ORGANIC PRODUCE DEMAND ESTIMATION UTILIZING RETAIL SCANNER DATA

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Applied Economics

MONTANA STATE UNIVERSITY-BOZEMAN
Bozeman, Montana

May, 1999

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ACKNOWLEDGMENTS

I would like to thank each of my graduate committee members: Dave Buschena, Gary Brester, and John Marsh. I learned more than I thought possible through the course of this research. For this I owe Dave Buschena for sharing his ideas, being patient and thorough, and always being available on a daily basis for questions. I thank Gary Brester for his exceptional writing (and editing) skills, his expertise in demand theory, and for helping me keep on track by simplifying and clarifying. And I thank John Marsh for taking the time to participate on my committee. I appreciate the time and effort each of you put forth.

The completion of this thesis depended heavily upon cooperation with the staff and members of the Bozeman Community Food Co-op. I would like to thank them for the use of their data, facilities, and time. I am especially grateful to the members who returned surveys, and Dana Huschle, without whose ideas and effort this research would not have been possible.

I would also like to thank Allison Banfield and Julie Hewitt for tremendous amounts of SAS related assistance, Nathan Ecret for helping me prepare the data, and Donna Kelly for helping me prepare this manuscript.

Finally, I would like to thank my parents, Joan and Del Trost for their much-needed emotional and financial support. A special thank you to Jodi Davis who always helped iron out the rough spots and gave me a life away from this thesis.

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ABSTRACT

Retail demand relationships for organic and non-organic bananas, garlic, onions, and potatoes are examined using scanner data from a retail co-operative food store located in Bozeman, Montana. A level version Rotterdam demand specification is used in a six-equation system to estimate Hicksian demand elasticities. The own-price elasticity for organic onions is negative and significant. All other own-price elasticities are not significantly different from zero. This indicates consumers may not be very price sensitive for the goods in question. With few exceptions, the cross-price elasticities which are significant are also positive. Income elasticities are mostly significant and positive. Elasticity measurement may be somewhat imprecise due to a lack of variability in prices and an ambiguous error structure. Key factors influencing the quantities of the produce items purchased include the number of children in a household, the average age of adults in a household, and employment status of the primary grocery shopper. Educational status did not have any significant impact on quantities purchased.

CHAPTER 1

INTRODUCTION

Problem Statement

Organic produce, defined as that grown without synthetic fertilizers or pesticides, is one of the fastest growing segments of agricultural production. In the United States, organic food sales have grown during the 1990's at an annual average rate of 24 percent (Thompson 1998). It is estimated that in 1996, the value of all organic products sold in the U.S. totaled $3.5 billion, up from just less than $2 billion in 1994 (Duram 1998; Park and Lohr 1996). Since the early 1990's all sectors of organic sales have increased, with stores dedicated to organic produce dominating sales (Duram 1998).

Most research indicates consumer preference for organic produce is linked to perceptions that such products are safer, fresher, more nutritious, and their production results in fewer detrimental environmental impacts (Jolly 1991; Huang 1996; Thompson and Kidwell 1998). Research also indicates that because of these attributes, many consumers are willing to pay relatively large price premiums for organic foods (Jolly 1991; Park and Lohr 1996). Most research has relied on self-reported purchase behavior, willingness-to-pay measures, and/or attitudes toward organic foods elicited from questionnaires or interviews (Thompson 1998).

While these studies have provided valuable information on attitudes and willingness-to-pay, notably absent are studies utilizing retail purchase data to estimate own and cross-price and income elasticities for organic and conventional produce. Given the large price premiums and the tempo at which this segment of the produce market is growing, "estimates of consumers' responsiveness to price changes are urgently needed," (Thompson 1998, 3) not only to better understand the future growth potential of organic produce, but also to aid in farmer, wholesaler, and retailer decision making.

This lack of demand elasticity estimation in previous research is presumably the result of an inability to obtain appropriate consumer-level price, quantity, and other data for organic produce. In fact, it is difficult to find any retail or wholesale price or quantity data for organics at a nationwide level. Organic produce is largely marketed from small speciality stores, food cooperatives, and farmers' markets which often do not use retail scanners and price lookup (PLU) codes. When available however, such scanner data offers considerable advantages to the oft drawn upon alternatives.

