

CONSUMER BEHAVIOR CHANGES ACROSS INCOME LEVELS: MEAT MARKET
ANALYSIS

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MARKET ANALYSIS

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CHAPTER 1

INTRODUCTION

1.1. Motivation

The consumer choice theory explains how the consumer maximizes his utility when he purchases something for consumption. The decision is made at the point of a tangent between a budget constraint and an indifference curve. The budget constraint represents price and income, and the indifference curve represents consumer preference. Thus if we want to analyze consumer behavior, we need to know price, income, and consumer preference. Unfortunately, consumer preference is not well understood by economic researchers, except that the shape is convex to the origin on the commodity space. This is why researchers who are analyzing consumer behavior measure the relationship between quantity demanded and price and income without preference.

Even though consumer preference plays an important role in determining consumer behavior, researchers tend not to focus on it. If preference is constant during the period of analysis, then it need not be considered seriously because each time period shares identical consumer preference. That might be a reason why researchers disregard the importance of consumer preference in the short term. However, we sometimes face the problem of heterogeneous preferences across time. Researchers have reported that there are different consumer preferences across time.¹ The most frequently cited

¹ Chavas (1983) tested the meat demand in the U.S. and concluded that there were changes of demand elasticities of meat. Choi and Kim (1990) find the existence of structural decline in US. red meat demand using the logistic function models.

preference change in the meat market might be the case of red versus white meat. In the U.S., it appears to many that the consumer demand for meat has experienced a structural change and a stronger preference for white meat has led to an increase in white meat consumption and to a decrease in red meat consumption has been occurring since the 1970s.²

Each one of us experience changes in our preferences every day. In fact, changes in our environment can be said to cause changes in our preferences. This is where we encounter problems when modeling economic choices. The econometric model loses its degrees of freedom in proportion to the number of variables included in the model. The number of degrees of freedom is linked directly to the confidence level of the model. Therefore including too many variables in the model makes it inefficient. Since every factor which is expected to cause a change in consumer preference cannot be considered in an analysis, it is better to focus on significant and stable changes or trends. We can obtain better results by controlling the dimension of the demand function at an appropriate level.

The world economy has grown for a long time and several significant trends have been observed in both developing and developed countries. The growing economy has created more jobs, attracted more people into urban areas, and created more income. These trends are thought to make consumer preferences change and are expected to continue in the future. They may be classified as individual factors but they seem to stem from an identical source, namely, economic growth, and have a strong correlation with each other. Therefore, for the purpose of an economic analysis, income can be a

² Haley (2001) argues that three factors can explain the consumer behavior shift: growing health concerns, need for time-saving dishes and the relative price between meat products.

representative variable among them. Income is easier to observe than others. Moreover, since it is already included in the analysis of consumer behavior, considering income as a factor of the preference shifter does not increase the number of dimensions of the demand function.

Several things are expected to happen to a consumption pattern in regards to income growth. First, there may be a variation in the expenditure share. In general, goods experience changes in their expenditure share with income growth. If an income elasticity of a good is greater than one, then its expenditure share increases with income growth. This type of good is considered to be a luxury. The necessity good is the opposite case. Thus the variation of the expenditure share can be directly linked to the variation of marginal demand with respect to income. The marginal demand for a good declines if its expenditure share decreases as income grows.³ When it comes to meat consumption, it is likely to change from being a luxury to being a necessity. Meat is included in the category of food, so it becomes a necessity. However, it is more expensive and is considered to be more desirable than grain products. Thus it is regarded as a luxury for a consumer who has low income.⁴ Therefore, the meat expenditure proportion is expected to increase at first and decrease as the real income level rises.

Second, a consumer is likely to become less sensitive to a price change of a good when he has more income. In other words, demand elasticities become smaller in absolute value as income grows. A price change has an effect on the real income and the extent of the income impact is proportional to the share of the good in question. Considering that the poor, in general, spend a greater share of a good than the affluent,

³ This is shown in 3-1 Engel's law in chapter 3.

⁴ Fan (1995) reports the expenditure elasticity of meat products as 1.27 using Chinese data from 1957 to 1990.

the poor are likely to feel a larger variation in real income than the affluent when the price of the good changes. Feeling a larger variation is likely to entail a larger response to the change. In extreme case of infinite income, a consumer would not respond to price and income changes at all and price and income elasticities would be zero.

Third, a consumer expands his consumption boundary as his income rises and there seem to be an order of priority among needs; once an urgent need is satisfied then another less urgent needs come into the consumption bundle.⁵ The goods included in the less urgent needs category would not compete with the goods in the more urgent needs category because there is an order of priority. Of course goods in the same category would compete with each other in terms of a marginal utility. In regards to food as a category, the primary role of food is alleviating hunger but it can be also used as family entertainment, or to build social relationships and more.

Consider a consumer who has alleviated hunger and now has expanded his consumption boundary to family entertainment. This consumer reveals his preference order: first to satisfy hunger and second to provide family entertainment. Any goods in the expanded need would not compete with food in the primary need. For example, if there is an income decline, then the demand in the second need would absorb the shock. This would make the demand included in the first need become inelastic. This step-like consumption pattern would grow further as a consumer has more income. At the same time, more and more goods hide behind newly added demands and are, in some sense, insulated from an economic environment. As a consequence, the consumer is likely to

⁵ Lavoie (2004) argues the lexicographic preference is more appropriate in explaining consumer behavior than the Neo-Classical preference which has a smooth shape.

have two distinct consumption patterns for an identical good. One part is less elastic to economic variables than the other part.

Consumer behavior, in general, measures the extent of consumer responses when there are variations in price and income. In cases of changes in the expenditure share and elasticity, it can be said that there are shifts in consumer behavior in terms of the consumer responses to economic variables. The marginal demand of a good with respect to income becomes inelastic if the expenditure share of the good falls. A decreasing elasticity implies that the responses with respect to income and price become inelastic as income rises. In case of the consumption expansion, it is not clear whether the consumer responses shift or not, because consumer behavior relates to marginal changes rather than to changes in the consuming structure.

As income has increased in most developing and developed countries, it has changed the way people live. Consumers can enjoy more leisure and pay attention to various interests which were not possible in the past. More and more amounts of and variety of commodities are ready to be consumed. At the same time, consumer behavior seems to have shifted through time. This study intends to investigate if there has been a change in consumer behavior and how it can be explained. Several functional forms and data regarding Korean and American meat markets will be employed in this study. This will contribute to a better understanding of consumer behavior and the market.

1.2. Significance

The issue of varying consumer behavior across income levels can be approached in two distinct ways. The first approach is to estimate elasticities of separate consumer

demands divided by income classes. This approach is useful when the consumption patterns of a certain income group are in question. A policy often targets a specific income class; a policy that subsidizes consumers, in general, targets the poor. Since the consumption pattern is a major determinant of the efficiency of a policy, a policy maker is more likely to be interested in information about poor consumers rather than average or affluent consumers. Better understanding of the income-specific consumption pattern would improve the efficiency of a policy. Most of the studies concerning varying consumer behavior follow this method⁶ and conclude that there are differences in consumer behavior across income levels.

The second approach is to estimate a single demand system of a group across income levels. This approach is useful when we want to know a broad picture of the market and know how the consumption pattern has changed through time. Several studies have been done for varying consumer behavior by employing quadratic or trend terms in the model.⁷

Researchers often use an econometric simulation model when they want to know what the market will be like in the future. In general, the model is divided into two parts: one involves building a set of equations which describe the current market condition, the other involves simulating the future step-by-step. The simulation creates future variables using the existing relationships between these variables. From this point of view, the future market structure which is predicted by the simulation model is a copy

⁶ Alderman (1986) makes a review of 15 different studies on varying consumer behavior. Twelve of them use cross-sectional data and three of them use time-series data or time-series data combined with cross-sectional data. Even in case of time-series data analysis, it makes a comparison between different income groups.

⁷ Pollak and Wales (1978) and Banks et al. (1997) tried to measure varying consumer behavior across income levels by adding quadratic terms and found these terms are significant for some commodities.

of the current market structure. In this sense, the simulation process can be justified within the assumption that the future market structure does not have any differences compared to the current market structure. If one or more relationships in the system have changed, then the simulation might generate biased results.

The most important two things required to describe the market might be demand and supply, because they determine the market equilibrium. The price at this equilibrium determines the allocation of resources and the size of the market. Since consumer behavior plays an important role in the market structure, an inappropriately estimated demand function can cause serious problems.

Suppose the consumer becomes less responsive to changes in price and income when he has a higher income level. The magnitude of the price and income parameters becomes smaller in absolute value than that of the parameters which do not take into account this income effect. The smaller parameters in absolute value would have led the demand function to have a steeper slope in the future. The steeper demand function would have generated a larger price fluctuation when there is a shock from the supply side. As a result, the demand function which does not include an income effect will provide biased results. This biased future prediction may put obstacles in the way of understanding how the market will evolve.

1.3. Objectives

This study examines if there are variations in consumer behavior as income rises using various functional forms. The interests of this study are three-fold: income share changes, changes in consumer responsiveness, and structural changes in consumption

pattern. Three functional forms are used in this study: Quadratic Almost Ideal Demand System (QUAIDS), the double log model with income effects, and the Linear Expenditure System (LES) with income effects. The first will examine changes in the expenditure share. The second will examine changes in consumer responsiveness. The last function will examine structural changes in consumption patterns. Among the models, the LES with income effects and the double log model with income effects will be developed to the state space model to accommodate time-varying parameter effects. Lastly, the Kalman filter technique is employed on the two state space models to see how the parameters have changed across time.

CHAPTER 2

LITERATURE REVIEWS

2.1. Neo-classical consumer choice theory

Consumer behavior can be derived from two criteria; The maximization of one's utility under a given income and the minimization of one's expenditure under a given utility level. The expression of the two criteria may be written as

$$\text{utility maximization: } \max u(x), \text{ subject to } xp = m$$

1

$$\text{expenditure minimization: } \min px, \text{ subject to } u(x) \geq u^*$$

where x and p are vectors for quantities demanded and prices; m is income and u^* is a given utility level. A solution for each criteria gives rise to a consumer demand. The demand from the maximization is called Marshallian (uncompensated) demand and the one from the minimization is called Hicksian (compensated) demand. Marshallian demand is composed of prices and income, whereas Hicksian demand is composed of prices and a utility level. Among the variables included in the two demands, a utility cannot be observed. This is why Marshallian demand is used in most empirical demand analyses instead of Hicksian demand. Hicksian demand is impossible to estimate directly from observed data due to an invisible utility level.

There is one more way to obtain Marshallian demand; by use of the indirect utility function,. The (direct) utility function is a function of goods while the indirect utility function has price and income as variables. The indirect utility function can be obtained

by simply putting the demand functions in place of the goods in the utility function. Then the indirect utility may be expressed as

$$u(x^*) = v(x(p, m)) = v(p, m) \quad 2$$

The advantage of having the indirect utility is that the function is already maximized in terms of a utility. The demand can be derived from the indirect utility using Roy's identity.

$$\text{Roy's identity: } x_i = - \frac{\frac{\partial v(p, m)}{\partial p_i}}{\frac{\partial v(p, m)}{\partial m}} \quad 3$$

Proving Roy's identity takes just a few lines. Since the indirect utility is identical to the maximized utility, the denominator and the nominator may be expressed as $\frac{\partial u(x^*)}{\partial m}$ and $\frac{\partial u(x^*)}{\partial p_i}$ respectively. Both expressions can be found in the first order condition of the maximization problem if we take derivatives with respect to income and price instead of goods. The former is λ and the latter is $-\lambda x_i$.⁸ Replacing the denominator and the nominator with λ and $-\lambda x_i$ respectively proves Roy's identity.

Several restrictions are imposed on Marshallian demand to satisfy the theoretical basis of the maximization problem. The restrictions are homogeneity and adding up conditions. The condition of homogeneity of degree zero relates to the budget constraint. If the price and income are changed by the same rate, call it α , then the budget constraint

⁸ λ is a Lagrange multiplier in the first order condition for the maximization problem.

may be expressed as $\alpha xp = \alpha m$. It is exactly the same condition to the original one after cancelling α . The homogeneous condition may be expressed as

$$\sum_i \frac{\partial x_j}{\partial p_i} p_i + \frac{\partial x_j}{\partial m} m = 0 \quad 4$$

The other restriction is adding-up conditions. The adding-up also relates to a budget constraint. Any solution of the maximization should satisfy $px(p, m) = m$. Taking derivative with respect to price and an income respectively, we obtain

$$\text{Engel aggregation: } \sum_i \frac{\partial x_i}{\partial p_j} p_i + x_j = 0 \quad 5$$

$$\text{Cournot aggregation: } \sum_i \frac{\partial x_i}{\partial m} p_i = 1$$

These conditions are not applicable to an individual demand equation or an incomplete demand system. They are applicable only to the complete demand system; the sum of individual expenditures included in the system should be identical to total income. Omitting one or more demands in the system results in a failure of the adding-up conditions.

Even though Hicksian demand is not observable, some of its theoretical properties are known. The most important properties might be the symmetry between cross-price responses and the homogeneity and the negativity condition. These conditions may be expressed mathematically as below.

$$\text{symmetry condition: } \frac{\partial x_i^H}{\partial p_j} = \frac{\partial x_j^H}{\partial p_i} \quad 6$$

$$\text{homogeneous condition: } x(\alpha p, u) = x(p, u)$$

$$\text{negativity condition: } \frac{\partial x_i^H}{\partial p_i} \leq 0$$

Between the two demands, there exists a theoretical relationship. The Marshallian is linked to the Hicksian through the Slutsky equation. The Slutsky equation decomposes a price response of the Marshallian into two parts: an income effect and a substitution effect.

$$\frac{\partial x_j(p, m)}{\partial p_i} = \frac{\partial x_j^H(p, u)}{\partial p_i} - x_i(p, m) \frac{\partial x_i(p, m)}{\partial m} \quad 7$$

The term on the left-hand side is a price response of Marshallian demand, the first term on the right-hand side is a substitution effect or a price response of Hicksian demand, and the second term on the right-hand side is an income effect multiplied by a quantity demanded. The Slutsky equation is sometimes developed into a relationship between expenditure share and elasticities. Multiplying $\frac{p_i}{x_i}$ on both sides of the equation gives

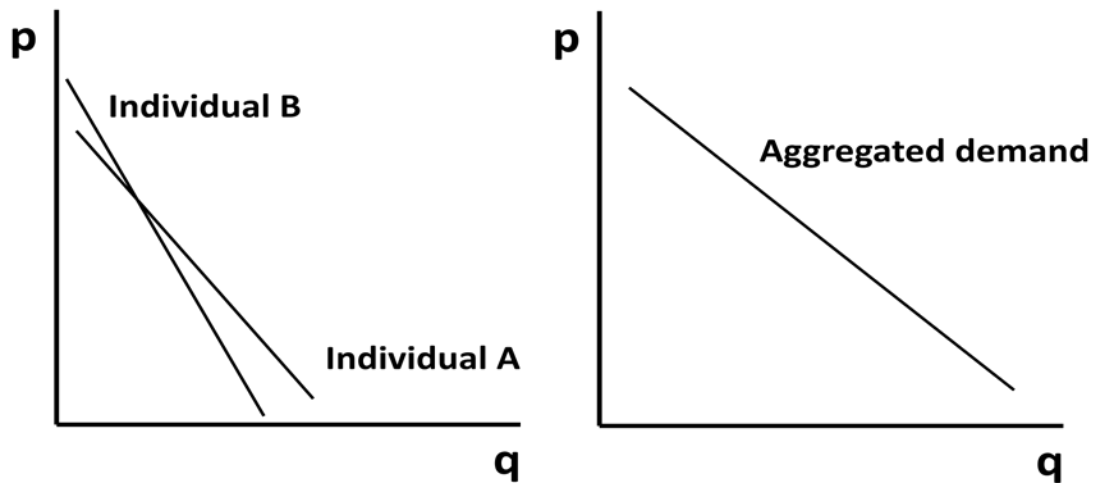
$$\frac{\partial x_i(p, m)}{\partial p_i} \frac{p_i}{x_i} = \frac{\partial x_i^H(p, u)}{\partial p_i} \frac{p_i}{x_i} - \frac{p_i x_i(p, m)}{m} \frac{\partial x_i(p, m)}{\partial m} \frac{m}{x_i} \quad 8$$

where superscript, H, represents the Hicksian demand.

Utility maximization concerns problems which are faced by an individual consumer. We, however, are often interested in consumer behavior of a group, such as

whole nation, rather than in that of an individual. The solution can be simple. By aggregating the individual demands horizontally on the price-quantity space, we can have an aggregated demand which represents consumer behavior of a group.

Figure 1: Aggregate demand



The issue in aggregating the individual demands is whether the aggregated demand maintains the properties of the individual demands such as homogeneity and the adding-up conditions. The homogeneity condition is known to be maintained after aggregation but the adding-up condition, in general, is not maintained.⁹ Thus imposing adding-up conditions on the aggregate demand, in general, may not be appropriate. However, as a special case, if an indirect utility function of a demand system follows the Gorman (1961) form for all consumers then the individual demand inherits the adding-up conditions after aggregating across individuals. The Gorman form of the indirect utility function is given as

⁹ Varian(1992), chapter 9.

$$v(p, m) = \frac{m - f(p)}{g(p)}$$

where $f(p)$ and $g(p)$ are functions which are homogeneous of degree one in prices. The linear expenditure system (LES) shares the same indirect utility function with the Gorman form. The $f(p)$ and $g(p)$ in LES is given as $f(p) = \sum p_i b_i$ and $g(p) = \prod p_i^{\alpha_i}$. The utility level of the indirect utility function increases when the price index, $g(p) = \prod p_i^{\alpha_i}$, gets lower and income, m , gets higher. $f(p)$ is usually interpreted as a minimum consumption and it does not contribute to a utility increase. A consumer is assumed to get utility in proportion to the difference between income and $f(p)$.

2.2. Post-Keynesian consumer theory

Post-Keynesian consumer theory suggests a new point of view on consumer behavior. It emphasizes income effects and considers price effects as a minor determinant of the consumer behavior. The theory assumes a lexicographic consumer preference mapping and asserts that utility cannot be represented by the scalar index. Instead the utility should be represented by a vector. It suggests that the consumer demand is determined by a hierarchical structure of needs rather than by a nicely-behaving utility function. Lavoie (2004) asserts six principles on which Post-Keynesian consumer theory relies: procedural rationality, satiable needs, the separability of needs, the subordination of needs, the growth of needs, and the principle of non-independence.

Neoclassical consumer theory assumes an ideal consumer. The consumer is expected to compute his utility whenever he consumes goods under perfect information

in order to maximize his utility. The principle of procedural rationality denies this ideal consumer. The consumer is assumed neither to have perfect information nor to carefully process the information. It assumes that consumers have designed a shortcut to reach decisions quickly under imperfect information. This procedure does not need to solve a maximizing problem and does not assume perfect information.

The principle of satiable needs means that there exists a threshold beyond which a consumer's utility does not increase any more. With this principle, a consumer is expected to stop increasing consumption a certain good when the amount of the good consumed touches the threshold. From the Neoclassical view, even though marginal utility decreases as the amount demanded increases, the marginal utility is still positive. As a consequence, a consumer can get additional utility by consuming more and more. So the Neoclassical theory expects the amount of demand to increase infinitely if the income is very high or the price is very low.

The principle of separability of needs is applicable to categories of goods. It means that there is little to no level of relation between groups. It assumes that a consumer distributes his income to groups first and that the allocated amount for a group is spent on goods in the group. With this principle, it is expected that a substitution effect between goods within distinct groups is zero or very small.

The subordination of needs concerns the order of consuming across various groups of characteristics. It can be considered as an ordered version of separability of needs and linked to satiable needs. A consumer consumes from the category of a necessary good first until the utility from this category is satiated. Next he steps up to consuming discretionary goods. This reflects a hierarchical preference in which a

necessity should be satisfied first. A necessity group is not supposed to be affected by the discretionary group because there is a strict order between these two groups. When he faces an economic disturbance such as a price rise or an income decline, the goods in the discretionary group are adjusted for absorbing the impact of the economic disturbance. This principle implies that the price of goods in discretionary groups does not have any or has little effects on a necessity.

The principle of growth of needs explains how a consumer expands his consumption bundle as his income increases. It can be linked to satiable needs and subordination of needs. A consumer is expected to have new needs to be satisfied and to create new ones if he does not have any needs currently as he has more and more income. The income is regarded as a determinant of the degree of needs.

The principle of non-independence explains how the consumer preference is formed. A consumer is expected to learn or imitate the consumption pattern of others. As a result, consumers included in the identical socio-economic environment share similar consumption patterns.

2.3. Engel's law

Engel's law states the following relationship between food expenditure share and income: the percentage of income spent on food decreases as income increases. Zimmerman (1932) interprets Engel's statement¹⁰ as follows: "the poorer is a family, the greater is the proportion of the total outgo which must be used for food." A decrease in food share does not mean a decrease in the amount demanded. Theoretically speaking,

¹⁰ The Engel's work in 1857 is written in German.

the amount demanded is increasing as long as the marginal demand with respect to income stays positive. The exact meaning of the law is that the growth rate of income is greater than that of the food expenditure.

Mathematical expression of Engel's law may be written as below

$$\frac{\partial \frac{px}{m}}{\partial m} < 0 \quad 10$$

Rearranging the above inequality, we get

$$\frac{\partial x}{\partial m} \frac{m}{x} < 1 \quad 11$$

The term on the left-hand side is the income elasticity. If the income elasticity is smaller than one, it can be said that the Engel's law holds.

Houthakker (1957) makes an international comparison to examine Engel's law using various data from 53 regions of 33 countries. He divides expenditures into four categories: food, housing, clothing, and others. All of the income elasticities of food are found to be smaller than one. However, the elasticities of other categories show various results. The income elasticities of housing are usually smaller than one, whereas those of clothing are usually greater than one. The results show that Engel's law is valid for the food category.

2.4. Some functional forms in demand analyses

2.4.1. Almost Ideal (AI) Demand System

Deaton and Muellbauer's (1980) AI demand system might be one of the most popular demand systems during the past few decades. Derived from the cost function, it satisfies most theoretical restrictions imposed on a demand system. The cost function of a PIGLOG class has a utility index which is expected to lie between zero and one. Zero represents a subsistence level and one represents a bliss level. The cost function is

$$\log c(u, p) = (1 - u) \log a(p) + u \log b(p) \tag{12}$$

$$\log a(p) = a_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj}^* \log p_k \log p_j$$

$$\log b(p) = \log a(p) + \beta_0 \prod_k p_k^{\beta_k}$$

where u is a utility level and p is price. a, α, β and γ are parameters to be estimated. Taking the derivative of the cost function with respect to $\log p_i$ gives an expenditure share of good i .

$$\frac{\partial \log c(u, p)}{\partial \log p_i} = \frac{\partial \log c(u, p)}{\partial c(u, p)} \frac{\partial c(u, p)}{\partial p_i} \frac{\partial p_i}{\partial \log p_i} = \frac{q_i p_i}{c(u, p)} = w_i \tag{13}$$

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i u \beta_0 \prod_k p_k^{\beta_k}$$

where w is an expenditure share, q is a quantity demanded and $\gamma_{ij} = \frac{1}{2} (\gamma_{ij}^* + \gamma_{ji}^*)$. Using the fact that the total expenditure is equal to the cost at equilibrium, the indirect utility can be obtained from equation (12) by replacing $c(u, p)$ with expenditure, X .

