.
- Kennedy, C. (2000). The future of frozen foods. *Food Science and Technology Today*, 14(4), 195–197.
- Kennedy, C. J. (2000). Managing frozen foods.
- Kidane, D. G., & Brækkan, E. H. (2021). Global Seafood Demand Growth Differences across Regions, Income Levels, and Time. *Marine Resource Economics*, 36(3), 000–000.
- Kim, S., Lee, S. K., Lee, D., Jeong, J., & Moon, J. (2019). The effect of agritourism experience on consumers' future food purchase patterns. *Tourism Management*, 70, 144–152.

- Kobayashi, M., Msangi, S., Batka, M., Vannuccini, S., Dey, M. M., & Anderson, J. L. (2015). Fish to 2030: the role and opportunity for aquaculture. *Aquaculture Economics & Management*, 19(3), 282–300.
- Kumar, N. (2007). Private label strategy: How to meet the store brand challenge. *Harvard Business Review Press*.
- Kumar, P. K., Rasco, B. A., Tang, J., & Sablani, S. S. (2020). State/phase transitions, ice recrystallization, and quality changes in frozen foods subjected to temperature fluctuations. *Food Engineering Reviews*, 1–31.
- Laato, S., Islam, A. N., Farooq, A., & Dhir, A. (2020). Unusual purchasing behavior during the early stages of the COVID–19 pandemic: The stimulus–organism–response approach. *Journal of Retailing and Consumer Services*, 57, 102224.
- Lamey, L., Deleersnyder, B., Dekimpe, M. G., & Steenkamp, J.–B. E. (2007). How business cycles contribute to private–label success: Evidence from the United States and Europe. *Journal of marketing*, 71(1), 1–15.
- Lassoued, R., & Hobbs, J. E. (2015). Consumer confidence in credence attributes: The role of brand trust. *Food Policy*, 52, 99–107.
- Laurent, G., & Kapferer, J.–N. (1985). Measuring consumer involvement profiles. *Journal of marketing research*, 22(1), 41–53.
- Lecocq, S., & Robin, J.–M. (2015). Estimating Almost–ideal Demand Systems with Endogenous Regressors. *The Stata Journal: Promoting communications on statistics and Stata*, 15(2), 554–573.
<https://doi.org/10.1177/1536867x1501500214>
- Lombart, C., Labbé–Pinlon, B., Filser, M., Anteblian, B., & Louis, D. (2018). Regional product assortment and merchandising in grocery stores: Strategies and target customer segments. *Journal of Retailing and Consumer Services*, 42, 117–132.
- Loy, J.–P., Ceynowa, C., & Kuhn, L. (2020). Price recall: Brand and store type differences. *Journal of Retailing and Consumer Services*, 53, 101990.
<https://doi.org/https://doi.org/10.1016/j.jretconser.2019.101990>
- Markets and Research (2020). Global \$156+ Billion Ready Meals Market for 2025. Retrieved 21 from <https://www.globenewswire.com/en/news->

- release/2020/12/02/2138109/28124/en/Global-156-Billion-Ready-Meals-Market-to-2025.html
- McNeill, L., & Wyeth, E. (2011). The private label grocery choice: consumer drivers to purchase. *The International Review of Retail, Distribution and Consumer Research*, 21(1), 95–109. <https://doi.org/10.1080/09593969.2011.537822>
- Melendrez-Ruiz, J., Chambaron, S., Buatois, Q., Monnery-Patris, S., & Arvisenet, G. (2019). A central place for meat, but what about pulses? Studying French consumers' representations of main dish structure, using an indirect approach. *Food Research International*, 123, 790–800.
- Mintert, J., Schroeder, T. C., & Marsh, T. (2001). Factors affecting beef demand. <https://krex.k-state.edu/dspace/bitstream/handle/2097/4544/cattle01pg20-22.pdf?sequence=1>
- Mújica-Paz, H., Valdez-Fragoso, A., Samson, C. T., Welti-Chanes, J., & Torres, J. A. (2011). High-pressure processing technologies for the pasteurization and sterilization of foods. *Food and Bioprocess Technology*, 4(6), 969–985.
- Ngobo, P.V., Legohérel, P., & Guéguen, N. (2010). A cross-category investigation into the effects of nine-ending pricing on brand choice. *Journal of Retailing and Consumer Services*, 17(5), 374–385. <https://doi.org/10.1016/j.jretconser.2010.03.018>
- Ngobo, P. V. (2011). What Drives Household Choice of Organic Products in Grocery Stores? *Journal of Retailing*, 87(1), 90–100. <https://doi.org/https://doi.org/10.1016/j.jretai.2010.08.001>
- Nijs, V. R., Srinivasan, S., & Pauwels, K. (2007). Retail-price drivers and retailer profits. *Marketing Science*, 26(4), 473–487.
- Noormann, P., & Tillmanns, S. (2017). Drivers of private-label purchase behavior across quality tiers and product categories. *Journal of Business Economics*, 87(3), 359–395.
- Nunnally, J. C. (1994). *Psychometric methods*. McGraw-Hill.
- Nuttall, F. Q. (2015). Body mass index: obesity, BMI, and health: a critical review. *Nutrition today*, 50(3), 117.
- OECD-FAO. (2016). *OECD-FAO Agricultural Outlook 2016–2025*. http://dx.doi.org/10.1787/agr_outlook-2016-en.