Scanner data have been used increasingly for demand analysis since the late 1980's. The attractiveness of scanner information stems from the availability of price, quantity, and consequently expenditure data for a myriad of products on a daily basis. Scanner data constitute a readily available current source of product-specific information (Capps 1989). However, such data bases often lack important socioeconomic data on individual consumers.

This thesis provides quantitative measures of own and cross-price and income elasticities for several organic and corresponding conventional produce items using shopper-specific, retail-level scanner data and shopper-specific socioeconomic data. This is possible because each point-of-sale (POS) transaction at a specific store is tracked via membership number specific to a unique household. The key hypotheses tested are that each (Hicksian) own-price elasticity is negative (as per economic theory). An added contribution of this study is that it constitutes a pilot for the use of scanner data coupled with socioeconomic data from membership, preferred customer, or debit card users on a larger scale.

Relationship to Previous Research

This study represents an improvement over previous approaches as it links scanner data to unique households from which additional socioeconomic information was obtained. The data are defined as longitudinal panel data, incorporating both time-series and cross-sectional components.[1] Traditional analysis of consumer demand generally has been based on aggregate annual, quarterly or monthly time-series data. These data are often too highly aggregated for analyses of product-specific decision making. Alternate methods of data collection (i.e., surveys and interviews) are expensive, often inaccurate (for quantity measurement), and frequently cannot produce price information (Capps 1989). In utilizing scanner data, utility maximizing consumer behavior is recorded, instead of inferred or solicited.

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[1]In a longitudinal panel, the sample subjects are measured repeatedly to yield a continuous flow of information for the same variables over a period of time. It provides information about changes in individual behavior that are most suitable for studying the dynamics of consumer behavior (Huang and Misra 1990).

Application of Research Results

Results of this study will be of particular interest to specialty store and other natural food retailers (and specifically, The Community Food Coop), organic produce wholesalers and growers, and economists. Others who might be interested in the methods employed in this study include those who manage "club membership" stores, retailers with "preferred customer" programs, and other marketing researchers with equivalent data available for modeling (from debit/credit card transactions etc.). The results of this study will not only aid food managers in pricing decisions, but also add to the entire industry's understanding of the demand for organic produce.

One limitation of this study is an inherent sample bias. The sample population is a subset of the general population in which consumers have self-selected themselves by shopping at a small natural foods store. However, the information provided by this study should be useful for extrapolation to similar populations and those with similar socioeconomic characteristics. Also, with the high rates of sales growth in organic food stores, this population appears an important subset for consideration by the food industry.

The thesis proceeds as follows. Chapter 2 reviews the existing body of literature relevant to this study. Research related to organic produce, and demand estimation using scanner data is considered. Chapter 3 discusses data development and presents descriptive statistics. Chapter 4 develops a theoretical framework for econometric analysis. Chapter 5 reports the empirical results of this analysis. Chapter 6 presents conclusions.

CHAPTER 2

LITERATURE REVIEW

Organic Produce

Although the organic produce market has grown considerably, few studies of this market have emerged. The available literature has most commonly focused on determining the characteristics inherent in consumers' choice of organic produce through discrete choice models and/or determining willingness-to-pay for organic produce (price premiums) as measured through hypothetical surveys.

Huang (1996) used data from a random mailing, stratified by income, of 580 households in Georgia. The participants constituted the Georgia Consumer Panel, a consumer panel maintained for economic and other research. His primary focus was to assess consumer preferences for organic produce and to determine the socioeconomic characteristics important in consumer choice for organic produce containing sensory defects. Specifically, Huang estimated probabilities that consumers would accept some produce sensory defects in exchange for perceived food safety and environmental benefits. Huang employed a qualitative choice model for the analysis. The results of the study indicate that potential buyers of organic produce are those who are concerned about pesticide use, and who are concerned about personal nutrition. Consumers who preferred organic produce tended to be Caucasian, higher-educated, and with large families. Also, the study clearly indicated that the majority of potential organic produce buyers are not any more tolerant of sensory defects in organic produce than in conventional produce.