Substituting the indirect utility for u in equation (13) gives AI demand system in budget share form.

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i (\log X - \log P)$$

14

$$\text{where } \log P = a_0 + \sum_k a_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log p_k \log p_j$$

Several restrictions are necessary to make the AI demand system theoretically sound. Adding up conditions are imposed by $\sum_i w_i = 1$, $\sum_i \alpha_i = 1$, $\sum_i \gamma_{ij} = 0$ and $\sum_i \beta_i = 0$. The homogeneity condition is imposed by $\sum_j \gamma_{ij} = 0$ and the symmetry condition by $\gamma_{ij} = \gamma_{ji}$.

The AI demand system is a complete demand system. In other words, the commodities considered in the system should account for a complete list of consumption. In fact, putting all the commodities consumed in the system is not easy, and it may not be desirable in some cases. Researchers sometimes estimate commodities only in a group with the group expenditure. In this case, the elasticities derived in the system¹¹ do not represent the income and the price elasticities correctly. Thompson (2004) proposes the two-step estimation system and elasticities of the system.

The first step is regressing group expenditure against income using an equation: $\log E = d_0 + d_y \log Y + d_A \log P + d_c \log CPI$ where E is group expenditure, Y is an

¹¹ The elasticities of AI demand system is given as

$$\text{income elasticity: } e_i = \frac{\beta_i}{w_i} + 1 \text{ and}$$

$$\text{price elasticity: } e_{ij} = \frac{\gamma_{ij} - \beta_i (w_j - \beta_j \log(\frac{x}{p}))}{w_i} - \delta_{ij}$$

where δ_{ij} is Kronecker's delta

income and CPI is a consumer price deflator. The second step is an estimation of an AI demand system. The elasticities are given as follows.

$$\text{income elasticity : } e_i = d_Y \left(\frac{\beta_i}{w_i} + 1 \right) \text{ and}$$

$$\text{price elasticity : } e_{ij} = \frac{\gamma_{ij}}{w_i} - \left[\left(\frac{\beta_i}{w_i} \right) - d_A \left(1 + \frac{\beta_i}{w_i} \right) \right] \left(\alpha_j + \sum_k \gamma_{jk} \log p_k \right) - \delta_{ij} \quad 15$$

where δ_{ij} is Kronecker's delta

2.4.2. Quadratic Almost Ideal Demand System

$\beta_i(\log x - \log P)$ in equation (14) represents an Engel curve. Following existing theoretical conjecture, the sign of the parameter should be negative for a necessity and positive for a luxury.¹² Sometimes we observe a change in the nature of a commodity as income rises. For example, meat products can be a necessity for the rich and a luxury for the poor. Banks et al. (1997) argue that the Engel curve of a commodity can change through income levels and thus propose QUAIDS.

Banks et al. (1997) examined the consumption of five commodity groups using the U.K. family expenditure survey data. They found a quadratic Engel curve in clothing and alcohol categories. In other words, the expenditure share of clothing and alcohol increases when the income level is low and declines when the income level is high. This finding suggests that some commodities or commodity groups need more dimensions in the Engel curve to represent the quadratic relationship.

QUAIDS is derived from an indirect utility function which is given as

¹² A necessity is considered to have the income elasticity less than one. The expenditure share relates negatively to income if the income elasticity is less than one. The income elasticity of a luxury is larger than one and its expenditure share relates positively to income.

$$\ln V = \left(\left[\frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right)^{-1} \quad 16$$

The above indirect utility form reduces to the indirect of AI demand system if $\lambda(p)$ becomes zero. Adding $\lambda(p)$ makes the system rank three.¹³ Applying Roy's identity¹⁴ to equation (16) gives the expenditure share written as

$$w_i = \frac{\partial \ln a(p)}{\partial \ln p_i} + \frac{\partial \ln b(p)}{\partial \ln p_i} \ln \left(\frac{m}{a(p)} \right) + \frac{\partial \lambda}{\partial \ln p_i} \frac{1}{b(p)} \left\{ \ln \left(\frac{m}{a(p)} \right) \right\}^2 \quad 17$$

Banks et al. (1997) proved that both coefficients of $\ln \left(\frac{m}{a(p)} \right)$ and $\left(\ln \left(\frac{m}{a(p)} \right) \right)^2$ cannot be independent of prices if the system is to be rank three. The specifications of $a(p)$, $b(p)$ and $\lambda(p)$ which make the system rank three are given as

$$\begin{aligned} \ln a(p) &= a_0 + \sum_k a_k \ln p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \ln p_k \ln p_j \\ b(p) &= \prod_i p_i^{\beta_i} \\ \lambda(p) &= \sum_i \lambda_i \ln p_i \end{aligned} \quad 18$$

Replacing each component in equation (17) with equation (18) gives QAIDS.

¹³ The term, rank, is used in the Lewbel (1991). The rank is a dimension spanned by Engel curve. In this study, he finds that the AI demand system and Translog model explain data relatively well when data are trimmed by removing the tails of the income distribution. However, when the data include all the income distribution, the systems do not fit data well. With this result, he suggests that the demand system should be at least rank three.

¹⁴ $-\frac{\partial \ln V}{\partial \ln p} = -\frac{p}{V} \frac{\partial V}{\partial p} = \frac{p}{m} \chi$

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\left(\frac{m}{a(p)}\right) + \frac{\lambda_i}{b(p)} \left\{ \log\left(\frac{m}{a(p)}\right) \right\}^2 \quad 19$$

The form of QUAIDS is identical to the AI demand system except for the last quadratic term. This quadratic income term, with a linear income term, represents the Engel curve which is expected to vary across income levels. QUAIDS is quite similar to AI demand system and inherits some of properties from AI demand system. The restrictions imposed on AI demand system can be imposed on QUAIDS. They are

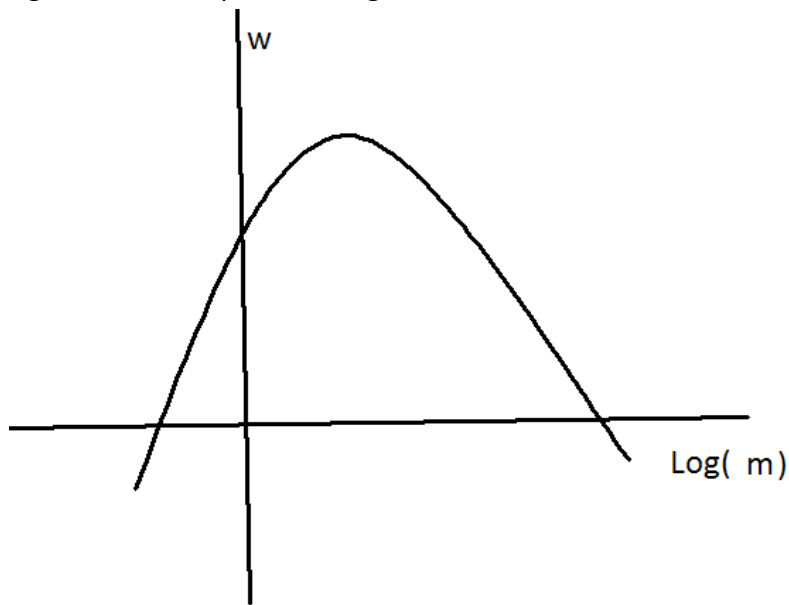
$$\text{adding up conditions: } \sum_i \alpha_i = 1, \sum_i \gamma_{ij} = 0, \sum_i \beta_i = 0 \text{ and } \sum_i \lambda_i = 0 \quad 20$$

$$\text{homogenous conditions: } \sum_j \gamma_{ij} = 0$$

$$\text{symmetry conditions: } \gamma_{ij} = \gamma_{ji}$$

Banks et al. (1997) emphasize a case of a negative quadratic term with a positive linear term. Clothing and alcohol in their study are the cases. In this case, the function has a concave shape and has its maximum in the first quadrant.

Figure 2: the shape of an Engel curve



The budget share in the figure above increases with income while the income level is low and declines when the income level is high. This shape of the function makes the income elasticity be larger than one when the income is low and be smaller than one when the income is high. This process shows how a good or a category of goods changes from a luxury to a necessity. In their study, a clothing group and an alcohol group have the shape of Figure 2.

2.4.3. Linear Expenditure System

The underlying indirect utility function of the linear expenditure system (LES) is given as

$$V(p, m) = \frac{m - f(p)}{g(p)}$$

21

where $f(p)$ is defined as a certain level of expenditure which does not make the utility increase. Commonly, it is called subsistence minimum, and the role of this expenditure is considered to maintain the lowest level of living rather than to increase the utility level. $g(p)$ is defined as a kind of price index which deflates income. Applying Roy's Identity to equation (21), we obtain

$$x_i(p, m) = \frac{g_i(p)}{g(p)} m + f_i(p) - \frac{g_i(p)}{g(p)} f(p) \quad 22$$

where $g_i(p)$ and $f_i(p)$ are derivatives of $g(p)$ and $f(p)$ with respect to p . With given $g(p) = \prod p_k^{a_k}$ and $f(p) = \sum p_k b_k$, we obtain LES

$$x_i = b_i + \frac{a_i}{p_i} (m - \sum p_k b_k) \quad 23$$

The functional form is similar to a Cobb-Douglas demand function which assigns a constant share of relative income to a quantity demanded. On the other hand, LES does so with the leftover after minimum consumption is subtracted. Examining the marginal demand with respect to prices and income reveals some interesting facts. The marginal demand with respect to prices and income may be calculated by the formula.

$$\begin{aligned} \text{expenditure: } \frac{\partial x_i}{\partial m} &= \frac{1}{p_i} a_i \\ \text{own-price: } \frac{\partial x_i}{\partial p_i} &= \frac{1}{p_i} b_i (1 - a_i) - \frac{x_i}{p_i} \\ \text{cross-price: } \frac{\partial x_i}{\partial p_j} &= -\frac{1}{p_i} a_i b_j \end{aligned} \quad 24$$

First, the income response of LES is identical to that of the Cobb-Douglas function. Second, the own-price response is smaller in absolute value in LES. The magnitude of the response is smaller in absolute value by $\frac{b_i}{p_i}(1 - a_i)$ compared to that of the Cobb-Douglas function. This means that the part included in the minimum consumption does not have any effect on the own-price response. As a result, if the minimum consumption increases for some reason, the marginal demand becomes inelastic. Third, the cross-price response has a value, and it is always negative.¹⁵ This is because increases in the prices of other goods make the minimum expenditure larger and the leftover smaller.

Pollak and Wales (1969) propose the dynamic version of the LES. Employing the dynamic parameters which include trend ($b_{it} = b_i^* + b_it$) or habit formation ($b_{it} = b_i^* + b_ix_{i,t-1}$), the dynamic LES may be rewritten as

$$p_{it}x_{it} = p_{it}(b_i^* + b_it) + a_i(m_t - \sum p_k(b_k^* + b_k t)) : \text{in case of the trend} \quad 25$$

Even though Pollak and Wales (1969) mention that the trend specification does not have good result in their study, it has some implications concerning the marginal demand with respect to the price. As is shown in their paper, the positive b_i makes the own-price response more inelastic.

¹⁵ The cross-price response of the Cobb-Douglas function is always zero since the expenditure share is constant. The changes in the the prices of other goods do not have any effect on the demand.

2.5. Some estimation methods

2.5.1. Maximum Likelihood Estimation

Maximum likelihood estimation offers a useful tool to estimate a nonlinear system as well as a linear one. It sets a likelihood function of unknown parameters and finds a set of parameters when the likelihood reaches the maximum value. Suppose observations are supposed to follow a certain distribution. If a density function of the distribution is known, then we can build a joint density function

$$f(y_1, \dots, y_n : \theta) = f(y_1 : \theta) \dots f(y_n : \theta) = \prod f(y_i : \theta) \quad 26$$

where y is a set of observations and θ is a vector of unknown parameters. Taking logarithms¹⁶ on both sides, we have

$$\log\left(\prod f(y_i : \theta)\right) = \sum \log(f(y_i : \theta)) \quad 27$$

A vector, θ , which makes the log likelihood maximized is a solution of the ML estimation.

In general, a normal distribution is used in an empirical analysis since it is the most commonly observed distribution.¹⁷ The density function of the normal distribution is given as

¹⁶ Since a logarithm is a monotonic transformation, it does not affect the result in maximizing problem.

¹⁷ The central limit theorem can be one possible explanation of the reason why a normal distribution is found frequently. It states that a mean of independent variables with a sufficiently large number follows a normal distribution. The per capita meat consumption used in this study might be an ideal example of the central limit theorem; conceptually, it is a mean of the unobserved individual consumptions.

$$f(y : \mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2\right) \quad 28$$

where μ and σ^2 are a mean and a variance of the distribution. Building a log likelihood function using the normal distribution density function gives the below.

$$\log L(\mu, \sigma^2) = -\frac{n}{2}\log(2\pi) - \frac{n}{2}\log(\sigma^2) - \frac{1}{2}\sum\left[\frac{(y_i - \mu)^2}{\sigma^2}\right] \quad 29$$

The solution of maximizing the above equation can be derived from the first derivatives by setting them to be zero.

$$\begin{aligned} \frac{\partial \log L}{\partial \mu} &= \frac{1}{\sigma^2} \sum (y_i - \mu) = 0 \\ \frac{\partial \log L}{\partial \sigma^2} &= \frac{n}{2\sigma^2} + \frac{1}{2\sigma^4} \sum (y_i - \mu)^2 = 0 \end{aligned} \quad 30$$

Solving the equations above, we get $\hat{\mu} = \frac{1}{n}\sum y_i$ and $\hat{\sigma}^2 = \frac{1}{n}\sum (y_i - \bar{y})^2$ which are consistent estimators.

Three hypothesis testing techniques are commonly used in ML estimation: the likelihood ratio test, the Wald test, and the Lagrange multiplier test (Green 2004). These three tests are different in a small sample, but as the number of the sample increases they are known to be equivalent under the null hypothesis. However, the small sample properties are rarely revealed so there is no clear rule for choosing among them.

The likelihood ratio using the ratio of two log likelihoods is given as

$$\lambda = \frac{\hat{L}_R}{\hat{L}_U}$$

where \hat{L}_R and \hat{L}_U are a restricted log likelihood function and an unrestricted log likelihood function. Since the log likelihood is greater in the unrestricted function than in the restricted one, the value of λ lies between one and zero. The ratio runs to zero as the restriction goes away from the true value. The test statistic $-2\ln(\lambda)$ is known to follow chi-squared distribution with degrees of freedom which are the number of restrictions. As shown in the test statistic, it needs both estimators: a restricted and an unrestricted estimator, whereas the other tests require only one of them. On the view of computational burden, the likelihood ratio test is more cumbersome than the others.

The Wald test statistic is given as

$$W = [c(\hat{\theta}) - q]'(Asy.Var[c(\hat{\theta}) - q])^{-1}[c(\hat{\theta}) - q] \quad 32$$

under $H_0 : c(\theta) = q$

where $c(\hat{\theta}) = q$ is a set of restrictions. If the null hypothesis is true then the value of $c(\hat{\theta}) - q$ should be close to zero; in the opposite case, the value should be large and the test statistic should become large, which leads to a rejection of the hypothesis. The Wald test statistic W , is a chi-squared distribution with degrees of freedom equal to the number of restrictions.

The asymptotic variance of $(c(\hat{\theta}) - q)$ can be derived from the information matrix. The estimator of the ML estimation is known to be an asymptotically normal

distribution, $\hat{\theta} \sim a N(\theta, \{I(\theta)\}^{-1})$.¹⁸ Using the asymptotic variance of $\hat{\theta}$, the variance of $(c(\hat{\theta}) - q)$ can be derived.

$$Asy. Var(c(\hat{\theta}) - q) = \left[\frac{\partial c(\hat{\theta})}{\partial \hat{\theta}'} \right]' I(\hat{\theta})^{-1} \left[\frac{\partial c(\hat{\theta})}{\partial \hat{\theta}'} \right] \quad 33$$

When solving the maximization problem with restriction, we take derivatives of the Lagrangean function with respect to parameters. Setting the derivatives to be zero gives the first order condition for the maximization problem.¹⁹

$$Lagrangean \ function = \ln L(\theta) + \lambda'(c(\theta))$$

$$\frac{\partial \ln L(\theta)}{\partial \theta} + \left[\frac{\partial c(\theta)}{\partial \theta} \right] \lambda = 0 \quad 34$$

The Lagrange multiplier, λ , shows how the restriction is strict so if the restriction is close to the true condition then the magnitude of λ becomes small. The Lagrange multiplier test statistic is given as

$$LM = \left(\frac{\partial \ln L(\hat{\theta}_R)}{\partial \hat{\theta}_R'} \right)' I(\hat{\theta}_R)^{-1} \left(\frac{\partial \ln L(\hat{\theta}_R)}{\partial \hat{\theta}_R'} \right) \quad 35$$

The test statistic follows a chi-squared distribution with degrees of freedom equal to the number of restrictions. One thing to note in the test is that all the estimators of the

¹⁸ The information matrix for normal distribution: $I(\theta) = \left[-E_0 \left(\frac{\partial^2 \ln L}{\partial \theta \partial \theta'} \right) \right]^{-1} = \begin{bmatrix} \sigma^2 / n & 0 \\ 0 & 2\sigma^4 / n \end{bmatrix}$

¹⁹ The derivative of the Lagrangean with respect to λ is omitted in this equation.

Lagrange multiplier test are computed in the restricted model only whereas the Wald test uses the unrestricted model.

2.5.2. Seemingly Unrelated Regressions model

Assume a model which is composed of multiple equations. Because each equation in the model is expected to relate to each other, it is better to solve the equations jointly. Assuming equations are linear in the parameters, an entire model can be built by stacking the equations vertically

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_M \end{bmatrix} = \begin{bmatrix} x_1 & 0 & \dots & 0 \\ 0 & x_2 & \dots & 0 \\ \vdots & \vdots & \dots & \vdots \\ 0 & 0 & \dots & x_M \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_M \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_M \end{bmatrix} \quad 36$$

where $E(e|x) = 0$ and $E(ee'|x) = \Omega$

where each subscript means a set of observations not a single point of an observation. Before solving this SUR model, we need to inspect error terms closely. Writing the covariance matrix of error terms, we have

$$\Omega = \begin{bmatrix} E(e_1e_1') & E(e_1e_2') & \dots & E(e_1e_M') \\ E(e_2e_1') & E(e_2e_2') & \dots & E(e_2e_M') \\ \vdots & \vdots & \dots & \vdots \\ E(e_Me_1') & E(e_Me_2') & \dots & E(e_Me_M') \end{bmatrix} \quad 37$$

If the equations are not correlated with each other, in other words, $E(e_t e_s') = 0$ for $t \neq s$, then the SUR model is not different from separate individual equations. So the estimators of the SUR model are identical to the separate OLS estimators. However, if we assume

the correlation between equations, then the OLS estimators are not efficient any more.²⁰

Zellner (1962) proposes the GLS estimator for the SUR model. Multiplying $\Omega^{-\frac{1}{2}}$ on each term of the equation (36), we have

$$\Omega^{-\frac{1}{2}}y = \Omega^{-\frac{1}{2}}x\beta + \Omega^{-\frac{1}{2}}e \quad 38$$

Solving equation (38), we have the GLS estimator.²¹

$$\hat{\beta} = (x'\Omega^{-1}x)^{-1}x'\Omega^{-1}y \quad 39$$

Even though the GLS estimator is an appropriate solution for the linear SUR model, there remains a problem; the covariance matrix, Ω , is not known. It needs an additional assumption to make the SUR model be tractable. Each element of equation (37), $E(e_i e_j')$, is assumed to be $\sigma_{ij}I$. So the covariance matrix may be written as

$$\Omega = \begin{bmatrix} \sigma_{11}I & \sigma_{12}I & \dots & \sigma_{1M}I \\ \sigma_{21}I & \sigma_{21}I & \dots & \sigma_{2M}I \\ \vdots & \vdots & \dots & \dots \\ \sigma_{M1}I & \sigma_{M2}I & \dots & \sigma_{MM}I \end{bmatrix} \quad 40$$

The sub-matrix, $\sigma_{ij}I$, in Ω means that each equation in SUR has a covariance matrix of a homogeneous variance with zero off-diagonals. Non-zero σ_{ij} for $i \neq j$ and heterogeneous

²⁰ Green (2004) summaries the properties of the GLS estimator as follows;

1. If the equations do not relate to each other, then there is no gain from the GLS estimation. The GLS estimator is identical to that of the equation-by-equation OLS.
2. If the equations have identical explanatory variables, then GLS and OLS are identical.
3. The efficiency gain from the GLS estimation is larger if the correlation between equations is large.
4. The efficiency gain from the GLS estimation is larger if the correlation between explanatory variables is small.

²¹ The GLS estimator is known as a minimum variance linear unbiased estimator. (Green, 2004, chapter 14)

diagonals, $\sigma_{ii} \neq \sigma_{jj}$, makes the SUR model be a model of heteroscedasticity and autocorrelation. Green (2004) introduces the estimator of σ_{ij} .

$$\hat{\sigma}_{ij} = \frac{\varepsilon_i' \varepsilon_j}{[(T - K_i)(T - K_j)]^{\frac{1}{2}}} \quad 41$$

where T is the number of observations, K is the number of parameters, ε is the residual of the OLS estimation, and the subscripts indicates the equation. The estimator, $\hat{\sigma}_{ij}$, is consistent if i equals to j . The GLS estimation takes two-step procedure. The first step is estimating each equation with OLS and obtaining the residuals. The weighting matrix is computed using the residuals. The second step is estimating the whole model with GLS.

2.5.3. Full-information maximum likelihood estimation²²

As explained in the previous part, the Zellner's GLS estimator of the SUR model is applicable for the linear regression model. To deal with the non-linear model, the ML estimator needs to be introduced. The non-linear SUR model of M equations and T observations may be written as

$$\begin{aligned} y_1 &= f_1(x_1; \theta_1) + e_1 \\ y_2 &= f_2(x_2; \theta_2) + e_2 \\ &: \\ y_M &= f_M(x_M; \theta_M) + e_M \end{aligned} \quad 42$$

²² This part is mainly drawn from Green (2004).