- Ostermeier, M., & Hübner, A. (2018). Vehicle selection for a multi-compartment vehicle routing problem. *European Journal of Operational Research*, 269(2), 682–694.
- Osuna, I., González, J., & Capizzani, M. (2016). Which Categories and Brands to Promote with Targeted Coupons to Reward and to Develop Customers in Supermarkets. *Journal of Retailing*, 92(2), 236–251.
<https://doi.org/https://doi.org/10.1016/j.jretai.2015.12.002>
- Palmer, A. (2010). Customer experience management: a critical review of an emerging idea. *Journal of Services Marketing*.
- Paloviita, A. (2021). Developing a matrix framework for protein transition towards more sustainable diets. *British Food Journal*, 123(13), 73–87. <https://doi.org/10.1108/BFJ-09-2020-0816>
- Pollak, R. A., & Wales, T. J. (1981). Demographic Variables in Demand Analysis. *Econometrica*, 49(6), 1533.
<https://doi.org/10.2307/1911416>
- Popescu, C. R. G., Popescu, V. A. A., & Popescu, G. N. (2017). Forecasting of the World's Frozen Food Market, the Key Developments to Date and the Sustainability and Social Responsibility Opportunities—An Economic and Social Perspective. *Manager*(25), 53–62.
- Porral, C. C., & Levy–Mangin, J.–P. (2016). Food private label brands: the role of consumer trust on loyalty and purchase intention. *British Food Journal*.
- Richards, T. J., & Hamilton, S. F. (2012). Obesity and hyperbolic discounting: an experimental analysis. *Journal of Agricultural and Resource Economics*, 181–198.
- Romero–Corral, A., Somers, V. K., Sierra–Johnson, J., Thomas, R. J., Collazo–Clavell, M., Korinek, J., Allison, T. G., Batsis, J., Sert–Kuniyoshi, F., & Lopez–Jimenez, F. (2008). Accuracy of body mass index in diagnosing obesity in the adult general population. *International journal of obesity*, 32(6), 959–966.
- Salvanes, K. G., & Devoretz, D. J. (1997). Household Demand for Fish and Meat Products: Separability and Demographic Effects. *Marine Resource Economics*, 12(1), 37–55.
<https://doi.org/10.1086/mre.12.1.42629181>
- Schrobback, P., Pascoe, S., & Zhang, R. (2019). Market integration and demand for prawns in Australia. *Marine Resource Economics*, 34(4), 311–329.

- Seale Jr., J. L., Marchant, M. A., & Basso, A. (2003). Imports versus domestic production: A demand system analysis of the US red wine market. *Applied Economic Perspectives and Policy*, 25(1), 187–202.
- Simonson, I. (1999). The effect of product assortment on buyer preferences. *Journal of Retailing*, 75(3), 347–370.
- Singh, R. (2019). Why do online grocery shoppers switch or stay? An exploratory analysis of consumers' response to online grocery shopping experience. *International Journal of Retail & Distribution Management*, 47(12), 1300–1317.
<https://doi.org/10.1108/IJRDM-10-2018-0224>
- Slesnick, D. T. (2005). Prices and demand: New evidence from micro data. *Economics Letters*, 89(3), 269–274.
- Statista. (2021). Ready meal retail sales in South Korea 2012–2021 <https://www.statista.com/statistics/644505/south-korea-retail-sales-of-ready-meals/>
- Stone, R. (1954). Linear expenditure systems and demand analysis: an application to the pattern of British demand. *The Economic Journal*, 64(255), 511–527.
- Sun, Y.–H. C. (2008). Health concern, food choice motives, and attitudes toward healthy eating: The mediating role of food choice motives. *Appetite*, 51(1), 42–49.
<https://doi.org/https://doi.org/10.1016/j.appet.2007.11.004>
- Suomala, P. (2004). The life cycle dimension of new product development performance measurement. *International Journal of Innovation Management*, 8(02), 193–221.
- Surathkal, P., Dey, M. M., Engle, C. R., Chidmi, B., & Singh, K. (2017). Consumer demand for frozen seafood product categories in the United States. *Aquaculture Economics & Management*, 21(1), 9–24.
- Swait, J., & Andrews, R. L. (2003). Enriching scanner panel models with choice experiments. *Marketing Science*, 22(4), 442–460.
- Szymkowiak, A., Guzik, P., Kulawik, P., & Zając, M. (2020). Attitude–behaviour dissonance regarding the importance of food preservation for customers. *Food Quality and Preference*, 84, 103935.
<https://doi.org/https://doi.org/10.1016/j.foodqual.2020.103935>
- Tabarestani, M., Keithly Jr, W. R., & Marzoughi–Ardakani, H. (2017). An Analysis of the US Shrimp Market: A Mixed