The disturbance term, e , is assumed to follow normal distribution individually as well as jointly. Picking the t -th observations from each equation gives the below.

$$\begin{aligned}
 y_{1t} &= f_1(x_{1t}; \theta_1) + e_{1t} \\
 y_{2t} &= f_2(x_{2t}; \theta_2) + e_{2t} \\
 &\vdots \\
 y_{Mt} &= f_M(x_{Mt}; \theta_M) + e_{Mt}
 \end{aligned}
 \tag{43}$$

The FIML estimation measures the likelihood using the equation (43) jointly instead of individually. There are M disturbances and they are expected to follow joint normal distribution. The joint normal density function can be built as

$$L_t = \frac{1}{(2\pi)^{\frac{M}{2}} |\Sigma|^{\frac{1}{2}}} \exp\left(-\frac{1}{2} [e_{1t} \ e_{2t} \ \dots \ e_{Mt}] \Sigma^{-1} [e_{1t} \ e_{2t} \ \dots \ e_{Mt}]\right)
 \tag{44}$$

where Σ is $E[(e_{1t} \ e_{2t} \ \dots \ e_{Mt})'(e_{1t} \ e_{2t} \ \dots \ e_{Mt})]$. As a consequence, the log likelihood is

$$\log L_t = -\frac{M}{2} \log(2\pi) - \frac{1}{2} \log|\Sigma| - \frac{1}{2} [e_{1t} \ e_{2t} \ \dots \ e_{Mt}] \Sigma^{-1} [e_{1t} \ e_{2t} \ \dots \ e_{Mt}]'
 \tag{45}$$

The last term of the equation (45) can be expressed using an operator, a trace.²³

$$\begin{aligned}
 [e_1 \ e_2 \ \dots \ e_M]_t \Sigma^{-1} [e_1 \ e_2 \ \dots \ e_M]_t' &= tr \left[[e_1 \ e_2 \ \dots \ e_M]_t \Sigma^{-1} [e_1 \ e_2 \ \dots \ e_M]_t' \right] \\
 &= tr \left[\Sigma^{-1} [e_1 \ e_2 \ \dots \ e_M]_t' [e_1 \ e_2 \ \dots \ e_M]_t \right]
 \end{aligned}
 \tag{46}$$

Summing the log likelihood through observations from 1 to T then we have

²³ The dimension of the last term of the (45) is (1×1) . So taking a trace does not make anything changed.

$$\log L = -\frac{MT}{2} \log(2\pi) - \frac{T}{2} \log|\Sigma| - \frac{T}{2} \text{tr}[\Sigma^{-1}W] \quad 47$$

$$\text{where } W = \frac{1}{T} \sum_t [e_1 \ e_2 \ \dots \ e_M]_t' [e_1 \ e_2 \ \dots \ e_M]_t$$

2.5.4. Serial correlation and AR process

In time series data analysis, we often find that error terms of an estimation equation are correlated to each other. Suppose a model has serial correlation as defined by:

$$y_t = x_t \beta + e_t \quad 48$$

The error term e_t is correlated with each other and the lagged error terms have information for the current one. Serial correlation is a violation of an assumption for OLS which is expressed as $E(ee'|x) = \sigma^2 I$. Even though a model of serial correlation does not satisfy the homoskedasticity assumption, the OLS estimator of β is still unbiased as long as $E(u|x) = 0$. However, the problem occurs when the variance of β is estimated. Suppose the covariance matrix of equation (48) to be $E(ee'|x) = \sigma^2 \Omega$. Then, by multiplying $\Omega^{-\frac{1}{2}}$ on both sides of equation (48), we can get a modified model which satisfies the homoskedasticity assumption.

$$\Omega^{-\frac{1}{2}} y = \Omega^{-\frac{1}{2}} x \beta + \Omega^{-\frac{1}{2}} e \quad 49$$

The variance of β can be obtained by

$$\text{var}(\beta) = \sigma^2(x'\Omega^{-1}x)^{-1}$$

50

The estimator is different from the OLS estimator of $\text{var}(\beta) = \sigma_{ols}^2(x'x)^{-1}$. Therefore the OLS estimator is not an efficient estimator any more. Wooldridge (2002) states that the OLS estimator of the variance is smaller than the true value with positive serial correlation. That makes the test statistic be larger and be more significant. For more investigation, let the structure of the correlation be $e_t = \sum_{i=1}^p \rho_i e_{t-i} + u_t$. Then, we have a model of

$$y_t = x_t\beta + e_t$$

$$e_t = \sum_{i=1}^p \rho_i e_{t-i} + u_t$$

51

where p is the number of lags considered in the model. Davidson and Mackinnon (2003) suggest a solution for the model. Substituting each e with the first row in equation (51), we have

$$y_t = \sum_{i=1}^p \rho_i y_{t-i} + (x_t - \sum_{i=1}^p \rho_i x_{t-i})\beta + u_t$$

52

The equation is linear in independent variables but not linear in parameters, β and ρ . Therefore, the model cannot be estimated by OLS. One of the methods which can estimate the model is the nonlinear least square. It minimizes the sum of squared

residuals iteratively. The nonlinear least square estimates are known to be asymptotically efficient and asymptotically equivalent to the maximum likelihood estimates.²⁴

Testing of serial correlation can be performed by the hypothesis of $H_0: \rho_1 = \dots = \rho_p = 0$. Green (2004) suggests several methods for the test: LM test, Q test, Durbin-Watson test, and Durbin's test. Among them, Durbin-Watson test is used in this study. D-W test statistic is given as

$$d = \frac{\sum_1^T (e_i^2 - e_{i-1})^2}{\sum_1^T e_i^2} = 2(1 - \rho) - \frac{e_1^2 + e_T^2}{\sum_1^T e_i^2} \quad 53$$

where T is a number of observations. Since the last term reduces to zero if the number of observation is sufficiently large, the test statistic becomes $d \approx 2(1 - \rho)$. If the null hypothesis is true ($\rho = 0$), then the test statistic becomes 2. Therefore, if there is a positive (negative) autocorrelation then d becomes smaller (larger) than 2. The distribution of d is follows the D-W statistic.

2.6. The Kalman filter

Kalman (1960) proposes a filtering technique which solves a system of time-varying parameters. The underlying structure of the Kalman filter is a technique to find an optimal estimator using two or more distinct estimates. Suppose two researchers estimate the price of beef. The mean and the variance of the estimate of one researcher are E(A) and V(A), respectively, and those of the other researcher are E(B) and V(B).

²⁴ E-views 6 User's Guide2. P:70

There are several ways to utilize these results. Choosing one of the estimators which has a smaller variance can be one way. However, using the two estimates, it is possible to obtain an optimal estimator which has a smaller variance than any of two given variances. This optimal estimator is a more accurate one than any of the two individually derived estimators from the statistical view point. The formulae for computing the optimal estimate, C, is given as

$$E(C) = \frac{V(B)}{V(A) + V(B)} E(A) + \frac{V(A)}{V(A) + V(B)} E(B) \quad 54$$

$$\frac{1}{V(C)} = \frac{1}{V(A)} + \frac{1}{V(B)}$$

The procedure above can be applied to state space model. Suppose the model given as

$$y_t = x_t \beta_t + e_t,$$

$$\beta_t = \beta_{t-1} + u_t, \quad 55$$

where y_t and x_t are dependent and independent variables. β_t is a parameter which has a variance P_t . The disturbance terms, e_t and u_t are assumed to follow normal distribution with variance R and Q, respectively. Suppose we want to estimate $x_t \beta_t$ at time t-1, the two best predictions for $x_t \beta_t$ might be $y_t - e_t$ and $x_t \beta_{t-1} + x_t u_t$. Replacing the predictions in equation (54), we have

$$\begin{aligned}
E(x_t\beta_t) &= \frac{V(y_t - e_t)}{V(x_t\beta_{t-1} + x_tu_t) + V(y_t - e_t)} E(x_t\beta_{t-1} + x_tu_t) \\
&\quad + \frac{V(x_t\beta_{t-1} + x_tu_t)}{V(x_t\beta_{t-1} + x_tu_t) + V(y_t - e_t)} E(y_t - e_t) \\
\frac{1}{V(x_t\beta_t)} &= \frac{1}{V(x_t\beta_{t-1} + x_tu_t)} + \frac{1}{V(y_t - e_t)}
\end{aligned} \tag{56}$$

Rearranging the equations above, we have

$$\begin{aligned}
x_t\beta_t &= x_t\beta_{t-1} + \frac{x_t(P_{t-1} + Q)x_t'}{x_t(P_{t-1} + Q)x_t' + R}(y_t - x_t\beta_{t-1}) \\
x_tP_t x_t' &= x_tP_{t-1}x_t' - \frac{x_t(P_{t-1} + Q)x_t'x_t(P_{t-1} + Q)x_t'}{x_t(P_{t-1} + Q)x_t' + R}
\end{aligned} \tag{57}$$

In the equation above, we are interested in β_t and P_t rather than $x_t\beta_t$ and $x_tP_t x_t'$. After canceling unnecessary things, we have

$$\begin{aligned}
\beta_t &= \beta_{t-1} + \frac{(P_{t-1} + Q)x_t'}{x_t(P_{t-1} + Q)x_t' + R}(y_t - x_t\beta_{t-1}) \\
P_t &= P_{t-1} - \frac{(P_{t-1} + Q)x_t'x_t(P_{t-1} + Q)}{x_t(P_{t-1} + Q)x_t' + R}
\end{aligned} \tag{58}$$

This process can be revised by a two-step estimation. The first step concerns the prior estimator which has a superscript of $^-$,

$$\begin{aligned}
b_t^- &= E(\beta_t) = E(\beta_{t-1} + u_t) = \beta_{t-1} \\
P_t^- &= \text{var}(\beta_t) = \text{var}(\beta_{t-1} + u_t) = P_{t-1} + Q
\end{aligned} \tag{59}$$

This first step is commonly labeled as a prediction. This step simply takes an expectation and a variance on the second equation in (55). The second step, which is labeled as updating, finds optimal estimators. This step follows equation (54). At this time, it is enough to replace the prior estimators in equation (58).

$$\beta_t = b_t^- + \frac{P_t^- x_t'}{x_t (P_t^-) x_t' + R} (y_t - x_t b_t^-)$$

$$P_t = P_t^- - \frac{P_t^- x_t' x_t P_t^-}{x_t P_t^- x_t' + R}$$
60

Repeating prediction and updating procedures under given initial values, (β_0 and P_0), and variances of error terms (R and Q), the system can be solved step-by-step through time. However, required information on which the system heavily depends is rarely known. Harvey (1981) proposes a maximum likelihood method which solves for R and Q . The log likelihood can be built as

$$\log L = -\frac{NT}{2} \log 2\pi - \frac{1}{2} \sum \log |F_t| - \frac{1}{2} \sum v_t^T F_t^{-1} v_t$$
61

F_t and v_t are a variance and an error term of the system, respectively.

$$F_t = x_t P_t^- x_t' + R$$

$$v_t = x_t (\beta_t - b_t^-) + e_t$$
62

Maximum likelihood estimation solves for R and Q. After applying maximum likelihood, there still remain unknowns: the initial value, β_0 and P_0 . In general, they are assumed to be zero and a diffuse prior.²⁵

2.7. Existing literature for varying consumer behavior

The possibility that different levels of income might cause a difference in consumer responses has been raised by many researchers. Alderman (1986) reviews 15 papers which are related to varying consumer behavior and finds the absolute value of price and income elasticities of various goods in the food category to decline as income rises. The studies included in his review cover cross-sectional and time-series data²⁶ of 11 countries and employ various estimation techniques.

Frisch (1959) suggests a method which can identify a complete matrix of own and cross-price elasticities from a budget proportion and the income elasticity. This method is useful in cross-sectional data analysis since an income elasticity is relatively easier to estimate than price elasticities. This method relies on the assumption of want independence. Want independence relates to the marginal utility. Frisch explains want independence: “the marginal utility of using more electricity in the home can safely be regarded as independent of the quantity of Swiss cheese consumed.”²⁷ This assumption requires wide differences in characteristics of goods; therefore want independence is considered to hold for broad categories of goods rather than individual goods.

²⁵ A diffuse prior means a very large number.

²⁶ Murty and Radhakrishna (1981) and Murty (1983) use time-series data of India.

²⁷ Want independence is a different notion from demand independence. Most goods are supposed to be related each other with a substitution or complementary effect. Even though goods do not fall into these effects, they are still bound through a budget constraint.

Pinstrup-Anderson et al. (1976) utilize survey data collected in Colombia during 1969 and 1970. The data cover 22 foods or groups of food as well as family incomes of 230 households. They found that the own-price elasticities increase and the income elasticities decrease with rising incomes. However, their study is criticized by Brandt and Goodwin (1980) who point out that the data used in Pinstrup-Anderson et al. (1976) are highly disaggregated and thus the assumption of want independence seems not to hold. The assumption might be valid among broad categories of goods, but in the case of individual commodities, the appropriateness of the assumption seems to be in question. They also raise another question about the reliability of the estimated money flexibility since money flexibility is not compatible with Frisch's conjecture.

Lluch and Williams (1975) studied the differences in demand patterns across countries. The data they used cover 8 categories of commodities in 14 countries. They utilized Extended Linear Expenditure System²⁸ (ELES) to estimate the demand function for 14 countries. After the estimation, the estimated own-price, cross-price, and income elasticities are regressed on GNP per capita of each country. Various results are made from these auxiliary regressions. First, the cross-price elasticities with respect to food price decline as GNP per capita increases. Second, in food and recreation functions, the total expenditure elasticities decline with increases in GNP. Third, the own-price elasticities of housing and personal care increase with increases in GNP.

²⁸ The ELES is derived from the LES by adding an aggregated consumption function to LES. The aggregated consumption function is made by adding up individual expenditure across goods.

$$p_i x_i = \alpha_i p_i + \beta_i (m - \sum \alpha_j p_j)$$

Where x_i is a quantity demanded, p is a price and m is an income. In the equation above, $\alpha_i p_i$ is called subsistence minima which are interpreted as a minimum spending on good i for subsistence. The equation has an income variable on the right hand side instead of a total expenditure in the LES. The expenditure term is canceled when the aggregated consumption function is added to the LES.

The study of Timmer (1981) focuses on compensated elasticities rather than on uncompensated ones. The data used in Timmer (1981) came from a 1976 Indonesian household survey. 18,000 households in 25 areas and of 12 income classes were selected in this survey. Even though the survey covers more than 100 food commodities, the study only used three: rice, fresh cassava, and total calorie intake from rice, fresh cassava and corn. Two step estimations are employed in this study. The first step is a regression of quantity on prices, income, and income squared. The second step is a regression of absolute values of estimated price elasticities on household income.

The parameter of the second estimation is -0.339. The negative value is evidence of decreasing elasticities in absolute value as income increases. An interesting part of this study is the comparison of the parameters of the auxiliary equation to the parameters of an income squared in rice and cassava demand. They are -0.347 and -0.326 respectively. From this finding, Timmer draws a relationship between the price elasticity and income elasticity; $\frac{\partial \epsilon_{ij}}{\partial m} = \frac{1}{2} \frac{\partial E_i}{\partial m}$ where ϵ_{ij} is a compensated price elasticity, E_i is an income elasticity and m is an income.

Strauss (1983) used survey data of Sierra Leone and estimates price elasticities using QES (Quadratic Expenditure System) across low, middle, and high income groups. The commodity groups are five food categories and a non-food group. Strauss found that the own price elasticities of rice and fish and animal products are decreasing in absolute value with income levels while those of root crops and other cereals and oils and fat are increasing.

Chavas (1983) uses the Kalman Filter (KF) to find time varying parameters. The data period is from 1950 to 1979 in the U.S. meat market, and the market in the 1970s is

examined, while the data from 1950 to 1970 are used to find initial values. Chavas (1983) sets the state space model which is the base of Kalman filtering as the below

$$\begin{aligned} Y_t &= X_t \beta_t + e_t \\ \beta_t &= \beta_{t-1} + u_t \end{aligned} \tag{63}$$

where X and Y are independent and dependent variables respectively. The measurement equation, the first equation in the model above, is given as

$$\frac{\Delta q_{i,t}}{q_{i,t-1}} = \beta_{i,0} + \sum \beta_{i,j} \frac{\Delta p_{j,t}}{p_{j,t-1}} + \delta_i \frac{\Delta I_t}{I_{t-1}} + e_{i,t} \tag{64}$$

The variables in the equation above are expressed as growth rates. In particular, this form of equation is convenient when the elasticities are in question, because the parameters in this equation directly represent the elasticities.

Chavas (1983) draws several conclusions from the empirical analysis. First, the structural change in consumer behavior is identified in beef and poultry. Second, the price and the income elasticity of beef declined in the 1970s. Third, the income elasticity of poultry increased. Fourth, the effect of the pork price on beef consumption increased.

Bouis (1995) proposes a new demand system to examine the subject. He divided the utility function into three parts: energy, variety, and taste function. The energy function measures the amount of food consumed, and the function is increasing in the amount of food. The variety function is a ratio of non-staple food to total food. The function increases in non-staple food and decreases in staple food. The taste function measures the utility from taste concerns in regards to quality rather than quantity. The demand system, which is derived from this new utility function, was used to test the data

of the household and expenditure survey of Pakistan in 1984-1985. He concludes "... low-income groups in poor countries have demonstrated a greater responsiveness to changes in food prices than high-income groups" (p40).

Park et al. (1996) examine subsistence expenditure, own price elasticities and income elasticities with data of a nationwide food consumption survey (1987-88). This study uses US data whereas previous studies are built on data from developing countries. In the sense that developing and developed countries are different in consumer behavior, this study might be meaningful. In this paper, they found income elasticities of the low income group have greater values than those of the high income group but fail to find any significant difference in own price elasticities. They conclude that it is not appropriate to use aggregated estimates to project individual demand. More accurate projections are possible by using different estimates for different income groups.

Banks et al. (1997) proposes the Quadratic Almost Ideal Demand System (QUAIDS). Banks et al. test a relationship between budget share and log expenditure using kernel regression in five categories of goods: food, fuel, cloth, alcohol, and other goods. The results are that the budget share of some commodity groups, clothes, alcohol, and other goods, does not show a linear relationship with log expenditure. Using the results, QUAIDS is built by adding a squared term of log expenditure into the original AI demand system.

The results of QUAIDS are compatible with the results of the kernel regression. In cloth and alcohol equation, the negative quadratic terms are identified. Banks et al. utilize this result to analyze the welfare cost of indirect tax reform. They find that models

which have linear expenditure term wrongly specify the distribution of welfare losses and generate biased welfare calculations.

Seale et al. (2003) studied food consumption in 114 countries that have distinct income levels and various commodities groups. This study deals with the comparison among countries which have distinct income levels, whereas previous studies dealt with the difference in income groups in a country. They find that countries in the low income level have larger price responses than wealthier countries. In addition to this result, there are other findings. First, regarding the food consuming path, consumers move from inexpensive to expensive food stuffs as their income increases. Second, low income countries have a greater food expenditure share to total expenditure and larger grain share of the total food than do wealthier countries. Third, grain has smaller income and price elasticities than meat, fish and dairy

CHAPTER 3

THEORETICAL DISCUSSION AND MODELS

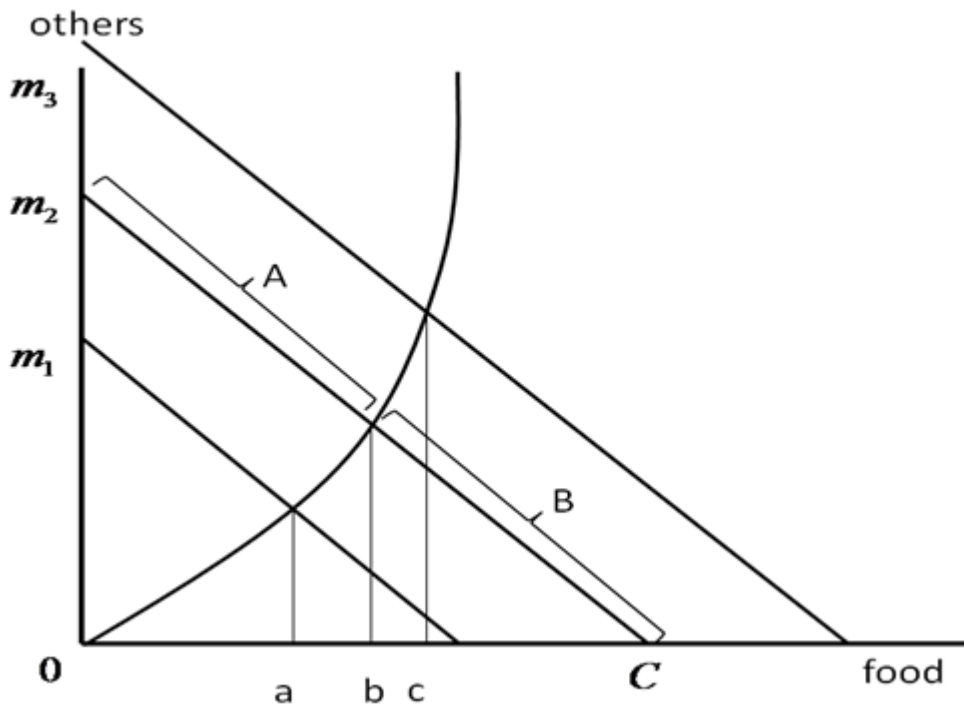
3.1. Engel's law

Engel's law is a relationship between a food expenditure share and income; a food share decreases as income level rises if there are no relative price changes. In general, people are likely to expand the variety of their consumption rather than spend more money on the goods that they already buy as their income rises. This tendency is closely linked to the decreasing marginal utility. As income rises, the quantity demanded increases and the marginal utility gets smaller. A consumer can obtain bigger marginal utility by expanding his consumption horizon instead of consuming more goods of which marginal utility is already low. The expansion of the consumption bundle implies that something is coming into the consumption lists and is taking a share. As a consequence, the existing shares should get smaller since the total sum of all shares needs to be one.

Engel's law does not imply that food consumption or expenditure decreases. It says that the growth rate of the food expenditure becomes more and more sluggish with income growth. Figure 3 depicts an expansion path of a food consumption which follows Engel's law. In Figure 3, the length from the origin to C represents the amount of food which can be purchased if all the income of m_2 is spent on food. It also represents the total income expressed in an equivalent quantity of food. The length from the origin to b represents not only the amount of food demanded at the level of income m_2 but also the food expenditure expressed in an equivalent quantity of food. As a consequence, the ratio of A to (A+B) represents the food expenditure share. The expansion path should move

away from the food axis in order to reflect the fact that the food share becomes smaller as an income rises. This graph can be easily linked to the marginal demand with respect to income. Two sections, (a-b) and (b-c), represent the marginal demand with respect to income at two distinct income levels, m_1 and m_2 , if there are no relative price changes.

Figure 3: Engel's law and the expansion path



Mathematically, the length of each section can be expressed as $\frac{\partial x}{\partial m}\bigg|_{m_1}$ and $\frac{\partial x}{\partial m}\bigg|_{m_2}$ respectively, where x is quantity demanded and m is income. The length of the sections is shown to get shorter as the budget constraint expands. This can be expressed as

$$\frac{\partial x}{\partial m}\bigg|_{m_1} > \frac{\partial x}{\partial m}\bigg|_{m_2}, \text{ for } m_1 < m_2$$

The above inequality means the marginal demand of food with respect to income is decreasing as income level rises. Figure 3 shows that the income response of a commodity which has a declining expenditure share becomes smaller as income rises under a condition of fixed prices. When it comes to an income elasticity, it is not clear whether it declines or not. Since an income elasticity, $\frac{\partial x}{\partial m} \frac{m}{x}$, has two components, $\frac{\partial x}{\partial m}$ and $\frac{m}{x}$, additional information is required about the size of each component. Even though $\frac{\partial x}{\partial m}$ declines, $\frac{m}{x}$ can make the income elasticity increase.

There is an equation which shows the relationship between income and price responses: the Slutsky equation shown in equation (8). It can be rewritten to show the relationship of income and price elasticities.

$$\varepsilon_{ii}^M = \varepsilon_{ii}^H - w_i \varepsilon_{im}$$

66

where ε is an elasticity, superscripts M and H are Marshallian and Hicksian, and w is a budget share. Among the terms in the equations above, the only one on which we have a clear idea is the expenditure share because it is observable. In the case of the income elasticity, it is likely to have a compatible variation with the marginal demand with respect to income. So the income elasticity is likely to decrease if the marginal demand decreases as a budget share falls.²⁹ However, declining marginal demand does not guarantee the declining income elasticity. Even if the variation of the income elasticity is known, there still remains a problem. Each equation in (66) has two more unknowns after the budget share and the income elasticity are revealed. We need more information other

²⁹ The relationship between the marginal demand with respect to income and budget share is shown in figure 3.

than the budget share and the income elasticity. That may be a reason why empirical analyses are necessary in order to identify varying consumer behavior.

Consumer behavior is considered to be a solution of utility maximization under a budget constraint. What if there is no budget constraint? This will happen if the consumer has an infinite income or if all the goods have zero prices. Since the utility function is supposed to increase in the amount of goods, the consumer will consume the infinite number of goods and the utility will increase unlimitedly. According to Neoclassical consumer theory, the marginal utility does not fall to zero even though it declines continuously. So the maximization point does not exist and the solution for the problem does not exist. However, if it is assumed that the utility function can be maximized anyway, the demand will be a function of other goods instead of prices and income. The budget constraint which defines the relationship between goods and prices and income does not exist in this case. Since the function does not have price and income as variables, the derivative of the demand with respect to prices and income will be zero. In other words, the demand does not respond to price and income changes. This procedure can be an explanation of the extreme end of an income growth even though the assumption is unrealistic.

The problem is that even though the income and price responses become zero at the extreme end, it is still unclear how the elasticities vary under a general environment. Each good in the market has its own characteristic and it has its income and price responses distinct from others. These responses can be expressed as $\frac{\partial x_i}{\partial m}$, $\frac{\partial x_i}{\partial p_i}$ and $\frac{\partial x_i}{\partial p_j}$ for an income, an own-price and cross-price elasticities. If these responses are believed to vary over income levels, the second derivatives can express the variation of the responses.

Therefore, varying consumer responses to price and income changes may be tested by setting the second derivatives to be zero. Mathematical expressions of the tests may be written as $\frac{\partial^2 x_i}{\partial m^2} = 0$, $\frac{\partial^2 x_i}{\partial p_i \partial m} = 0$ and $\frac{\partial^2 x_i}{\partial p_j \partial m} = 0$ for an income, an own-price, and a cross-price response respectively.

Often researchers use an elasticity instead of a marginal demand because it has convenient features in analyzing a consumer demand. It is a constant measurement regardless of a unit of a variable. This feature is particularly useful when the analysis is performed for multiple groups such as multiple countries. In general, each country has its own weights and measures different from other countries. The unit of currency also varies across countries. Under this circumstance, using the elasticity as a measurement of consumer behavior has the merit of reducing additional computing costs. Thus the elasticities are to be examined in this study instead of the marginal demand. The test of

the elasticities may be expressed as $\frac{\partial \frac{\partial x_i m}{\partial m x_i}}{\partial m} = 0$, $\frac{\partial \frac{\partial x_i p_i}{\partial p_i x_i}}{\partial m} = 0$ and $\frac{\partial \frac{\partial x_i p_j}{\partial p_j x_i}}{\partial m} = 0$ for the income elasticity, the own-price elasticity and the cross-price elasticity.

Among various demand functional forms, a double log demand function is convenient to obtain elasticities. Each parameter of this function represents an elasticity with respect to each variable, therefore it does not need additional computation to obtain elasticities. Suppose a demand function of a double log form

$$\log(y_t) = \sum \beta_i \log(p_{i,t}) + \alpha \log(m_t) + e_t$$

67

where y is a quantity demanded, p is a vector of prices, and m is income. Taking derivatives with respect to a log of price and a log of income directly gives a price and an income elasticity.

$$\frac{\partial \log(y)}{\partial \log(p_i)} = \frac{\partial y}{\partial p_i} \frac{p_i}{y} = \beta_i, \text{ and } \frac{\partial \log(y)}{\partial \log(m)} = \frac{\partial y}{\partial m} \frac{m}{y} = \alpha \quad 68$$

The demand elasticities are assumed as a function of income and to be differentiable with respect to income. These assumptions are needed in order to take the second order derivative with respect to income. Let the price and income elasticities be functions of income, $\beta_i(m_t)$ and $\alpha(m_t)$, respectively. Developing $\beta_i(m_t)$ and $\alpha(m_t)$ using Taylor expansion, we get

$$\beta_i(m_t) = \beta_i(m_{t-1}) + \beta_i'(m_{t-1})(m_t - m_{t-1}) + \frac{\beta_i''(m_{t-1})}{2}(m_t - m_{t-1})^2 + \dots \quad 69$$

$$\alpha(m_t) = \alpha(m_{t-1}) + \alpha'(m_{t-1})(m_t - m_{t-1}) + \frac{\alpha''(m_{t-1})}{2}(m_t - m_{t-1})^2 + \dots$$

What we are interested in is the first order derivatives. Their sign represents the direction of changes in elasticities. Assuming that all the rest of the equation from the third term can be represented as a disturbance term which follows a normal distribution gives

$$\beta_i(m_t) = \beta_i(m_{t-1}) + \beta_i'(m_{t-1})(m_t - m_{t-1}) + a_t$$

$$\alpha(m_t) = \alpha(m_{t-1}) + \alpha'(m_{t-1})(m_t - m_{t-1}) + b_t \quad 70$$

where a_t and b_t are assumed to follow normal distribution with mean zero respectively.

Combining equation (67) and (70), we have

$$\log(y_t) = \sum \beta_i(m_t) \log(p_{i,t}) + \alpha(m_t) \log(m_t) + e_t$$

$$\beta_i(m_t) = \beta_i(m_{t-1}) + \beta_i'(m_{t-1})(m_t - m_{t-1}) + a_{it}$$

71

$$\alpha(m_t) = \alpha(m_{t-1}) + \alpha'(m_{t-1})(m_t - m_{t-1}) + b_t$$

The state space model above expresses the demand function which has time varying parameters. The sign of β' and α' is the direction of an elasticity change. Each parameter in the model is assumed to be a function of income, and it is assumed to be differentiable with respect to an income. The parameter at time t is expressed as itself at time t-1, the first derivative with respect to an income and an income increment. We now can test

$$\frac{\partial \frac{\partial x_i m}{\partial m x_i}}{\partial m} = 0, \frac{\partial \frac{\partial x_i p_i}{\partial p_i x_i}}{\partial m} = 0 \text{ and } \frac{\partial \frac{\partial x_i p_j}{\partial p_j x_i}}{\partial m} = 0 \text{ by identifying the value of } \beta_i'(m) \text{ and } \alpha'(m). \text{ The}$$

above model, unfortunately, cannot be solved by conventional econometric methods; more assumptions are needed to make it tractable. What we want to know in the equation above is an average of the derivatives rather than the individual values of the derivatives at each time. So, let them be expressed by an average and an error respectively.

$$\beta_i'(m_t) = \beta_i' + c_{i,t}$$

72

$$\alpha'(m_t) = \alpha' + d_t$$

If the error terms, c_t and d_t , in equation (72) are not correlated with $(m_t - m_{t-1})$, then equation (70) may be rewritten as

$$\beta_i(m_t) = \beta_i(m_1) + \beta_i'(m_1)(m_t - m_1) + \delta_{it}$$

73

$$\alpha(m_t) = \alpha(m_1) + \alpha'(m_1)(m_t - m_1) + \varepsilon_t$$

where $\delta_{i,t} = \sum_j a_{i,j}$ and $\varepsilon_t = \sum_j b_j$. Combining equation (67) and (73), we have the model which is tractable with conventional econometric methods.

$$\log(y_t) = \sum_i \left[\beta_i(m_1) \log(p_{i,t}) + \beta_i'(m_t - m_1) \log(p_{i,t}) \right] + \alpha(m_1) \log(m_t) + \alpha'(m_t - m_1) \log(m_t) + e_t \quad 74$$

3.2. The Quadratic Relationship between income and expenditure share

Growing income in the developing and developed countries has allowed consumers to enjoy an expansion of a budget constraint. This expansion has made consumers more affluent and seems to have altered the consumption pattern over time. Most of the demand systems have focused on the average of the consumer behavior; in case of a time-series model, the average consumer behavior of the whole time period is the concern of the model. The QUAIDS model, however, has paid attention to the varying consumer behavior other than the average. The primary concern of the QUAIDS is the shift of the relationship between the expenditure share and income. QUAIDS is given as

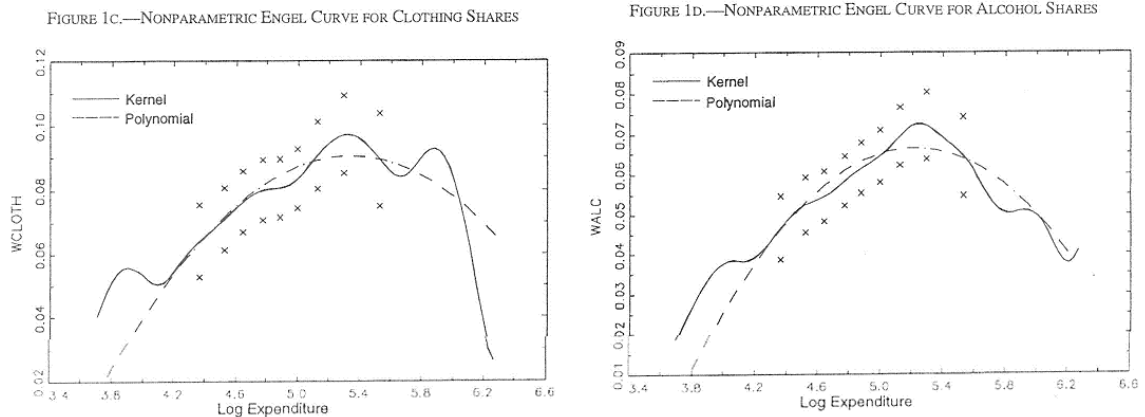
$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\left(\frac{m}{a(p)}\right) + \frac{\lambda_i}{b(p)} \left\{ \log\left(\frac{m}{a(p)}\right) \right\}^2$$

where $\log a(p) = a_0 + \sum_k a_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log p_k \log p_j$ 75

$$b(p) = \prod_i p_i^{\beta_i} \text{ and } \sum_i \lambda_i = 0$$

The first three terms on the right-hand side are identical to the AI demand system and the last term is added. The added term represents the quadratic relationship between the expenditure share and the total expenditure. As shown in the figure 4 below, the expenditure share of the cloth and alcohol group has a quadratic relationship in the total expenditure. The shares are increasing at first and declining as the total expenditure increases. This relation cannot be captured by the linear expenditure term in the AI demand system.

Figure 4: Non-parametric Engel curve

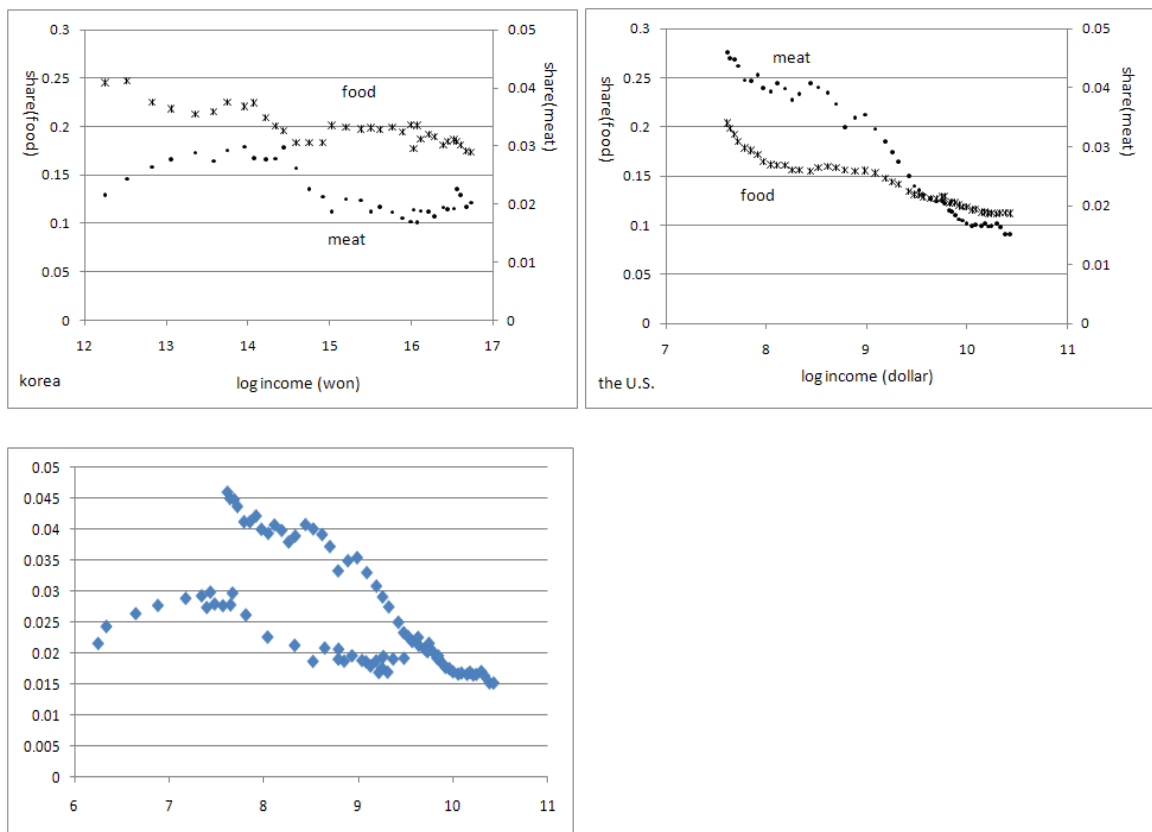


Source: Banks et al. (1997), p 529

Figure 5 depicts the food and meat expenditure shares of Korea and the U.S. Among the shares, the meat share in Korea is unique. It shows an increase for a relatively long period when income is low. The meat expenditure share of Korea resembles the quadratic shape of cloth and alcohol share in Figure 4. It starts at 2.16%, reaches up to 2.99% and decreases after it touches the peak. The purpose of employing a quadratic term in the demand function is measuring this effect. The negative parameter of quadratic term indicates that a commodity changes from a luxury to a necessity. The other three shares

decrease in their size with fluctuations. The shape of Engel curve of food and meat in the U.S. shows quite a similar pattern while those in Korea look widely different. The correlation between shares is 0.51 in Korea and 0.97 in the U.S.

Figure 5: the meat expenditure share of Korea and the U.S.



Note: The picture at the bottom depicts the expenditure shares of both countries. The Korean won is converted to the U.S. dollar.

Data: Korea: *Material on Price, Supply and Demand of Livestock Product*. National Agricultural Cooperative Federation and Statistics Korea (website: <http://kostat.go.kr>). the U.S.: Food and Agricultural Policy Research Institute and Economic Research Service (website: <http://www.ers.usda.gov>).

The quadratic parameter has two aspects: if it is negative then the Engel curve is concave and if positive then the Engel curve is convex. The concave Engel curve might appropriately represent the Korean case in Figure 5.³⁰ In Korea, the meat expenditure

³⁰ The sign cannot be predicted precisely with the figure because prices are not controlled. However, the figure of the expenditure share can offer a rough idea for the Engel curve.

share increases until the log income reaches around 14.³¹ On the other hand, the share in the U.S. declines continuously with decreasing rate. In this case, the sign of the quadratic term is likely to be positive. The problem is that the positive parameter of the quadratic term indicates an Engel curve has an increasing section. In general, an increases in the Engel curve is not expected in the market at a high level of income. Therefore, the gain from the quadratic term is limited whereas the risk of a biased estimation is high when the sign of the parameter is estimated to be positive. In the case of positive parameter, it may be better to omit the quadratic term.³²

Banks et al. (1997) calculate the income and the price elasticities as below.

$$\text{income elasticity: } \frac{\partial x_i}{\partial m} \frac{m}{x_i} = \frac{\mu_i}{w_i} + 1$$

$$\text{price elasticity: } \frac{\mu_{ij}}{w_i} - \delta_{ij}, (\delta_{ij} \text{ is the Kronecker delta})$$

76

$$\text{where } u_i = \beta_i + \frac{2\lambda_i}{b(p)} \ln\left(\frac{m}{a(p)}\right) \text{ and}$$

$$u_{ij} = \gamma_{ij} - \mu_i \left(\alpha_j + \sum \gamma_{jk} \ln p_k \right) - \frac{2\lambda_i \beta_j}{b(p)} \left[\ln\left(\frac{m}{a(p)}\right) \right]^2$$

3.3. Post-Keynesian Consumer Theory

Lavoie (2004) summarizes the six principles on which the Post-Keynesian consumer theory relies: procedural rationality, satiable needs, the separability of needs, the subordination of needs, the growth of needs, and the principle of non-independence.

³¹ The peak was reached when the income is 1,150,108 won in 1981 in Korea. The equivalent in dollar was \$1,699.

³² Banks et al (1997) also omit the quadratic term in food and fuel equation in their analysis.

The six principles offer a new perspective on explaining consumer behavior. The theory pays attention to a role of income in the consumption.

Imagine a consumer who is expanding his consumption as his income rises. He begins his consumption by spending his money on very basic needs such as food and shelter and expands his consumption boundary to the goods in discretionary categories. The lexicographic preference is involved in this expansion of the consumption. The structure of the lexicographic preference can be found in the study of Maslow (1943)³³. In the lexicographic preference, the consumption grows through the order of urgency of needs; more urgent needs have priority in being satisfied. The higher level of needs does not increase any utility without a fulfillment of the basic needs.

Once a consumer accomplishes a certain level of utility from the basic needs, as his income rises, he moves up to the higher level of consumption rather than increasing the amount of goods in the basic needs. Drakopoulos (1990) states “Once the primary criteria are satisfied, the secondary criteria become relevant”. The mechanism of moving up to the higher level may be explained by the diminishing marginal utility in Neoclassical consumer theory, and satiable needs and the growth of needs in Post-Keynesian consumer theory. If the marginal utility from a good is very low (the Neoclassical) or zero (Post-Keynesian), it is better for a consumer to consume other goods which give more utility. Satiabile needs may be understood as a strict version of the diminishing marginal utility.

Suppose a consumer who has already moved up to the secondary consumption level faces economic disturbances such as income and price fluctuations. A consumer

³³ Maslow categorizes human needs into five categories: physiological needs, safety needs, love and belonging needs, self-respect and esteem needs and self-actualization needs.

should react to this economic disturbance by changing the focus of his consumption. According to Post-Keynesian consumer theory, he is likely to choose to adjust goods in secondary needs rather than goods in basic needs. This selection reflects the order of urgency of needs; more urgent needs come first and less urgent needs come second. Since the utility from goods which belongs to basic needs is already saturated, consuming more goods in that category rarely increases his utility. On the other hand, lessening the consumption of goods which belongs to the basic needs entails the big loss in his utility. A consumer can maximize his utility gain by consuming more goods in secondary needs and minimize his utility loss by reducing the goods in secondary needs. The possibility that a consumer enjoys a higher level of the consumption increases as he has more income. More and more categories of needs would be saturated as the consumer expands his consumption boundary. As a result, the consumer behavior for goods which belong to a lower level is likely to become less elastic when he becomes wealthier.

The categories of needs, in general, are classified horizontally. For example, food is considered as a category of preventing hunger so it belongs to basic needs. However, we observe that food consumption increases continuously, even in the developed countries, although most of the people in these countries are believed to have escaped from hunger. According to Post-Keynesian consumer theory, the utility from food should have been saturated already and the consumption should have stopped increasing. This problem may be solved if the concept of vertical classification is introduced; food may be classified as both a necessity and a luxury at the same time. Among the total food consumed, some part belongs to basic needs and the other part belongs to discretionary needs. As a result, some part of the food consumption may be locked in basic needs and

may be insulated from an economic disturbance. The other part of the food consumption may face a competition with other goods in the same level of needs in terms of the marginal utility.

Comparing two persons with different income levels, the richer one is likely to consume goods in a higher level of needs than the other. Whenever a consumer steps up to the higher level of needs, the utility from the lower level is considered to be saturated. As a result, the richer consumer is likely to have more must-have lists of which goods are likely to be, in some sense, insulated from an economic environment. The same thing can be applied to the vertical classification. The rich are likely to prefer more and a greater variety of goods than the poor.

Assume a model in which the demand is divided into two parts: the demand which relates to an economic environment such as income and price and the demand which is not affected by prices.

$$x_i = f_i(p, (m - \sum p_k b_k)) + b_i \quad 77$$

where b represents the amount which is not affected by price; p and m are price and income respectively. In this demand system, a consumer is assumed to make a two-step decision on his consumption. He spends his income on the minimum level of the consumption which is supposed not to be affected by prices; the b in equation (77) represents the minimum level of the consumption. The level of b is considered to vary according to the income of the consumer. Next, the remaining income is allocated to goods considering an economic environment. For simplicity, let the model be the two-good system. Taking total differential, we have

$$dx_i = \left(\frac{\partial f_i}{\partial p_1} + \frac{\partial f_i}{\partial M} \frac{\partial M}{\partial p_1} \right) dp_1 + \left(\frac{\partial f_i}{\partial p_2} + \frac{\partial f_i}{\partial M} \frac{\partial M}{\partial p_2} \right) dp_2 + \left(\frac{\partial f_i}{\partial M} \frac{\partial M}{\partial m} + \frac{\partial b_i}{\partial m} \right) dm \quad 78$$

$$\text{where } M = m - \sum p_k b_k$$

Solving this system, we have 6 parameters with 10 unknowns. As a result, this system is not tractable empirically.³⁴ This result indicates that building a minimum consumption model that is empirically tractable requires more assumptions.