- Demand Approach. *Marine Resource Economics*, 32(4), 411–429.
- Tanusondjaja, A., Nenycz–Thiel, M., Dawes, J., & Kennedy, R. (2018). Portfolios: Patterns in brand penetration, market share, and hero product variants. *Journal of Retailing and Consumer Services*, 41, 211–217.
- Torrissen, J. K., & Onozaka, Y. (2017). Comparing fish to meat: perceived qualities by food lifestyle segments. *Aquaculture Economics & Management*, 21(1), 44–70.
- Toufique, K. A., Farook, S. N., & Belton, B. (2018). Managing fisheries for food security: Implications from demand analysis. *Marine Resource Economics*, 33(1), 61–85.
- Townsend, C., & Kahn, B. E. (2014). The “visual preference heuristic”: The influence of visual versus verbal depiction on assortment processing, perceived variety, and choice overload. *Journal of Consumer Research*, 40(5), 993–1015.
- Tveterås, S., Asche, F., Bellemare, M. F., Smith, M. D., Guttormsen, A. G., Lem, A., Lien, K., & Vannuccini, S. (2012). Fish is food—the FAO’ s fish price index. *PLoS One*, 7(5), e36731.
- Tziva, M., Negro, S., Kalfagianni, A., & Hekkert, M. (2020). Understanding the protein transition: The rise of plant–based meat substitutes. *Environmental Innovation and Societal Transitions*, 35, 217–231.
- Vandenbroele, J., Van Kerckhove, A., & Zlatevska, N. (2019). Portion size effects vary: The size of food units is a bigger problem than the number. *Appetite*, 140, 27–40.
- Vanhuele, M., & Drèze, X. (2002). Measuring the price knowledge shoppers bring to the store. *Journal of marketing*, 66(4), 72–85.
- Wan, X., Evers, P. T., & Dresner, M. E. (2012). Too much of a good thing: The impact of product variety on operations and sales performance. *Journal of Operations Management*, 30(4), 316–324.
- Woodridge, J. (2010). *Econometric Analysis of Cross Section and Panel Data*, 2nd Edition. The MIT Press.
- Yoon, S., Gao, Z., & House, L. (2022). Do efforts to reduce packaging waste impact preferences for meal kits? *Food Quality and Preference*, 96, 104410.
<https://doi.org/https://doi.org/10.1016/j.foodqual.2021.104410>

Appendix A

Table A1. Items and confirmatory factor analysis results of health concern scale.

Item	Description	M1	M2
HC1	I am concerned about getting a lot of salt in my food	0.791	0.787
HC2	I am concerned about getting a lot of fat in my food	0.975	0.873
HC3	I am concerned about getting a lot of sugar in my food	0.832	0.830
HC4	I am concerned about getting a lot of cholesterol in my food	0.840	0.837
HC5	I am not concerned about getting a lot of salt in my food (R) ^a	Dropped	Dropped
HC6	I am concerned about getting a lot of calories	0.653	0.653
HC7	I am concerned about gaining weight	Dropped	Dropped
HC8	I am concerned about food additives in my food	0.641	0.634
Cronbach' s α		0.759	0.862
CR ^b		0.900	0.899
KMO ^c		0.860	0.858
AVE ^d		0.604	0.600

^aItem for which scoring is reversed is marked (R).