3.3.1. The LES with income effects

This idea of locked-in consumption is well-expressed in the Linear Expenditure System (LES). LES assumes that a consumer spends his income on the subsistence minimum³⁵ which does not relate to an economic environment. After he fulfills the minimum consumption, he makes an economic decision on the additional consumption with his income leftover. The interpretation of the subsistence minima is the amount of consumption chosen regardless of price and income when focusing on the demand function. The other interpretation may be made when focusing on the utility function; the amount of consumption does not contribute to an increase in the utility. Altering the parameters of the minimum consumption, Pollak and Wales (1969) suggest two dynamic models: a time trend model and a habit formation model.

³⁴ The n-good system has n(n+1) parameters and n(n+3) unknowns. So each derivative cannot be identified.

³⁵ The subsistence minimum means the smallest amount of consumption to make a consumer stay in the subsistence level. Lluch and William (1975).

$$p_i x_i = p_i b_i + a_i (m - \sum p_k b_k)$$

$$\text{time trend model: } b_{i,t} = b_i^* + \beta_i t$$

79

$$\text{habit formation model: } b_{i,t} = b_i^* + \beta_i x_{i,t-1}$$

In the model, the parameters which represent the subsistence minima are considered as a function of time or lagged consumption. Now suppose the b's are allowed to vary across income levels instead of a time trend or lagged consumption. While the dynamic version of LES can be derived by simply substituting dynamic b's into the demand system, the first one in the equation (79), LES with income effect, needs more step to derive it. Since the b's are supposed to be a function of income and LES is derived from the indirect utility function, the substitution should be made at the level of the indirect utility. The indirect utility function is given as

$$V(p, m) = \frac{m - f(p)}{g(p)}$$

80

$$\text{where } f(p) = \sum b_k p_k \text{ and } g(p) = \prod p_k^{a_k}$$

Now b's become a function of income as well as prices, and as a result, $f(p) = \sum b_k p_k$ should be replaced by $f(p, m) = \sum b_k(m_t) p_k$. Applying the Roy's identity, we get

$$x_i(p, m) = \frac{b_i + \frac{a_i}{p_i} (m - \sum b_k p_k)}{1 - \sum \frac{\partial b_k}{\partial m} p_k}$$

81

Since b 's are assumed to be a function of income, they should not be a fixed parameter in the system. Using the Taylor expansion which are the same steps with equation (69) and (70), b 's can be developed to

$$b(m_t) = b(m_{t-1}) + \left. \frac{\partial b}{\partial m} \right|_{m_{t-1}} (m_t - m_{t-1}) + a_t \quad 82$$

where a_t is assumed to be normally distributed with mean zero. Rewriting equation (81) with a stochastic notation and combining it with equation (82), we obtain the state space model.

$$x_{i,t}(p_t, m_t) = \frac{b_i(m_t) + \frac{a_i}{p_{i,t}}(m_t - \sum b_k(m_t) p_{k,t})}{1 - \sum \beta_{k,t} p_{k,t}} + e_t$$

$$b_i(m_t) = b_i(m_{t-1}) + \beta_{i,t} \times (m_t - m_{t-1}) + a_t \quad 83$$

where $\beta_{i,t} = \left. \frac{\partial b_i}{\partial m} \right|_{m_{t-1}}$

where e_t is an error which is assumed to follow normal distribution with mean zero. The LES with income effects has properties distinct from those of LES even though they share a very similar indirect utility function. First, the LES with income effects is not an exactly aggregable demand system anymore.³⁶ Second, the indirect utility of the LES with income effects is not homogeneous with degree zero in prices and income. This issue can be solved if the real prices and income are considered; thus the LES with income effects should have real terms as its variables.

³⁶ The indirect utility of LES has a type of Gorman form, so LES is an exactly aggregable demand function through individuals.

The state space model, equation (83), can be developed to the non-linear time-series model. The second row of equation (83) can be developed by replacing $b(m_{t-1})$ with $b(m_{t-1}) = b(m_{t-2}) + \beta_{t-1}(m_{t-1} - m_{t-2})$ and repeating this replacement through time. Then we have

$$b(m_t) = b(m_1) + \sum_i [\beta_i \times (m_i - m_{i-1})] + \sum_i a_i \quad 84$$

Assuming $\beta_t = \beta + c_t$, where β is an average of β_t and c_t is an error which follows a normal distribution with mean zero. And the covariance between c_t and $(m_t - m_{t-1})$ is assumed to be zero. These assumptions transform the state space model into the fixed parameter model and are same with assumptions imposed on equation (72) and (73). Then equation (84) can be rewritten as

$$b(m_t) = b(m_1) + \beta \times (m_t - m_1) \quad 85$$

Substituting equation (85) for b 's in equation (83) gives a non-linear time-series model for the LES with income effects.

$$x_{i,t} = \frac{b_i(m_1) + \beta_i(m_t - m_{t-1}) + \frac{a_i}{p_{i,t}} (m_t - \sum (b_k(m_1) + \beta_k(m_t - m_{t-1})) p_{k,t})}{1 - \sum \beta_k p_{k,t}} + e_t \quad 86$$

The primary concern of the LES with income effects is the sign of β . If β is positive, then $b(m_t)$ increases as income rises. This positive β implies the part of demand which is defined as a minimum consumption increases. An increasing minimum consumption implies two things. The first is that the consumer expands his consumption boundary with income growth. The second is that the good in question is continuously

demanded in newly expanded needs. It makes a difference in consumer behavior whether the demand of a good occurs in the frontier or not. In general, the horizon of needs tends to be extended with income growth. Considering the order of the expansion determined by the degree of urgency, the demand which occurs on the frontier of needs is supposed to be the least urgent for the consumer. This order of urgency reflects consumer behavior. The demand which belongs to existing needs is more valuable than the demand which belongs to newly introduced needs. As a result, if a consumer faces an economic disturbance, such as an income decrease or a price rise, goods demanded in new needs are likely to absorb the shock first. This makes the demand in existing needs be inelastic and that in new needs be elastic.

Imagine two distinct commodities with different consumption patterns. One has the stagnant demand (commodity A) and the other has the increasing demand (commodity B). A is likely to be demanded only in existing needs while B is likely to be demanded both in existing and newly added needs. Considering the order of urgency, existing needs have priority. Therefore a consumer is likely to allocate his income to commodity A and some part of B. After existing needs are satisfied, he is likely to consume the other part of B. In this structure of decision making, A and some part of B are not sensitive to an economic environment. On the other hand, the other part of B is in a competing environment between commodities which belong to the same level of needs.

If this example is examined on the commodity base instead of the needs base, the difference in consumer behavior between the commodities can be found. Consumer behavior for the commodity A can be said to become less responsive to an economic environment as the consumption boundary expands. In case of the commodity B, it is not

clear whether consumer behavior changes or not. Since consumer behavior is defined as a marginal sensitivity to price and income, the major determinant of consumer behavior for the commodity B is the situation in the frontier of needs. In other words, the commodity B's marginal sensitivity in the newly introduced needs dominates consumer behavior for whole demand of B. Therefore, it is not possible that a general rule concerning consumer behavior apply to commodity B.

The marginal demand with respect to income, own-price, and cross-price can be calculated by the formulae below.³⁷

$$\begin{aligned}
 \text{income: } \frac{\partial x_{i,t}}{\partial m_t} &= \frac{\beta_{i,t}}{1 - \sum p_{k,t} \beta_{k,t}} + \frac{a_i}{p_{i,t}} \\
 \text{own-price: } \frac{\partial x_{i,t}}{\partial p_{i,t}} &= \frac{b_{i,t} - a_i b_{i,t} + \beta_{i,t} x_{i,t} p_{i,t}}{p_{i,t} (1 - \sum p_{k,t} \beta_{k,t})} - \frac{x_{i,t}}{p_{i,t}} \\
 \text{cross-price: } \frac{\partial x_{i,t}}{\partial p_{j,t}} &= \frac{-a_i b_{j,t} + \beta_{j,t} x_{i,t} p_{i,t}}{p_{i,t} (1 - \sum p_{k,t} \beta_{k,t})}
 \end{aligned}
 \tag{87}$$

However, these marginal demand do not give a clear idea on their variations across income levels.

³⁷ The steps are shown in Appendix A.

CHAPTER 4

EMPIRICAL ANALYSIS

4.1. Data³⁸

This study uses data of two meat markets: per capita consumption and prices of beef, pork and chicken in both Korea³⁹ and the U.S. The data period is 1974 to 2008 for Korea and 1960 to 2007 for the U.S. The statistics of the data are shown in Table 1.

Table 1: statistics of data

Korea	beef	pork	chicken	income
price and income(won per kilogram, won, nominal)				
Average	14,043	5,695	2,171	6,503,294
Variance	104,754,974	18,900,131	1,027,187	3.35E+13
Min	1,306	702	412	208,585
Max	37,274	16,820	4,259	18,476,245
Quantity(kilogram, per person)				
Average	2.96	10.56	4.34	
Variance	1.03	18.36	3.29	
Min	1.48	2.75	1.54	
Max	5.62	16.22	7.71	
the number of observation: 35 (1974-2008)				

³⁸ Data sources are *Material on Price, Supply and Demand of Livestock Product* of National Agricultural Cooperative Federation (Korea), and Food and Agricultural Policy Research Institute. (the U.S.)

³⁹ Korean data do not include imported meat; they are composed of price and quantity only of domestically produced meat. The reasons are that the consumer price of imported meat is not reported and the period of the import is relatively short. The Korean meat market opened with tariff in 1997 for pork and chicken and in 2001 for beef. Before the tariffication, quotas are imposed on each meat product.

The U.S.	beef	pork	broiler	income
price and income(cents per pound, dollar, nominal)				
Average	218	165	74	13336
Variance	10684	5830	640	94624604
Min	75	56	38	2021
max	416	287	112	33707
Quantity(pound, per person)				
average	74	52	53	
variance	71	13	369	
min	63	43	24	
max	95	61	87	
the number of observation: 48 (1960-2007)				

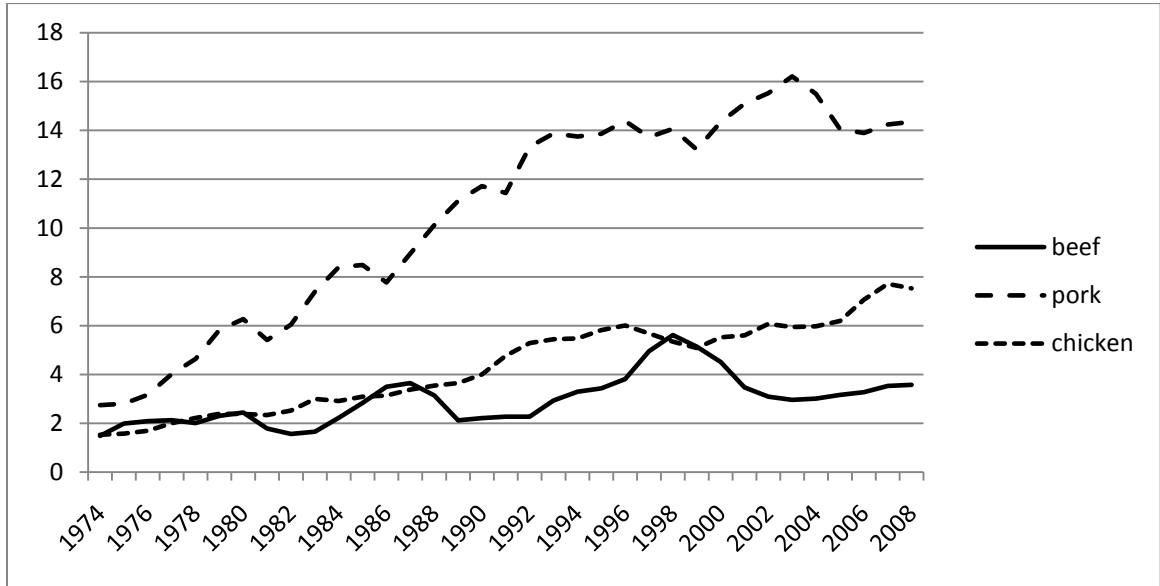
4.1.1. Meat consumption in Korea

Korea has experienced fast economic growth and per capita income in 2008 has grown more than 80 times since 1974; the annual income growth rate is 14.1 percent in nominal terms. With income growth, diet habits also have shifted. One of the most significant shifts in diet habits might be the growth of meat consumption; grain consumption has declined 32% whereas the meat consumption has increased 3.5 times during the period.⁴⁰ Koreans consumed 35.5kg of meat in 2008. It is composed of 53% of pork, 25.2% of chicken, and 21.1% of beef. The large amount of meat consumption in Korea is accounted for by imported meat. The portion of the imported meat has grown gradually up to 28.4% in 2008. Beef was lowest in self-sufficiency; only 47.6% of the

⁴⁰ Hwang (2009)

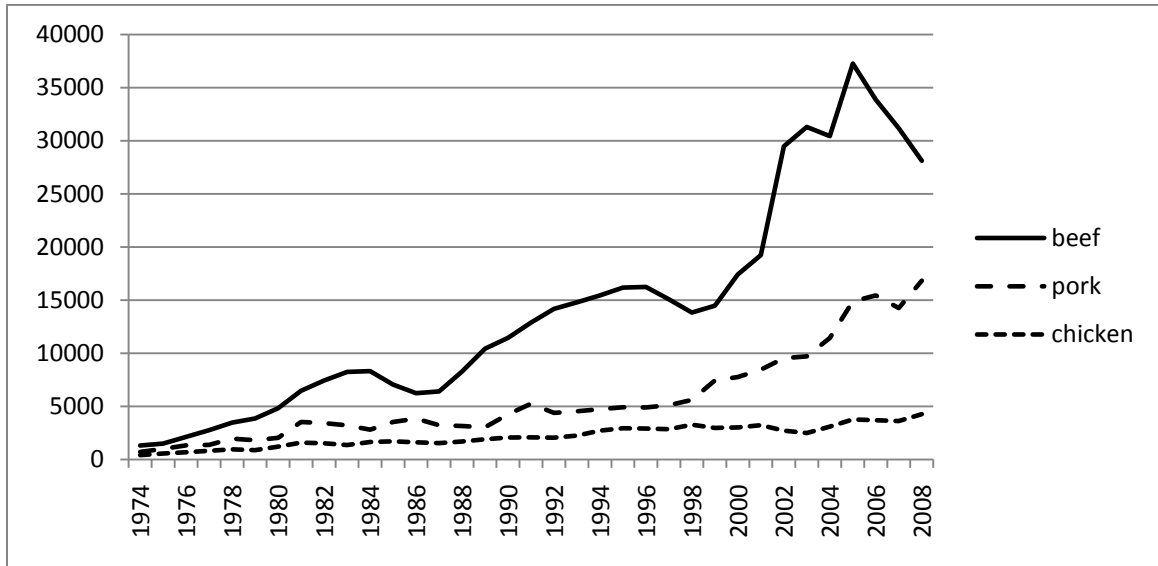
beef consumption was domestically produced in 2008. Figure 6 depicts the annual consumption per capita for meats.

Figure 6: meat consumption per capita (kg), Korea



The nominal price of meat also has increased fast. The pork price has shown the fastest growth. The price in 2008 was 23 times higher than that in 1974. Beef and chicken prices have risen by 21 times and 9 times, respectively. In Korea, the beef price is much higher than that of other meats. The average beef price during the period is 2.4 and 5.8 times higher, respectively than that of pork and chicken. This compares to 1.3 and 3.1 times in the U.S. Relative preference for beef in Korea may be stronger than that in the U.S. at the margin. However, the price difference between pork and chicken is 2.3 times which is similar to 2.4 times in the U.S. One thing to note in Korean meat market is that the prices of beef and pork have increased even in real terms. This suggests income effects on the meat demand are quite strong. In case of the U.S., the real prices of all three meat products have declined. Figure 7 depicts the price of meat.

Figure 7: The meat price, Korea, won/kg, nominal.

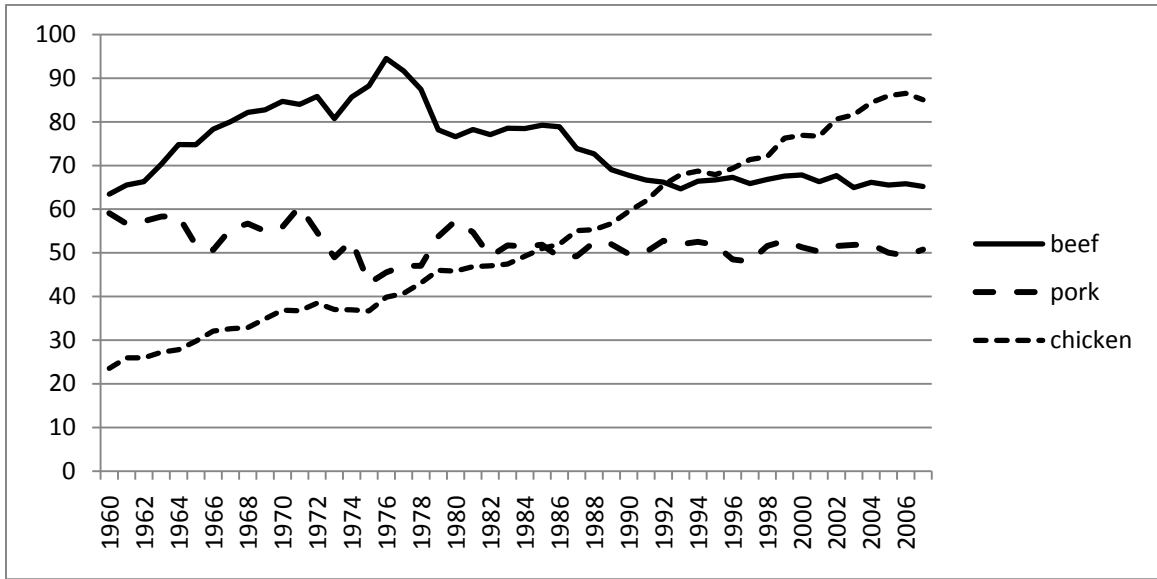


4.1.2. Meat consumption in the U.S.

Income in the U.S. has grown 16.7 times from 1960 to 2007 in nominal terms; the annual income growth rate is 6.2 percent in nominal terms. One of the most significant trends in the American meat market is the consumption growth in white meat. The meat consumption data of the U.S. shows a strong trend in white meat. The amount of chicken has increased 3.6 times since 1960 while demands for the other meat products have declined slightly. Several studies explain this preference shift to be caused by growing health concern, need for time-saving dishes, and the relatively cheap chicken price.⁴¹ Beef consumption reached its peak in 1976 and after that it has declined at a fast speed. Pork consumption has decreased gradually during all time period. Total meat consumption has grown from 146 pound in 1960 to 201 pound in 2007. Figure 8 depicts the consumption of meat in the U.S.

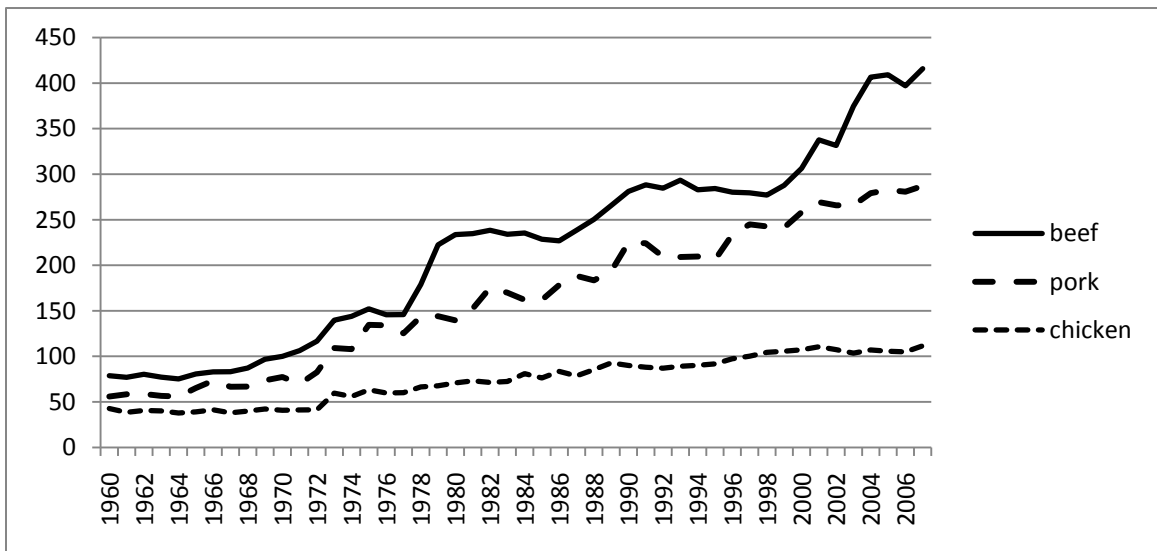
⁴¹ Putnam (1999) argues that searching for low fat and cholesterol entails consumer substitution of white meat for red meat. Haley (2001) explains this trend with three factors: growing health concern, searching for time-saving dishes due to increasing in working women, and the relatively cheap price of chicken.

Figure 8: The meat consumption per capita (lbs.), the U.S.



In nominal terms, the beef price has increased 5.3 times, the pork price 5.1 times and the chicken price 2.6 times in the U.S. since 1960. In real terms, all three prices of meat products have declined through the period.

Figure 9: the prices of meat products, the U.S., cent/lbs, nominal.



4.2. Estimation and Results

4.2.1. Quadratic Almost Ideal Demand System

The model used in the estimation is shown in equation (75). This model is non-linear in parameters because $a(p)$ and $b(p)$ are functions of prices. But if the two functions, $a(p)$ and $b(p)$, are given, then QUAIDS becomes linear in parameters. Banks et al. (1997) utilized this conditional linearity. Under a given $a(p)$ and $b(p)$, the system is estimated. The result of the estimation updates $a(p)$ and $b(p)$ and the system estimated based on the updated $a(p)$ and $b(p)$ again. This iterative procedure is repeated until $a(p)$ and $b(p)$ become stable.

The estimation in this study follows the iterative method. The initial values for $a(p)$ follows the Stone's (1953) index which is given as

$$a(p) = \sum w_i \log(p_i), \text{ where } w_i \text{ is a expenditure share} \quad 88$$

and the initial value of $b(p)$ is computed by⁴²

$$b(p) = \prod p_i^{w_i}, \text{ where } w_i \text{ is a expenditure share} \quad 89$$

SUR (Seemingly Unrelated Regression) is used to estimate the linearized QUAIDS. The homogeneity, symmetry and adding-up conditions are imposed in the estimation. The restrictions may be expressed as

⁴² The discussion about the initial value of $b(p)$ is not shown in the Banks' study. Since the restriction imposed on the $b(p)$ is $\sum \beta_i = 0$, the assumption of $\beta_i = w_i$ does not look correct. However, any choice of β_i does not change the result in the present study. It becomes stable very quickly.

$$\text{adding up conditions : } \sum_i \alpha_i = 0, \sum_i \gamma_{ij} = 0, \sum_i \beta_i = 0, \sum_i \lambda_i = 0$$

$$\text{homogenous conditions : } \sum_j \gamma_{ij} = 0$$

90

$$\text{symmetry conditions : } \gamma_{ij} = \gamma_{ji}$$

The estimated equations are beef, pork, and chicken. The other equation, which is the last equation in the system, is excluded to avoid a multicollinearity problem. The estimation results for both Korea and the U.S. are shown in the table below.

Table 2: Estimation results of QUAIDS

Korea	beef		pork		Chicken	
	coefficient	std. error	coefficient	std. error	coefficient	std. error
α	*0.0077	0.0068	-0.0557	0.0053	-0.0058	0.0016
γ_{beef}	*-0.0015	0.0011	0.0022	0.0007	0.0005	0.0002
γ_{pork}	0.0022	0.0007	0.0083	0.0007	-0.0001	0.0002
γ_{broiler}	0.0005	0.0002	*-0.0001	0.0002	0.0023	0.0003
γ_{other}	*-0.0011	0.0011	-0.0104	0.0008	-0.0026	0.0004
β	*0.0009	0.0033	0.0193	0.0025	*-0.0009	0.0005
λ	*-0.0007	0.0007	-0.0046	0.0005	*0.0000	0.0001
R-squared	0.722		0.882		0.970	
The US.	beef		pork		Broiler	
	coefficient	std. error	Coefficient	std. error	Coefficient	std. error
α	0.1595	0.0215	0.1353	0.0103	0.0233	0.0049
γ_{beef}	0.0160	0.0022	-0.0014	0.0008	-0.0003	0.0004
γ_{pork}	-0.0014	0.0008	-0.0068	0.0011	0.0000	0.0005
γ_{broiler}	*-0.0003	0.0004	*0.0000	0.0005	0.0022	0.0005
γ_{other}	-0.0143	0.0024	0.0081	0.0016	-0.0020	0.0008
β	-0.0287	0.0124	-0.0646	0.0069	*-0.0049	0.0034
λ	*0.0020	0.0021	0.0093	0.0012	*0.0008	0.0006
R-squared	0.963		0.994		0.962	

Note: * is not significant at the 10% significant level.

The expected sign of λ 's, the parameters of quadratic terms, are negative for Korea and positive for the U.S., considering the relationship between the expenditure share and income shown in Figure 5. The shape of an Engel curve in Korea appears to be quadratic whereas that in the U.S. appears to be linear. This expectation can be justified by the fact that meat is a more expensive and more desirable commodity than grain products. So it is likely to be regarded as a luxury when the income lies at a low level. The peak in the meat expenditure share in Korea was reached when the income was 1,150,108 won in 1981 while the peak in the U.S. looks to have been reached before the data period in this study. The U.S. in 1960 was not a poor country, whereas Korea in 1974 was not rich.⁴³

The estimation results confirm the expectation about λ even though some of them are not significant statistically. λ 's in the Korean model are negative with one exception being in the chicken equation. Those in the model of the U.S. are positive without exception. Negative λ implies a concave Engel curve and the commodity in question changes its property from a luxury to a necessity. When the Engel curve increases the income elasticity is greater than one, and when it decreases the income elasticity is smaller than one. Beef and pork in Korea are relevant to the case; they were luxuries when the country was poor. However, chicken is an exception. The Engel curve of chicken has dropped continuously during the period of the analysis. The reason might be that chicken is less preferred than the other meat, and thus the income effect of beef or pork is greater than that of chicken. This preference appears in the relative prices. The relative beef and pork prices to chicken in Korea in 2007 were 8.6 and 3.9 respectively.

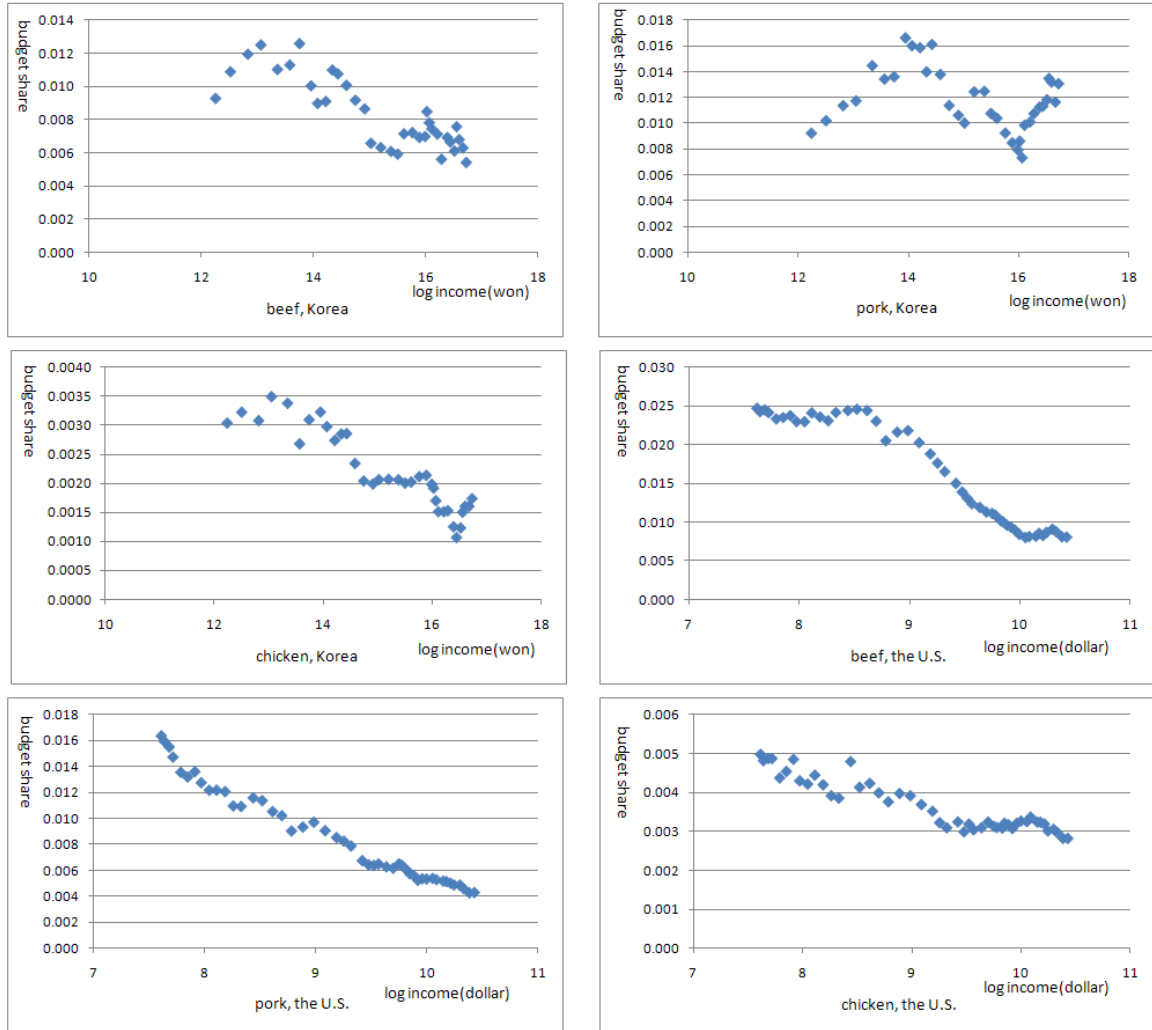
⁴³ The income was \$2021 and \$515 for the US. in 1960 and Korea in 1974 respectively.

These prices are much higher than the relative prices in the U.S. which were 3.7 and 2.6 in the same year.

Even though consumers in the U.S. have expanded their meat consumption during the period of analysis, the expenditure share of meat has not increased. It seems that the peak in the expenditure share had passed before the year of the starting data in this study. Therefore all three meat products in the U.S. can be classified as a necessity at least during the period of analysis. Figure 10 depicts the relationship between income and expenditure shares. Since the figure does not have control of the prices, it cannot represent the exact relationships. But it still can provide a rough picture of the relationships. The estimation results predict the concave function for beef and pork in Korea and the convex function for the others. These predictions are compatible with Figure 10.

Considering the roll of the quadratic term in QUAIDS, the negative λ plays a role in finding the transformation of the commodity's property while the positive λ does not have any clear contribution. In general, it is hard to find a commodity of which Engel curve has a concave shape. Therefore, applying QUAIDS to the U.S. meat market does not have clear advantages while it has some possible risks.

Figure 10: the relationship between the expenditure share and log of the income in both Korea and the US.



4.2.2. The LES with income effects

Under conditions of growing income, consumption is likely to evolve into a higher level of needs. In other words, a consumer is likely to expand his consumption boundary in which the higher needs are included. As the boundary is expanded, more and more goods are included in the basic needs categories and regarded as a minimum consumption.

The LES with the income effects model expresses overall this divided demand: the elastic part and the inelastic part to price changes. The inelastic part of the demand is defined as a minimum consumption, that is, a subsistence level of consumption. Following the spirit of LES, a consumer does not obtain any utility from this consumption. It is the minimum required for a consumer to live at subsistence level, and thus it is something to be obtained at any cost. Therefore, this part of the consumption is rarely affected by changes in price. A consumer makes a decision on his consumption considering his economic condition after he completes the minimum consumption.

The estimated model is given in equation (83). It is estimated by FIML (Full Information Maximum Likelihood). As explained in chapter 3, the variables in the model should be real terms instead of the nominal. The results are shown in Table 3. The sign for β is expected to be positive if the amount of the minimum consumption increases as income rises and be negative if the amount decreases.

The estimated sign of the parameter, β , is positive for pork and chicken and negative for beef in Korea. This result reflects that more and more pork and chicken are considered as essential diets in Korea with an income growth. Negative β^{44} in the beef equation is unexpected since the quantity of beef consumed also has increased through time. One possible conjecture for it is the existence of a close substitute of imported beef. Imported beef accounts for a large part of the beef consumption in Korea. In recent years, more than a half of consumption is accounted for by imported beef. Moreover, the price of imported beef is much lower than the price of domestic beef.⁴⁵ It may be that imported

⁴⁴ It is not significant statistically.

⁴⁵ Sirloin steak of domestic beef was 62,876 won/kg and the same part from Australia was 41,112 won/kg in 2008. These prices are equivalent to 57 \$/kg and 37 \$/kg. Data: www.kati.net.

beef substitutes for domestic beef and so the minimum consumption of domestic beef decreases.

Table 3: Estimation results of LES with income effects

Korea	beef		Pork		chicken	
	coeff.	std. error	coeff.	std. error	coeff.	std. error
a	0.0083	0.0019	0.0040	0.0013	*3.782E-13	0.0004
b	*0.7391	1.1949	3.2587	1.5133	1.6599	0.6215
β	*-1.10E-07	9.82E-08	4.00E-07	1.47E-07	3.10E-07	1.20E-07
R-squared	0.851		0.937		0.952	
The US.	beef		Pork		chicken	
	coeff.	std. error	coeff.	std. error	coeff.	std. error
a	*2.171E-08	0.0006	*1.82E-07	0.0007	0.0029	0.0003
b	73.9621	2.4617	55.3138	1.7328	27.0293	4.9168
β	*-1.17E-04	1.80E-04	-3.52E-04	2.06E-04	3.99E-04	2.02E-04
R-squared	0.059		0.183		0.988	

Note: * is not significant at the 10% significant level.

The sign of β in the chicken equation of the U.S. is positive, whereas those in the beef and the pork are negative.⁴⁶ These results are compatible with total demand of each meat product. The demand for chicken in the U.S. has increased by more than three times from 24 pounds in 1960 to 85 pounds in 2007, while the demand of beef and pork has decreased during the period.

The joint test for the variation of minimum consumption is performed with Wald test statistics. The test statistics in both countries are larger than the 10% significant level.

⁴⁶ The parameter in the beef equation is not significant statistically.

Therefore the results confirm that the variations in the minimum consumption exist in both countries and they are jointly significant statistically.

Table 4: Wald test statistics

Korea
$H_0: \beta_{beef} = \beta_{pork} = \beta_{chicken} = 0$
chi-square: 22.8 with d.f. of 3
the U.S.
$H_0: \beta_{beef} = \beta_{pork} = \beta_{chicken} = 0$
chi-square: 7.1 with d.f. of 3

4.2.3. The double log demand with income effects

The double log with income effects measures the price and income elasticities and their variations. The model estimated is shown in equation (74). This model can directly examine consumer behavior without additional complicated computation. β and α are price and income elasticities at time 1 and the sign of the derivatives, β' and α' , directly indicates the direction of the consumer behavior change. This model is estimated using the least squares method and an AR process is employed in some equations because of serial correlation. The estimated results are shown in the table below.

Table 5: results of the double log demand with income effects

Korea	**beef		**pork		**chicken	
	coeff.	std. error	coeff.	std. error	coeff.	std. error
β_{beef}	-1.6406	0.2557	0.2360	0.1320	*0.1207	0.1382
β_{pork}	*-0.2792	0.1852	-0.4417	0.0895	*-0.0071	0.0954
$\beta_{chicken}$	*0.4821	0.2824	*-0.1449	0.1402	-0.3834	0.1524
α	0.9840	0.1720	0.3395	0.0880	0.2058	0.0945
β'_{beef}	8.92E-08	2.75E-08	*-1.35E-08	1.43E-08	*-1.04E-09	1.46E-08
β'_{pork}	*1.05E-08	2.80E-08	*1.44E-08	1.58E-08	*-1.77E-08	1.78E-08
$\beta'_{chicken}$	*-3.00E-08	3.55E-08	*8.25E-09	1.89E-08	*3.51E-08	2.09E-08
α'	-4.46E-08	2.14E-08	*-4.00E-09	1.06E-08	*-5.95E-09	1.10E-08
R-squared	0.930		0.991		0.989	
D.W. without AR	0.89		0.56		0.98	

The US.	**beef		pork		**chicken	
	coeff.	std. error	coeff.	std. error	coeff.	std. error
β_{beef}	-0.6323	0.1103	0.4275	0.0794	*0.0044	0.1124
β_{pork}	0.1474	0.0851	-1.1076	0.0811	*0.1510	0.1017
$\beta_{chicken}$	*-0.1220	0.0949	*0.1129	0.0994	-0.3736	0.1136
α	0.5466	0.0212	0.4747	0.0090	0.3989	0.0117
β'_{beef}	1.94E-05	7.59E-06	-1.53E-05	5.58E-06	*-3.73E-07	7.71E-06
β'_{pork}	*-7.65E-06	9.09E-06	4.30E-05	1.02E-05	*-6.64E-06	1.07E-05
$\beta'_{chicken}$	*1.42E-05	9.80E-06	*4.70E-06	1.05E-05	*1.19E-05	1.15E-05
α'	-4.35E-06	1.28E-06	-3.71E-06	7.87E-07	*1.16E-06	1.05E-06
R-squared	0.961		0.879		0.996	
D.W. without AR	1.06		1.60		1.08	

Note 1: * is not significant at the 10% significant level.

Note 2: ** AR (1) procedure is employed.

The lower bound of D-W test statistics at a 5% significant level are 1.01 for 34 observations and 8 explanatory variables (Korea) and 1.21 for 47 observations and 8 explanatory variables (the U.S.). Therefore, only American pork is found not to have autocorrelation. Five meat products are re-estimated with AR(1) process.

All initial own-price and income elasticities are statistically significant and compatible to the theory in both Korea and the U.S. whereas most initial cross-price

elasticities are either not significant or not compatible with theory.⁴⁷ In case of the variations of the cross-price elasticities, most of them are also not significant so it fails to find the income effects in the cross-price elasticities.

For the directions of consumer behavior changes, if consumer behavior becomes less sensitive to price and income changes as income rises, then the absolute value of elasticities would become smaller. In other words, an increase in own-price elasticities and a decrease in income elasticities would make consumer behavior be less sensitive to price and income changes. Therefore the derivatives of the own-price elasticity are expected to be positive while those of the income elasticity are expected to be negative if consumer behavior becomes less responsive to price and income changes.

Income growth tends to make a ratio of price to income and an expenditure share become smaller in not only food but also general commodities. This is likely to make consumer behavior less sensitive to price and income changes. Since both Korea and the U.S. have experienced economic growth for a long time, consumers in the two countries are expected to have less sensitive consumption patterns than before. Therefore, the expected signs for the derivatives of own-price elasticities are positive and those of income elasticities are negative. The results of the estimation indicate that the estimated signs in all meat models of the both countries are compatible with the expectation, with the exception of the chicken model of the U.S. The income elasticity of American chicken is estimated to increase as income rises. It appears to reflect that white meat preference has grown in the U.S. Besides this exception, there are some insignificant

⁴⁷ I expected for the meat products to be the substitutes to each other and the sign of cross-price elasticities to be positive. However, most initial cross-price elasticities are not either significant statistically or compatible with my expectation.

estimates. The derivatives of own-price and income elasticities in the pork and the chicken models of Korea and the chicken model in the US. are not significant statistically.

Summing up the estimation results, consumer behavior changes are found in some meat equations of both countries: the beef equation of Korea and the beef and the pork equation of the U.S. The direction of the changes is positive for the own-price elasticities and negative for the income price elasticities. These directions indicate that consumer behavior becomes less sensitive to price and income changes as income rises. In other equations, the estimates are found not to be significant statistically even though they have the right sign: the pork and the chicken model of Korea and the chicken model of the U.S. These insignificant coefficients have something in common. The quantities demanded in these equations have increased during the period of the analysis. The connection between the insignificant estimates and the increasing quantities demanded will be examined more in the following section.

4.2.4. Combining the results of both the double log and LES with income effects

Combining the estimation outputs of the two models reveals interesting results. This study finds in the double log model with income effects that even though some results are not significant statistically, the income and the own-price elasticities become smaller in absolute value as income rises. The insignificant estimates are found in the pork and the chicken equations of Korea and the chicken equation of the U.S. These models have increasing quantities demanded through time in common. The findings in the LES with income effects are increments in the minimum consumption in the pork and

the chicken equations of Korea and the chicken equation of the U.S. These results of two models closely overlap each other. These results are summarized in the table below.

Table 6: combining results

		Korea			the US			
		beef	pork	chicken	beef	pork	chicken	
elasticities	beef	sign	+	-	-	+	-	-
		significance	yes	no	no	yes	yes	no
	pork	sign	+	+	-	-	+	-
		significance	no	no	no	no	yes	no
	chicken	sign	-	+	+	+	+	+
		significance	no	no	no	no	no	no
	income	sign	-	-	-	-	-	+
		significance	yes	no	no	yes	yes	no
	Minimum consumption	sign	-	+	+	-	-	+
		significance	no	yes	yes	no	yes	yes

Note 1: The 'sign' means the sign of the derivative of price and income elasticity and minimum consumption with respect to income.

1. The three double log equations of beef of Korea and beef and pork of the U.S. show a decrease in the own-price and the income elasticities in absolute value; the counterparts of the LES show no increments in the minimum consumption.
2. The three double log equations of pork and chicken of Korea and chicken of the U.S. show no significant decrease in the own-price and the income elasticities in absolute value; the counterparts of the LES show increments in the minimum consumption.

As explained in chapter 3, an increase in the demand and in the minimum consumption is likely to indicate an expansion in needs; a commodity demanded in the frontier of needs is likely to face severe competition with commodities also in the same level of needs in terms of the marginal utility. Since consumer behavior is defined as the marginal sensitivity, the marginal sensitivity on the frontier represents consumer behavior for the commodity in question. In this case, it is hard to apply a general rule to the consumer behavior changes. On the other hand, if the demand for a commodity is stagnant, the decreasing sensitivity to price and income changes is applicable. The results of 2 above are the case of the increasing minimum consumption. In case of 2, consumer behavior does not show a significant decrease in sensitivity. The results of 1 are the case of the stagnant demand. In case of 1, consumer behavior shows decreasing sensitivity.

Korean beef is an exception. The demand for beef increases while the minimum consumption of beef decreases. This seems to reflect a unique situation of the beef market in Korea. Imported beef is a close substitute for domestic beef and the imported beef is much cheaper than the domestic. The result implies that the Korean consumers include the imported beef in the basic consumption instead of the domestic beef. The decrease in the minimum consumption of the beef might be explained with this substitution effect.

4.2.5. Another approach

As mentioned in the data section, Korean data do not include the imported meat. The main reason of the exclusion is there are no imported meat price data. Therefore, it is impossible to consider imported meat as a variable independently. However, it is possible

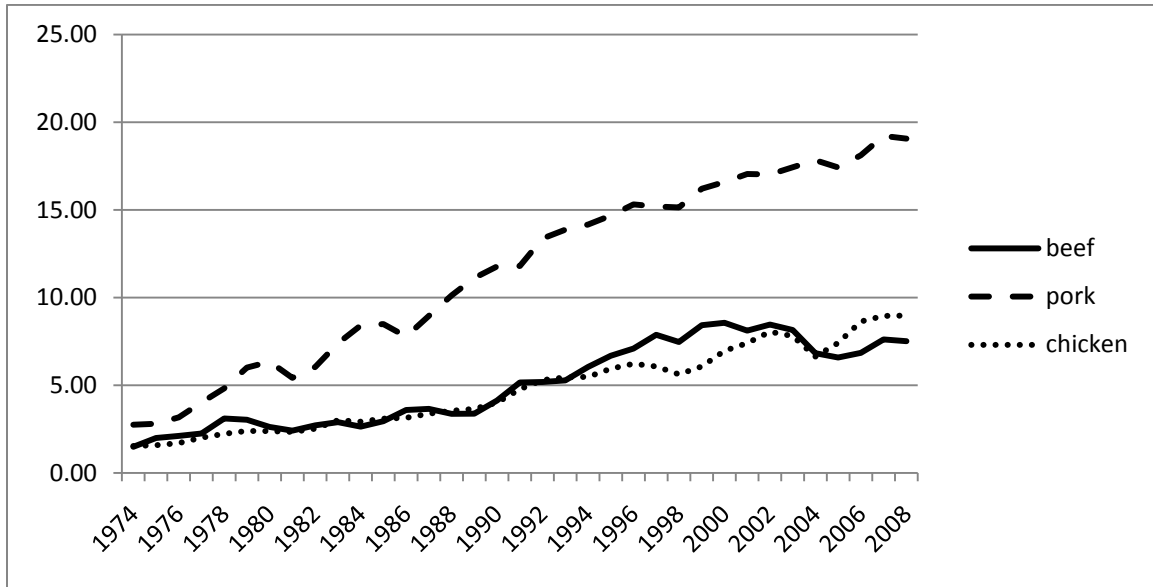
to combine quantity of both domestic and imported meat together. This aggregate can be permitted if the imported meat price is closely correlated with the domestic meat price.