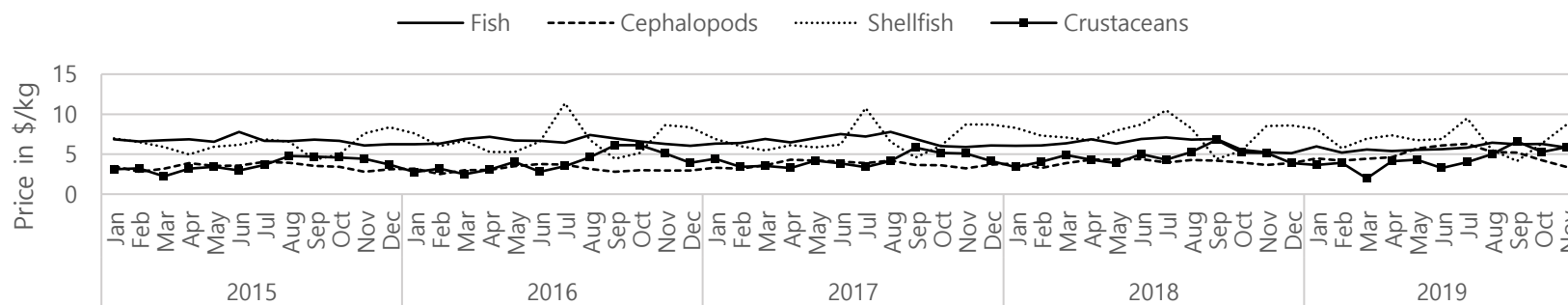
^bCR denotes composite reliability.

^bKMO denotes Kaiser–Meyer–Olkin value.

^bAVE denotes average variance extracted.

Table A2. Definitions of sociodemographic variables and average monthly expenditure shares for each consumer segment.

		Average monthly expenditure shares (%)						
		M1			M2			
		Terrestrial		Plant–				
		meat	Seafood	based	Fish	Cephalopods	Shellfish	Crustaceans
Presence of children	Have children	74.7	18.9	6.4	39.0	16.8	24.1	20.1
	No children	66.8	25.2	8.0	44.0	13.8	24.4	17.8
Age	≤ 30	89.2	5.7	5.2	14.8	12.0	73.2	0.0
	31 – 40	79.0	14.4	6.6	32.1	18.8	19.8	29.3
	41 – 50	79.3	15.0	5.6	31.4	19.8	24.7	24.0
	51 – 60	76.1	17.8	6.1	38.3	16.9	24.6	20.2
	61 – 70	65.8	26.3	7.9	45.5	14.1	23.7	16.6
	> 70.0	64.5	26.5	8.9	44.4	13.3	23.9	18.4
BMI	Underweight	75.2	18.6	6.2	36.4	18.6	22.6	22.3
	Normal weight	72.5	20.6	7.0	40.9	15.6	24.2	19.3
	Overweight	74.7	18.9	6.4	39.1	17.3	24.4	19.2
	Obese	63.3	31.0	6.0	30.8	15.0	23.8	30.3
HC	≤ 2	77.0	17.0	6.0	28.1	17.4	29.7	24.8
	2.1 – 3	76.0	19.0	5.0	35.2	20.9	23.8	20.2
	3.1 – 4	72.0	21.0	7.0	41.8	16.8	22.8	18.6
	≥ 4.1	74.0	19.0	7.0	39.9	14.6	25.4	20.2
Overall		73.0	20.0	7.0	40.3	16.0	24.2	19.5



^aAugust 3, 2021 Exchange Rate: 1 US\$ = 1,149 Won (South Korean currency)

Figure A1. Aggregated Prices of Four Seafood Categories over the Data Period.

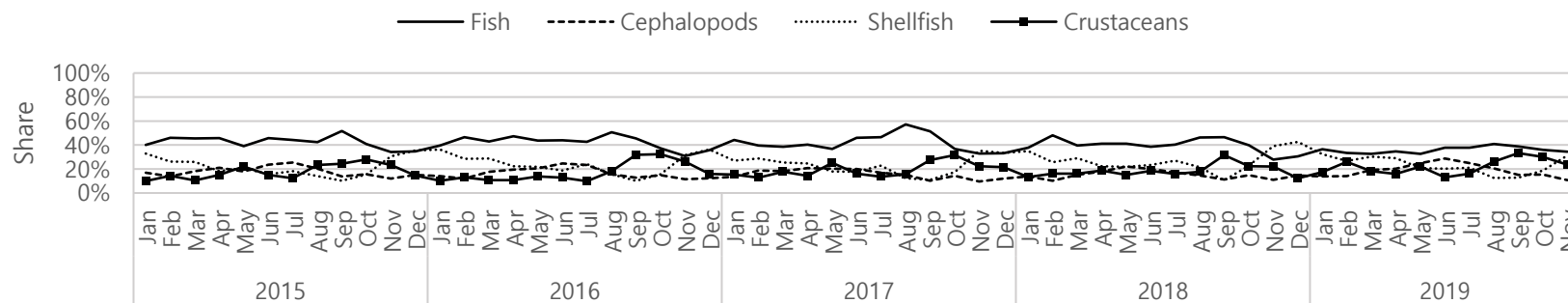


Figure A2. Shares of Four Seafood Categories in Overall Seafood Expenditures over the Data Period.

Appendix B

Table B1. Description of product categories.

Category	Description
Appetizer	Small dish food usually served before or alongside main dishes (e.g., nugget, dumpling, french fries, etc.)
Entrée	Ready-to-eat main dish food products including cooked meat, foreign or exotic prepared foods (e.g., steaks, roast chicken, pizza, etc.)
Noodle	Noodles-based food products (e.g., ramen, pasta, pad thai, etc.)
Cooked rice	Rice-based food products (e.g., curry, risotto, paella)
Salad	A dish consisting of mixed pieces of food, typically with at least one raw vegetables
Soup	Thick, liquid-based foods
Stew	Dish of meat or vegetables cooked slowly in liquid in a closed dish or pan

Table B2. Random effects of estimation results.

Dependent variable		M1	M2
		ln(Sales)	
Independent variables			
Protein _i (Ref.=Non)	Terrestrial protein		0.231***
	Seafood protein		0.166**
	Plant protein		-0.037
Preserve _i (Ref.=Frozen)	Chilled		0.026
	Ambient		-0.641***
RMR _i			0.580***
PL _i			1.080***
Control variables ¹⁾			
Unit price (\$/g)		-2.287**	-1.976**
Category _i	Entreeé	0.274***	0.201***
(Ref.=Appetizers)	Noodle	0.261**	0.413***
	Cooked rice	-0.071	0.139**
	Salad	0.403***	0.379***
	Soup	-0.612***	-0.279***
	Stew	0.443***	0.482***
Constant		7.340***	7.014***
Number of observations		52,941	52,941
Number of products		3,300	3,300
R ² within		0.094	0.094
R ² between		0.099	0.192
R ² overall		0.109	0.183
Wald chi ²		3042.85	3527.96
Prob > chi ²		0.000	0.000

¹⁾Month variables are not reported in the table.

Significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Source: Own, based on sales data using STATA version 16 (StataCorp, 2015).

국 문 초 록

최근 전 세계적으로 수산물 소비가 증가했음에도 불구하고, 수산물 단백질 수요에 대한 연구는 타 단백질 공급원에 비해 부족한 실정이다. 이에 본 연구에서는 한국에서 주로 섭취되는 세 가지 단백질 공급원(축산물, 수산물, 식물성 단백질)의 수요를 모델링했다. 첫 번째 연구에서는 소비자 패널들의 농식품 구매 영수증 데이터를 실증 분석하여 2차 준이상 수요체계 (QUAIDS)를 사용하여 한국 단백질 소비자의 수요탄력성을 조사했다. 여기서 더 나아가, 수산물 단백질을 4개의 범주(어류, 연체류, 조개류, 갑각류)로 나누어 수산물 안에서도 각 범주에 대한 수요탄력성을 조사했다. 연구 결과, 식물성 단백질은 축산물과 수산물 두 동물성 단백질과 대체 관계에 있음을 확인했다. 또한 수산물 단백질 내의 4개의 범주는 서로 대체 관계에 있음을 확인했다. 두 번째 연구에서는 확률 효과 패널 회귀 모델을 사용하여 온라인 식료품 소매업체 내에서 단백질 기반 간편식의 매출에 영향을 미치는 요인을 조사한다. 본 연구는 단백질 기반 간편식의 단백질 공급원의 종류를 포함한 제품 특성 요인과 제품이 속한 카테고리 특성 요인의 간편식의 매출에 미치는 효과를 실증 분석한다. 연구 결과, 단백질 기반 간편식의 매출은 제품이 냉동보관, 레스토랑 제휴 브랜드, 유통사 자체 개발 제품일 경우 유의하게 높음을 확인했다. 또한, 제품에 단백질이 없는 경우에 비해 단백질이 있는 간편식 제품의 경우 제품이 속한 카테고리의 집중도가 높을수록 매출실적이 높게 나온다는 점에서 단백질 공급원 변수의 주효과와 상호작용 효과를 확인했다. 본 연구의 시사점 및 향후 연구를 위한 제언을 각 연구의 마지막 장에 수록하였다.

주요어 : 단백질 수요, 간편식, 2차 준이상 수요체계, 패널회귀분석

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