The underlying assumption for the exclusion is a perfect independence between imported and domestic meat. Under this assumption, imported meat does not have any effects on domestic meat so the exclusion from the demand system can be justified. On the other hand, the quantity aggregation assumes that two goods are perfect substitutes for each other. A perfect substitute means two goods are treated as an identical good so there is no need to use both prices. Of course, the relation between domestic and imported meat would lie somewhere between the extreme ends. But the lack of imported meat price data forces us into employing the extreme assumptions.

The predicted difficulty of the quantity aggregation is price differences between goods. In case of beef, the price differences are quite large. Moreover, imported beef has accounted for more than half of consumption since 2001. This is expected to make the problem worse. However, there might be a possibility of improving the analysis. In previous analyses, there was an unexpected result: even though beef consumption has increased, the own-price and income elasticities have declined. This result might be caused by the fact that imported beef is a close substitute for domestic beef. Since the quantity aggregation assumes perfect substitution, this unexpected result might be solved by the aggregation.

Figure 11 depicts the aggregate meat consumption. Compared to figure 6, these data have less fluctuations and steeper slopes.

Figure 11: meat consumption per capita (kg), Korea



The aggregated data are applied to the LES with income effects and the double log equations with income effects. The aggregated data are composed of combined quantities of domestic and imported meat and price of domestic meat. The results are shown in table (7) and (8).

Table 7: LES with income effects, aggregated quantities, Korea.

	beef		pork		Chicken	
	coeff.	std. error	coeff.	std. error	coeff.	std. error
a	0.0083	0.0026	0.0040	0.0026	*3.78E-13	0.0004
b	*0.7391	1.1183	3.2587	1.3008	1.6599	0.6762
β	2.16E-07	1.25E-07	7.23E-07	2.77E-07	4.70E-07	1.08E-07
R-squared	0.921		0.966		0.974	

Note 1: * is not significant at the 10% significant level.

These results are similar to table 3. Only one changed much is β , the derivative of the minimum consumption, of the beef equation. It turns to be positive and statistically significant. It is negative and insignificant in table 3. In all three meat products, the minimum consumptions increase and this result is compatible with increasing meat consumption in Korea.

Table 8: the double log model with income effects, aggregated quantities, Korea

Korea	beef		**pork		**chicken	
	coeff.	std. error	coeff.	std. error	coeff.	std. error
β_{beef}	*0.2773	0.1842	*0.1155	0.1515	*0.1482	0.1647
β_{pork}	0.7947	0.2450	-0.4144	0.0895	*-0.0051	0.1137
$\beta_{chicken}$	-1.1560	0.3519	*-0.1238	0.1452	-0.4271	0.1801
α	*0.0410	0.1192	0.3795	0.0902	0.2136	0.1107
β'_{beef}	*-3.51E-08	2.61E-08	*-1.37E-08	1.55E-08	*-5.85E-10	1.76E-08
β'_{pork}	-1.34E-07	2.50E-08	*2.65E-08	1.56E-08	*-2.55E-09	2.16E-08
$\beta'_{chicken}$	1.18E-07	4.08E-08	*1.73E-09	1.87E-08	*2.25E-08	2.40E-08
α'	4.21E-08	2.21E-08	*-6.21E-09	1.06E-08	*-7.02E-09	1.31E-08
R-squared	0.960		0.993		0.989	
D.W. without AR	1.22		0.57		0.93	

Note 1: * is not significant at the 10% significant level.

Note 2: ** AR (1) procedure is employed.

Turning to the estimates from the double log model with income effects, and with aggregated quantity data in table 8. A quite confusing result comes out in the beef equation. The cross-price effects turn to be significant statistically whereas own-price and income elasticities become insignificant. Moreover, the own-price elasticity is positive. It does not look like the domestic beef price properly represents the aggregated beef price.

This is likely to come from the facts that there is a large price gap between domestic and imported beef and imported beef occupies a large part of beef consumption. For pork and chicken equations, it appears the domestic prices represent the aggregated prices reasonably well.

For the derivatives of elasticities, there is no evidence that the beef own-price and income elasticities decrease in absolute value as income rises. This result is opposite of the previous analysis in table 5. It might be interpreted as beef consumption continuously faces severe competition and maintains its price and income sensitivity. Since this aggregated quantity analysis employs the substitution effects in the system, the previous presumption on domestic beef consumption might be justified. In previous analysis, the sensitivity of domestic beef consumption decreases even though the domestic beef quantity demanded increases. The reason might be the lack of a substitution effect. However, the representation of the domestic price for aggregated quantity is in question. For the pork and the chicken equations, the results are similar to previous analysis.

4.2.6. Kalman Filter

This study examined consumer behavior which varies over income levels. It utilized three functional forms: QUAIDS, the double log with income effects, and LES with income effects. Among the functional forms the double log and LES with income effects were developed to the state space form which can accommodate varying parameters over time. Solutions for the state space form may be various. However, the method employed in this study measures the average income effects. This method is convenient when we are interested in the average of the effects. Moreover, it is relatively

easy to handle, interpret, and draw inferences. However, when we are interested in how parameters have changed through time, the method does not offer enough information. This method identifies the initial elasticities and their first derivatives. So the relationship between the elasticity and income is represented by a linear line. This part of the study will be devoted to finding how the consumer behavior has changed through time rather than the average direction of the change, by employing Kalman filter.

Kalman filter is one of the possible solutions for the state space model. Since it identifies varying parameters for each time, it offers more convenient results to depict the variation of parameters than fixed parameter model. I want to revisit the state space model which is shown in equation (71). For convenience, let the model be the below

$$y_t = x_t \beta_t + e_t \quad 91$$

$$\beta_t = \beta_{t-1} + \Delta m_t \beta' + c_t$$

where y_t is a log of a quantity demanded, x_t is a row vector of log of prices and income, β_t and β'_t are a column vector of parameters and Δm_t is income differentiated. The disturbance terms, e_t and c_t , are assumed to follow normal distributions of mean zero and variance R and Q,⁴⁸ respectively. The solution for the model is composed of two steps. Following the procedure shown in equation (59) and (60), we have

⁴⁸ c_t is a vector of errors and so Q is a vector of variances.

$$\text{prediction: } \beta_t^- = \beta_{t-1} + \Delta m_t \beta' + c_t$$

$$P_t^- = P_{t-1} + Q$$

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$$\text{updating: } \beta_t = \beta_t^- + P_t^- x_t^T (x_t P_t^- x_t^T + R)^{-1} (y_t - x_t \beta_t^-)$$

$$P_t = (I - P_t^- x_t^T (x_t P_t^- x_t^T + R)^{-1} x_t) P_t^-$$

Information required for the model to work relates to variances of disturbance terms, R and Q , and initial values, P_0 and β_0 , and β' . This study already estimated the state space models in the context of the time-series. The two estimations of the time-series and Kalman filter share an exactly identical to the state space model. Therefore, it is possible to obtain information about the initial values for the Kalman filter from the existing results. Even though the results of the time-series estimation might not be exact estimators for the unknowns, they can be reasonable estimators for them.

For the variances and initial values, the estimation results of equation (74) are utilized for the unknowns. For R , the equation variance are used. For β_0 and P_0 , the estimates of β , α and their covariance matrix are used. For β' , the estimates of β' and α' are used. For Q , the variances of β' and α' are used.

The LES with income effects can be solved in exactly the same way. Even though the functional form looks complicated and non-linear, the model is linear under a given β .

Rewriting equation (83):

$$x_i(p_t, m_t) = \frac{b_i(m_t)}{1 - \sum \beta_k p_{k,t}} + \frac{a_i m_t}{p_{i,t} (1 - \sum \beta_k p_{k,t})} - \frac{a_i \sum b_k(m_t) p_{k,t}}{p_{i,t} (1 - \sum \beta_k p_{k,t})}$$

93

$$b_i(m_t) = b_i(m_{t-1}) + \beta_i(m_t - m_{t-1}) + e_t$$

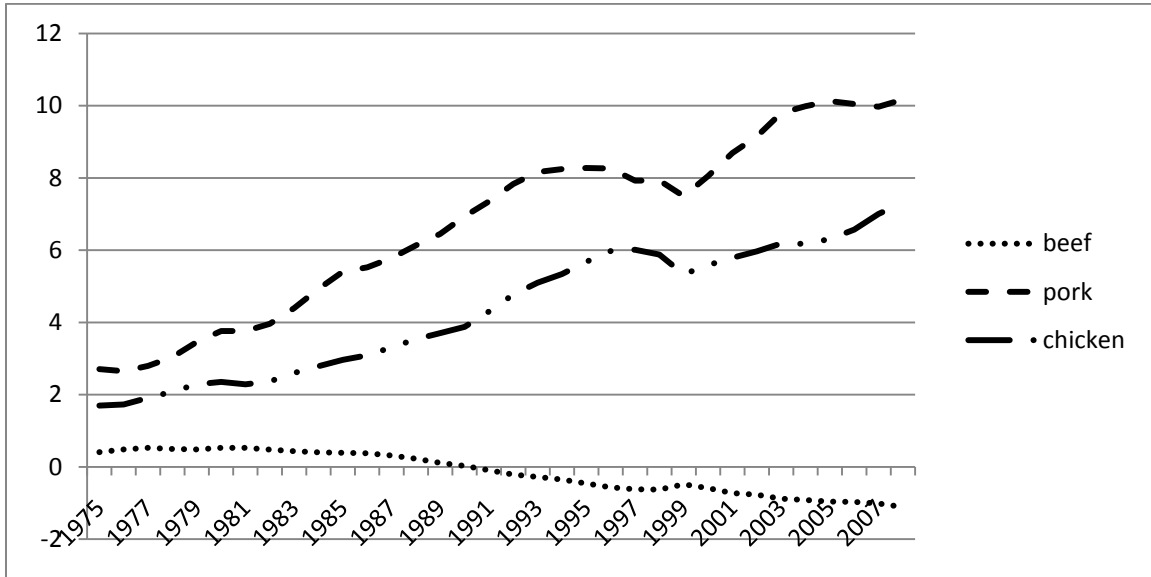
Since a_i and β_i are estimated by the time-series, the model is linear in $b_i(m_t)$. The procedure in equation (92) can be employed without alteration. The method to gather information from the time-series estimation is the same with the method used for the double log with income effects. The following figures, Figure 12 to Figure 19, are the results of Kalman filter estimation.

- Changes in minimum consumption, Figure 12 and
- Figure **13**

The variations of the minimum consumption are compatible with the variations of the quantities demanded except for beef in Korea. The demand for beef increases while the minimum consumption decreases. It appears to reflect the existence of a close substitute with a much cheaper price. The minimum consumption of pork and chicken in Korea reflects the increase in their demand. The fluctuation around year 1997~1999 looks to have occurred due to the exchange crisis in Korea in 1997. The sharp increase in the exchange rate made the feed price rise and the Hanwoo herd was reduced by 29% during the period.⁴⁹ The minimum consumption in the U.S. reflects the demand. The demands for beef and pork decrease while the demand for chicken increases. The minimum consumption is compatible with them.

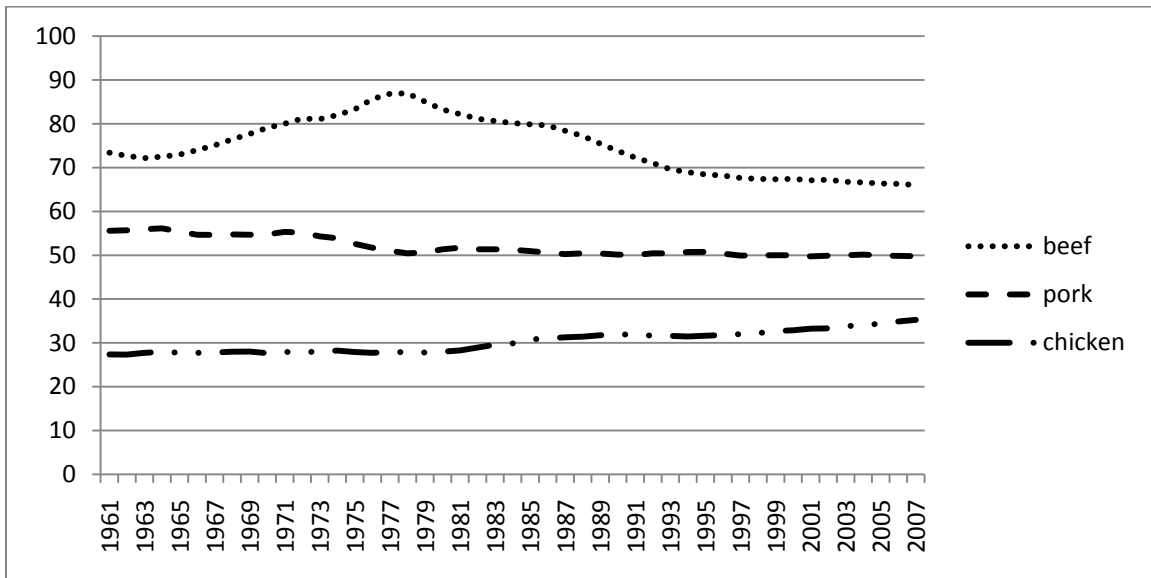
⁴⁹ Hanwoo is a name of the Korean native cattle. The number of cattle was 2,383,133 in 1997 and 1,951,989 in 1999. That period of Asian exchange crisis, some Asian countries including Korea had experienced severe drops in income and consumption.

Figure 12: the variation of the minimum consumption in the LES with income effects model, Korea



Note: The vertical axis is the minimum consumption (kg)

Figure 13: the variation of the minimum consumption in the LES with income effects model, the US.

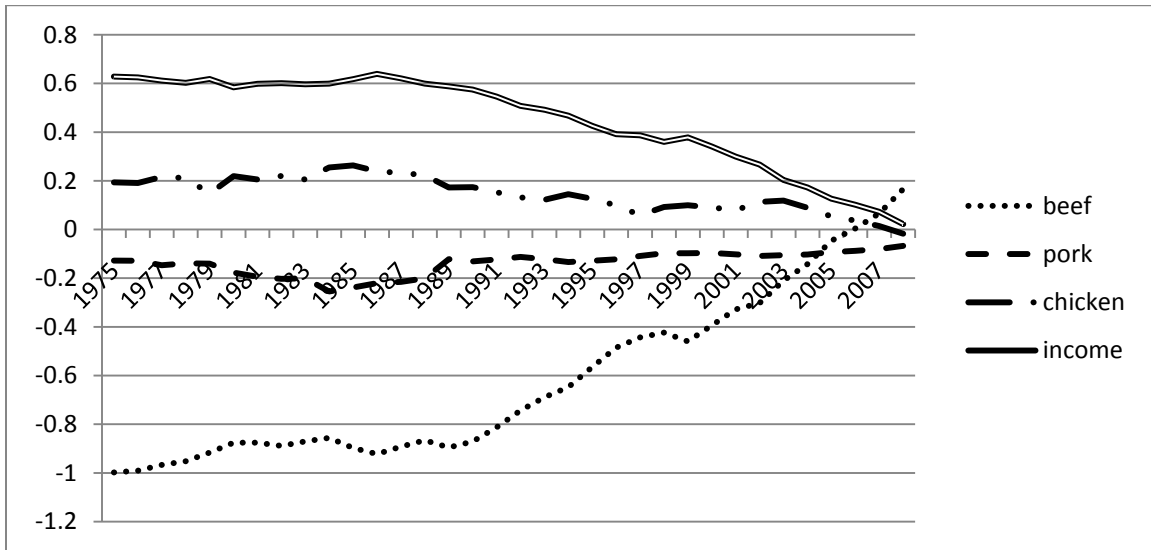


Note: The vertical axis is the minimum consumption (lbs.)

- Changes in elasticities, in case of Korea, Figure 14 to Figure 16:

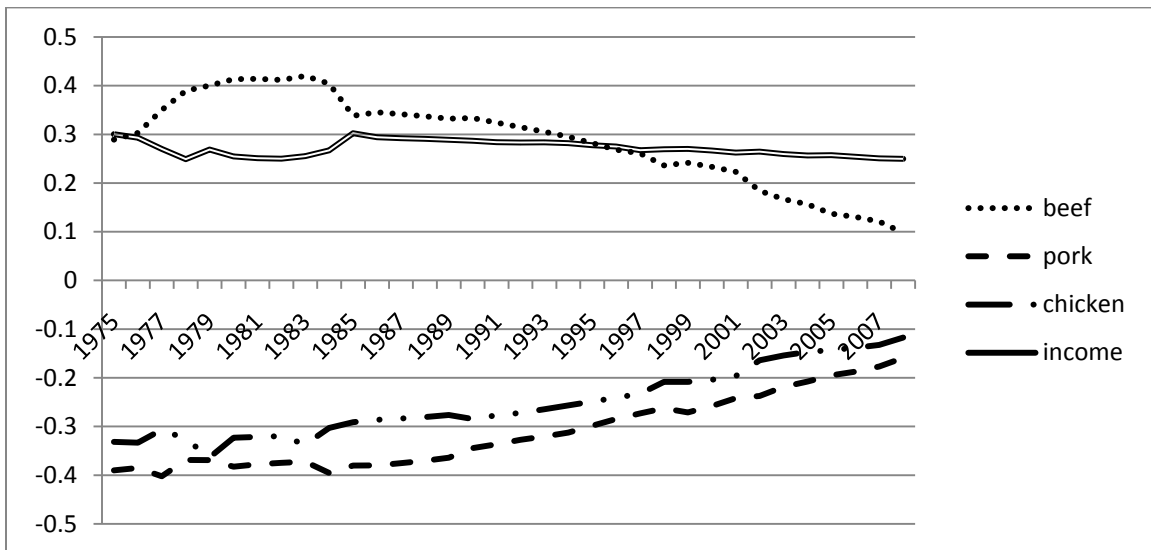
The own-price elasticities show most significant variation among other elasticities. The income elasticity declines quite fast in the beef model but the other income elasticities are stable through time.

Figure 14: the variation of elasticities in the double-log with income effects, beef equation, Korea



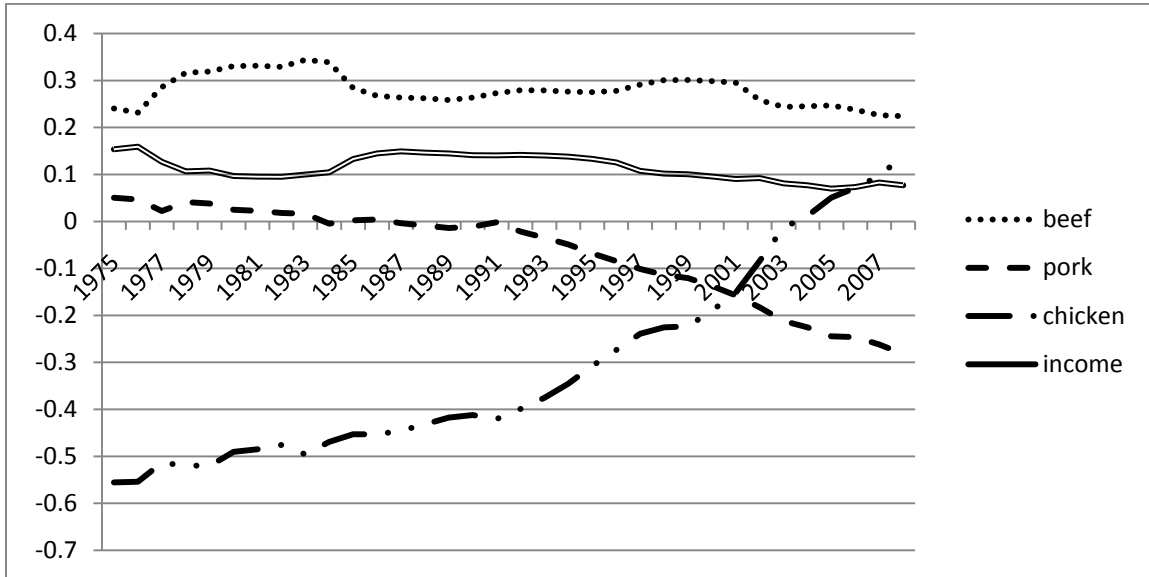
Note: The vertical axis is the elasticity.

Figure 15: the variation of elasticities in the double-log with income effects, pork equation, Korea



Note: The vertical axis is the elasticity.

Figure 16: the variation of elasticities in the double-log with income effects, chicken equation, Korea

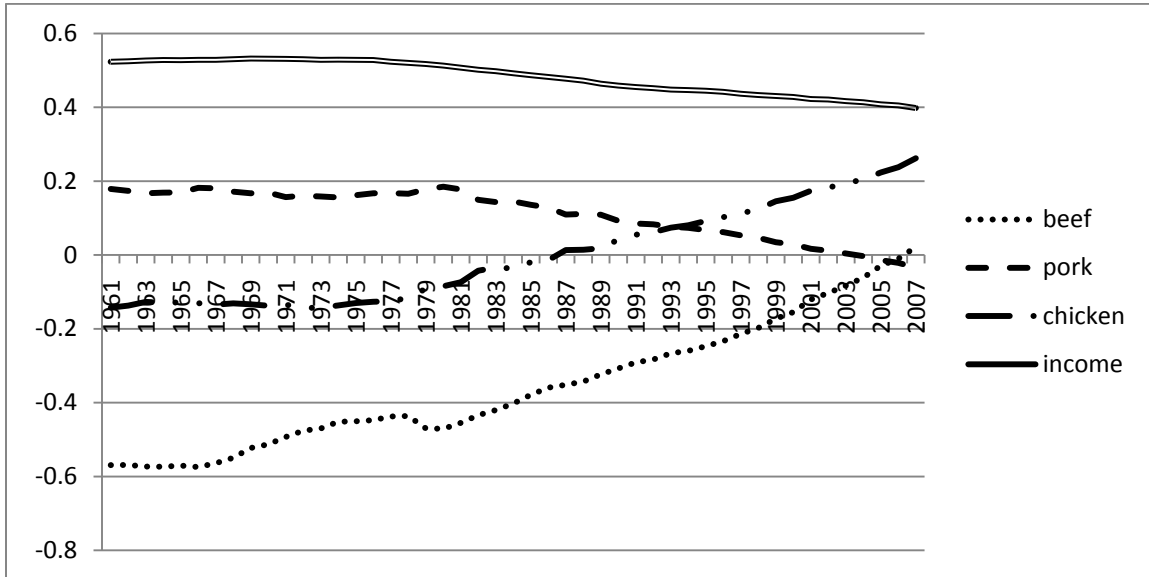


Note: The vertical axis is the elasticity.

- Changes in elasticities, in case of the U.S., Figure 17 to Figure 19.

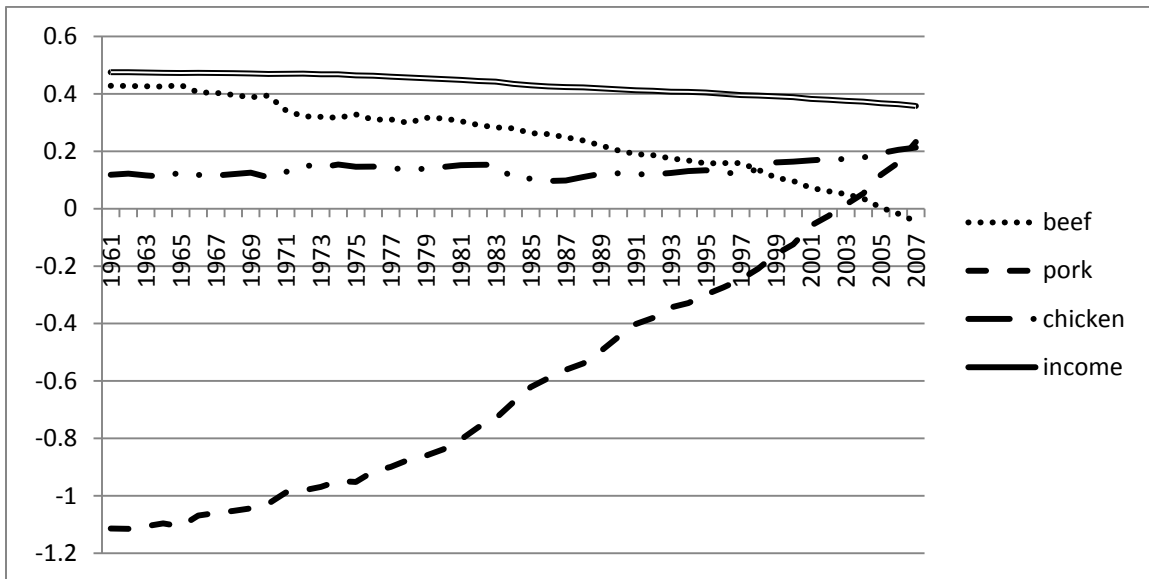
The own-price elasticities in the US decline in absolute value at the fastest rate among other elasticities. The income elasticity declines in the beef and pork models but it slightly increases in the chicken model.

Figure 17: the variation of elasticities in the double-log with income effects, beef equation, the US.



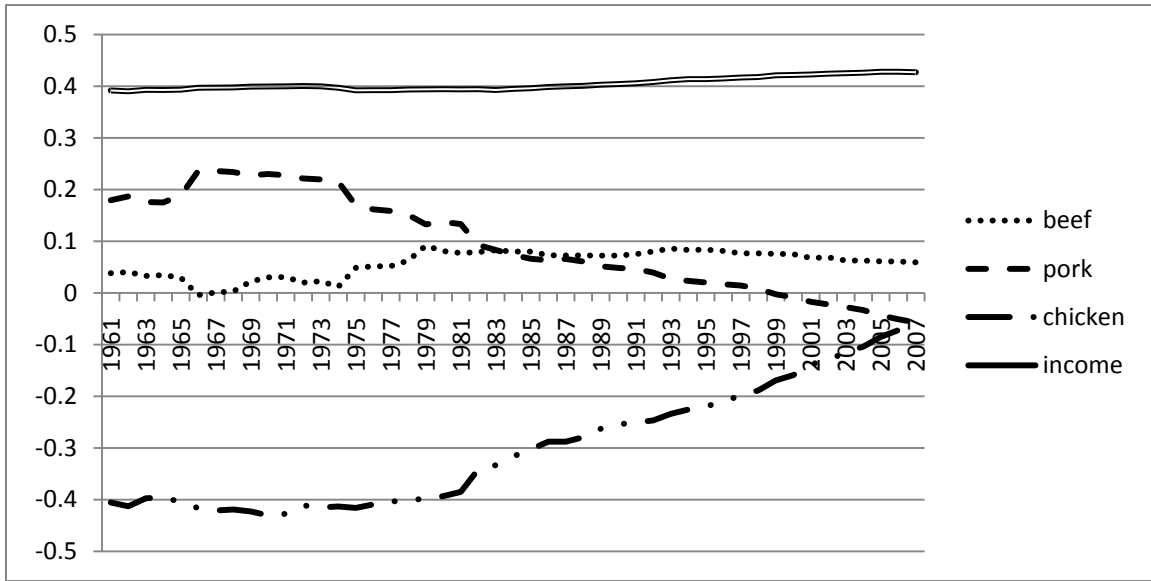
Note: The vertical axis is the elasticity.

Figure 18: the variation of elasticities in the double-log with income effects, pork equation, the US.



Note: The vertical axis is the elasticity.

Figure 19: the variation of elasticities in the double-log with income effects, chicken equation, the US.



Note: The vertical axis is the elasticity.

CHAPTER 5

CONCLUSION

This study examined how consumer behavior varies over income levels using meat market data in both Korea and the US. It examined this question in three perspectives: (1) changes in the expenditure share, (2) changes in price and income elasticities and (3) the expansion of the consumption. Lastly, the traces of consumer behavior changes are examined by the Kalman filter technique.

The first perspective is dealt by QUAIDS which is designed to investigate the quadratic Engel curve. This quadratic relationship is found in the Korean model but not in the US model. The negative sign of the quadratic terms indicate that Engel curve has a concave shape and the goods in question were a luxury at the low level of income. Therefore, beef and pork in Korea are identified to have been a luxury when Korea was poor. Because meat is more nutritious, more expensive and is considered, in general, tastier than grain products, a consumer is very likely to expand the meat consumption when his income rises. In the U.S. cases, the sign of the parameters are positive. The positive Engel curve implies that beyond some level of income, the expenditure share would increase instead of decline. Because these cases of the increasing expenditure share, the gain from the quadratic term in the U.S. is limited. Therefore, it looks better to omit the quadratic term in the American model.

The second perspective is examined using the double-log demand with income effects. All the own-price and the income elasticities in both countries are found to decline in absolute value across income levels even though some of them are not

significant statistically. However, one exception is found in the income elasticity of chicken of the U.S. It actually increases slightly as income rises. Insignificant elasticities are found in the pork and the chicken model of Korea and the chicken model of the U.S. What they have in common is the demands for them have increased continuously.

The last perspective is examined using the LES with income effects which employs the concept of the minimum consumption. The minimum consumption of pork and chicken in Korea and chicken in the U.S. are found to increase with income. On the other hand, that of beef in Korea and beef and pork in the U.S. does not increase. These results overlap with the results of the double log demand with income effects exactly. The commodities whose elasticities show significant decrease in absolute value have non-increasing minimum consumption. On the other hand, those whose elasticities do not show significant decline have the increasing minimum consumption.

The second and the third perspectives are re-examined by aggregating the quantity demanded in Korea. It is assumed that a perfect substitute relation between domestic and imported meat exists. It is useful because strong substitution effect is detected in the domestic data analysis. As expected, domestic beef and imported beef shows a relation of substitution in Korea. However, the large price difference and large portion of imported meat possibly prevent the domestic price in Korea from representing the aggregated beef price properly.

The increase in minimum consumption implies that the demand for a commodity increases with income growth. It also implies that some part of demand for the commodity occurs on the frontier of growing needs. The demand on the frontier of growing needs is expected to face severe competition with other commodities in terms of

the marginal utility. So the commodity is expected to stay sensitive to price changes. That can be a reason why the increase in the minimum consumption makes the demand responsiveness stay stable.

In contrast, the commodity of which minimum consumption does not increase is likely to be affected by two things. Its relative price declines with a consumer's income growth. This would make a consumer feel less serious about changes in an economic environment. Therefore, the demand for the commodity becomes less elastic. Another factor is a consumer's consumption priority. The commodity is included in the consumption bundle because a consumer feels an urgent need in consuming the commodity. More urgent need should be satisfied even if doing so requires the sacrifice of less urgent needs. This can explain why the demand becomes inelastic with an income growth.

In table 9, the results of this study are summarized again. (1) Goods can change their nature from a luxury to a necessity. The evidence found beef and pork in Korea did change. (2) Commodities for which consumers' sensitivity declines do not show an expansion of consumption. This research finds this case for beef and pork in the U.S. (3) Commodities for which consumer's sensitivity does not decline shows an expansion of consumption. The research shows this outcome for pork and chicken in Korea and chicken in the U.S. (4) Beef in Korea shows declining consumer's sensitivity while an expansion of consumption does not occur. This exception is found because there is a strong substitution effect between domestic and imported beef in Korea. (5) An assumption of perfect substitution solved this problem.

Table 9: The summary of the results

			korea			the U.S.		
			beef	pork	chicken	beef	pork	chicken
	quadratic Engel curve		yes	yes	no	no	no	no
		significance	no	yes	no	no	yes	no
perfect	decreasing	own-price	yes	yes	yes	yes	yes	yes
independence	elasticity	significance	yes	no	no	yes	yes	no
		income	yes	yes	yes	yes	yes	no
		significance	yes	no	no	yes	yes	no
		increasing min. con.	no	yes	yes	no	no	yes
		significance	no	yes	yes	no	yes	yes
perfect	decreasing	own-price	no	yes	yes	-	-	-
substitute	elasticity	significance	no	no	no	-	-	-
		income	no	yes	yes	-	-	-
		significance	yes	no	no	-	-	-
		increasing min. con.	yes	yes	yes	-	-	-
		significance	yes	yes	yes	-	-	-

Note1 : Decreasing elasticities are expressed in absolute value.

Note2: Perfect independence means data contains domestic production only; perfect substitution means aggregated quantity data in Korea.

An implication may be drawn from the results of this study. Utilizing long series of data in the analysis might be dangerous unless the possibility of consumer behavior changes is adequately considered. Researchers can get a benefit of high degrees of freedom by increasing the number of observations. Large number of observations means in the time series data large differences in income. If there are changes in consumer behavior during the period, the analysis can generate an unexpected bias. Therefore, when long series of data are used in the demand analysis, it is important to test if there are changes in consumer behavior first. Especially, when the purpose of the analysis is

forecasting the future, researchers might get results that are biased with the bias likely proportional to the length of data and the forecasting period.

Appendix A: the marginal demand of equation (82)

$$\text{Equation (82): } x_i(p_t, m_t) = \frac{b_i(m_t) + \frac{a_i}{p_{it}}(m_t - \sum (b_k(m_t)p_{kt}))}{1 - \sum (\beta_{kt}p_{kt})}$$

1. The marginal demand with respect to income:

$$\begin{aligned} \frac{\partial x_{it}}{\partial m_t} &= \frac{\frac{\partial b_i(m_t)}{\partial m_t} + \frac{a_i}{p_{it}} \left(\frac{\partial m_t}{\partial m_t} - \sum \frac{\partial b_k(m_t)}{\partial m_t} p_{kt} \right)}{1 - \sum (\beta_{kt}p_{kt})} \\ &= \frac{\beta_{it} + \frac{a_i}{p_{it}}(1 - \sum \beta_{kt}p_{kt})}{1 - \sum (\beta_{kt}p_{kt})} \\ &= \frac{\beta_{it}}{1 - \sum (\beta_{kt}p_{kt})} + \frac{a_i}{p_{it}} \end{aligned}$$

2. The marginal demand with respect to own-price:

$$\begin{aligned} \frac{\partial x_{it}}{\partial p_{it}} &= \frac{b_i(m_t) + \frac{a_i}{p_{it}}(m_t - \sum (b_k(m_t)p_{kt}))}{(1 - \sum (\beta_{kt}p_{kt}))^2} \beta_{it} + \frac{-\frac{a_i}{(p_{it})^2}(m_t - \sum b_i(m_t)p_{kt}) - \frac{a_i}{p_{it}}b_i(m_t)}{1 - \sum (\beta_{kt}p_{kt})} \\ &= \frac{x_{it}\beta_{it}p_{it}}{(1 - \sum (\beta_{kt}p_{kt}))p_{it}} + \frac{-\frac{a_i}{p_{it}}(m_t - \sum b_i(m_t)p_{kt}) - a_i b_i(m_t) - b_i(m_t) + b_i(m_t)}{(1 - \sum (\beta_{kt}p_{kt}))p_{it}} \\ &= \frac{x_{it}\beta_{it}p_{it} - a_i b_i(m_t) + b_i(m_t)}{(1 - \sum (\beta_{kt}p_{kt}))p_{it}} - \frac{x_{it}}{p_{it}} \end{aligned}$$

3. The marginal demand with respect to cross-price:

$$\frac{\partial x_{it}}{\partial p_{jt}} = \frac{b_i(m_t) + \frac{a_i}{p_{it}}(m_t - \sum (b_k(m_t)p_{kt}))}{(1 - \sum (\beta_{kt}p_{kt}))^2} \beta_{jt} + \frac{-\frac{a_i}{p_{it}}b_j(m_t)}{1 - \sum (\beta_{kt}p_{kt})}$$

$$\begin{aligned}
&= \frac{x_{it}\beta_{jt}p_{it}}{(1-\sum(\beta_{kt}p_{kt}))p_{it}} + \frac{-a_j b_j(m_t)}{(1-\sum(\beta_{kt}p_{kt}))p_{it}} \\
&= \frac{x_{it}\beta_{jt}p_{it}-a_j b_j(m_t)}{(1-\sum(\beta_{kt}p_{kt}))p_{it}}
\end{aligned}$$

Appendix B: data

1. Meat market data, Korea

year	Consumption			Consumption		
	(domestic, Kg, per person, per year)			(domestic+imported, Kg, per person, per year)		
	beef	pork	chicken	beef	pork	chicken
1974	1.5	2.7	1.5	1.5	2.7	1.5
1975	2.0	2.8	1.6	2.0	2.8	1.6
1976	2.1	3.2	1.7	2.1	3.2	1.7
1977	2.1	4.0	2.0	2.2	4.0	2.0
1978	2.0	4.6	2.2	3.1	4.8	2.2
1979	2.3	5.8	2.4	3.0	6.0	2.4
1980	2.4	6.3	2.4	2.6	6.3	2.4
1981	1.8	5.4	2.3	2.4	5.4	2.3
1982	1.6	6.0	2.5	2.7	6.0	2.5
1983	1.7	7.4	3.0	2.9	7.4	3.0
1984	2.2	8.4	2.9	2.6	8.4	2.9
1985	2.8	8.5	3.1	2.9	8.5	3.1
1986	3.5	7.8	3.1	3.6	7.8	3.1
1987	3.7	9.0	3.4	3.7	9.0	3.4
1988	3.1	10.1	3.5	3.4	10.1	3.5
1989	2.1	11.1	3.6	3.4	11.1	3.6
1990	2.2	11.7	4.0	4.1	11.8	4.0
1991	2.3	11.4	4.8	5.2	11.8	4.8
1992	2.3	13.3	5.3	5.2	13.4	5.3
1993	2.9	13.9	5.4	5.3	13.9	5.4
1994	3.3	13.8	5.5	6.0	14.2	5.5

1995	3.4	13.9	5.8	6.7	14.7	5.9
1996	3.8	14.4	6.0	7.1	15.3	6.2
1997	5.0	13.7	5.7	7.9	15.2	6.1
1998	5.6	14.1	5.3	7.5	15.1	5.6
1999	5.1	13.2	5.1	8.4	16.2	6.1
2000	4.5	14.3	5.5	8.6	16.6	7.0
2001	3.5	15.1	5.6	8.1	17.0	7.4
2002	3.1	15.5	6.1	8.5	17.0	8.0
2003	3.0	16.2	5.9	8.2	17.4	7.8
2004	3.0	15.5	6.0	6.8	17.8	6.6
2005	3.2	14.1	6.2	6.6	17.4	7.4
2006	3.3	13.9	7.1	6.8	18.1	8.6
2007	3.5	14.2	7.7	7.6	19.2	9.0
2008	3.6	14.4	7.5	7.5	19.1	9.0

1. Meat market data, Korea (continued)

year	Price(won/kg, nominal)			Income (won, per person)	Price index
	beef	pork	chicken		
1974	1,306	702	412	208,585	10.2
1975	1,488	992	556	272,098	12.7
1976	2,126	1,332	672	371,220	14.7
1977	2,760	1,370	815	469,106	16.2
1978	3,460	1,962	956	630,019	18.5
1979	3,858	1,810	880	786,271	21.9
1980	4,820	2,028	1,212	935,004	28.2
1981	6,464	3,526	1,583	1,150,108	34.2
1982	7,432	3,420	1,522	1,292,032	36.6
1983	8,236	3,208	1,363	1,496,823	37.9
1984	8,316	2,802	1,642	1,684,106	38.8
1985	7,054	3,522	1,711	1,857,109	39.7
1986	6,234	3,838	1,613	2,165,738	40.8
1987	6,396	3,232	1,532	2,541,406	42.1
1988	8,276	3,156	1,684	3,005,923	45.1
1989	10,426	3,028	1,894	3,354,135	47.6
1990	11,450	4,250	2,063	4,001,856	51.7
1991	12,884	5,242	2,073	4,802,682	56.5
1992	14,170	4,384	2,052	5,423,215	60.1
1993	14,790	4,538	2,244	6,053,955	62.9
1994	15,438	4,736	2,713	7,034,345	66.9
1995	16,186	4,908	2,934	7,994,473	69.9
1996	16,236	4,894	2,916	8,844,209	73.3
1997	15,074	5,108	2,851	9,536,798	76.6
1998	13,822	5,610	3,274	9,138,621	82.3

1999	14,470	7,446	2,963	9,976,818	83.0
2000	17,418	7,766	3,007	11,011,425	84.9
2001	19,234	8,448	3,227	11,850,322	88.3
2002	29,478	9,538	2,706	13,144,056	90.8
2003	31,300	9,698	2,490	13,886,474	93.9
2004	30,448	11,440	3,085	14,978,324	97.3
2005	37,274	14,888	3,765	15,539,482	100.0
2006	33,874	15,438	3,691	16,271,858	102.2
2007	31,176	14,256	3,621	17,430,446	104.8
2008	28,118	16,820	4,259	18,476,245	109.7

2. Meat market data, the U.S.

year	Consumption			Price			Income	Price index
	(pound, per person, per year)			(dollar/pound, nominal)			(dollar,	
	beef	pork	broiler	beef	pork	broiler	per person)	
1960	63.5	59.1	23.5	0.79	0.56	0.43	2021	21.0
1961	65.5	56.7	26.0	0.77	0.58	0.38	2078	21.3
1962	66.3	57.2	25.9	0.80	0.59	0.41	2171	21.6
1963	70.3	58.3	27.2	0.77	0.57	0.40	2246	21.8
1964	74.8	58.4	27.8	0.75	0.56	0.38	2410	22.1
1965	74.8	51.8	29.8	0.81	0.65	0.39	2563	22.5
1966	78.3	50.6	32.1	0.83	0.73	0.41	2734	23.2
1967	80.0	55.4	32.6	0.83	0.67	0.38	2895	23.9
1968	82.2	56.7	32.9	0.87	0.67	0.40	3113	24.9
1969	82.7	55.0	34.9	0.97	0.74	0.42	3325	26.2
1970	84.7	55.9	36.9	1.00	0.77	0.41	3587	27.5
1971	84.0	60.6	36.7	1.06	0.70	0.41	3861	28.9
1972	85.8	54.7	38.5	1.17	0.83	0.41	4140	30.2
1973	80.7	49.0	37.0	1.40	1.09	0.60	4616	31.9
1974	85.7	52.8	36.9	1.44	1.08	0.56	5010	34.7
1975	88.2	43.0	36.7	1.52	1.35	0.63	5498	38.0
1976	94.5	45.5	39.8	1.46	1.34	0.60	5972	40.2
1977	91.7	47.0	40.7	1.46	1.25	0.60	6517	42.8
1978	87.5	47.0	43.1	1.79	1.44	0.66	7224	45.8
1979	78.2	53.7	46.0	2.22	1.44	0.68	7967	49.6
1980	76.6	57.3	45.8	2.34	1.40	0.71	8822	54.1
1981	78.3	54.7	46.8	2.35	1.52	0.73	9765	59.1
1982	77.1	49.1	47.0	2.38	1.75	0.71	10426	62.7

1983	78.6	51.7	47.4	2.34	1.70	0.72	11131	65.2
1984	78.5	51.5	49.2	2.35	1.62	0.81	12318	67.7
1985	79.2	51.9	51.0	2.29	1.62	0.76	13037	69.7
1986	78.9	49.0	52.0	2.27	1.78	0.84	13649	71.3
1987	73.9	49.2	55.1	2.38	1.88	0.78	14241	73.2
1988	72.7	52.5	55.3	2.50	1.83	0.85	15297	75.7
1989	69.1	52.0	56.7	2.66	1.93	0.93	16257	78.6
1990	67.8	49.7	59.5	2.81	2.25	0.90	17131	81.6
1991	66.7	50.2	61.9	2.88	2.24	0.88	17609	84.5
1992	66.2	52.8	65.5	2.85	2.09	0.87	18494	86.4
1993	64.7	52.0	67.9	2.93	2.09	0.89	18871	88.4
1994	66.4	52.5	68.7	2.83	2.10	0.90	19555	90.3
1995	66.7	51.8	67.9	2.84	2.06	0.92	20287	92.1
1996	67.3	48.5	69.4	2.80	2.34	0.97	21091	93.9
1997	65.9	48.0	71.4	2.80	2.45	1.00	21940	95.4
1998	66.8	51.6	72.0	2.77	2.43	1.04	23161	96.5
1999	67.6	52.7	76.3	2.88	2.41	1.06	23968	97.9
2000	67.8	51.3	76.9	3.06	2.58	1.07	25473	100.0
2001	66.3	50.3	76.7	3.38	2.69	1.11	26242	102.4
2002	67.7	51.6	80.6	3.32	2.66	1.07	27183	104.2
2003	65.0	51.8	81.6	3.75	2.66	1.03	28076	106.4
2004	66.2	51.9	84.4	4.07	2.79	1.07	29592	109.5
2005	65.6	50.0	86.0	4.09	2.83	1.06	30611	113.0
2006	65.8	49.4	86.5	3.97	2.81	1.05	32263	116.7
2007	65.2	50.8	85.1	4.16	2.87	1.12	33707	119.8

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