In a similar study by Thompson and Kidwell (1998), data were collect at two Tucson area stores--a cooperative and a speciality store. Prices and cosmetic defects were recorded for 5 organic and matching conventional produce items. In addition, randomly selected shoppers (a total of 350) were given questionnaires (after making all their produce decisions) requesting socioeconomic and demographic information. While the shopper filled out a survey, the produce items they had selected were recorded. Thompson and Kidwell used a discrete bivariate probit model where the choice of store (cooperative or speciality) and produce type (organic or conventional) were simultaneously estimated using prices, an index for defects, and socioeconomic characteristics as regressors. The findings indicated that organic preference was strongly linked to store choice. Specifically, shoppers frequenting a food cooperative were much more likely to buy organic produce. Also, shoppers with children were more likely to choose organic produce. Shoppers with graduate or professional degrees, and shoppers with higher incomes were less likely to buy organic produce, which contrasts with Huang's results using shoppers in Georgia. Shoppers at the speciality store were more price sensitive than those shopping at the food cooperative. For speciality store shoppers, an increase in the price margin between organic non-organic produce, caused a statistically significant decrease in the probability of purchasing organic produce while the margin effects were insignificant for the co-op shoppers. Finally, the effects of sensory defects on produce were either insignificant or had minuscule impacts on shoppers' choices.

Huang and Misra's (1993) study concentrated on consumer food safety perceptions and willingness-to-pay for residue-free produce. Like Huang's 1996 study, the data for this analysis was gathered via the Georgia Consumer Panel. A three-equation simultaneous model was used to analyze the relationships between perception, attitudes, and willingness-to-pay. The regressions consisted of several socioeconomic variables as well as survey responses regarding attitudes toward pesticides, and answers to the question, "How much more than current market price are you willing-to-pay for certified pesticide free produce (from five to 20 percent)?" The empirical results indicate that employed and married females, and shoppers who had children, were much more likely to be concerned about pesticides than others. Simply having children in a household increased the likelihood of perceiving pesticides as a risk by 20 percent. People willing to pay more for pesticide-free produce were more likely to perceive pesticides as harmful and considered pesticide testing to be very important. Household income was significant and positive in determining willingness-to-pay for pesticide free produce, with an elasticity of about 0.26. This indicates a highly inelastic response in willingness-to-pay from changes in income levels.

Park and Lohr (1996) considered the wholesale demand and supply of organic produce. Their goal was to quantify the effects of changes in market characteristics on price and quantity of organic produce. They used data on weekly organic wholesale prices and quantity for broccoli, carrots, and romaine lettuce obtained from the Organic Market News and Information Service (OMNIS), and weekly nonorganic prices extrapolated from monthly U.S. Department of Agriculture data. Wholesale data were used, Park and Lohr (1996) note that "At the wholesale level it is possible to account for wholesale, retail, and consumer factors that effect demand." A partial adjustment dynamic demand and supply equilibrium system was specified and estimated using two-stage least squares (2SLS). The results indicated that an increase in price margins between conventional and organic produce, and/or per capita personal income, positively affected the aggregate output of each commodity. An increase in per capita personal income also had a positive, significant effect on broccoli and lettuce price. Although both supply and demand factors influenced prices and output, equilibrium price was primarily determined by demand.

Most of the research discussed above plus several additional studies are summarized and critiqued in a paper by Thompson (1998). The similarities between the majority of these studies are widespread. Attitudes and willingness-to-pay for organic produce have been measured but to-date, no retail-level scanner data have been utilized to estimate elasticities. Socioeconomic characteristics such as age, number and age of children, educational attainment, and choice of store may be important factors in explaining the choice of organic produce. In his conclusions, Thompson highlights the need for additional research at the retail level especially in price and income elasticity estimation adding, "Scanner data linked with consumer panels may facilitate this avenue of research" (1998, 9).

Scanner Data

Throughout the last two decades, consumer choices among food purchase alternatives have occasionally been considered using point-of-sale scanner data. Scanner data has several advantages over more aggregated data. Both product-specific price and quantity information are readily available and the data are not inferred or obtained from surveys, but from actual transactions. Raw purchase data is much more reliable than hypothetical or purchase information obtained by consumer recall.

Capps (1989) used scanner data from a retail food chain in Houston to conduct an empirical demand analysis of specific meat products. The chain averaged 600,000 customers per week from which all meat purchases were obtained. Purchases were divided into three categories (beef, poultry, pork) and seven groups (roast beef, steaks, ground beef, chicken, pork chops, pork loin, and ham). Weighted average weekly prices were calculated for each group, and total weekly sales were divided by number of customers to develop a weekly average purchase per customer. A single equation, double log specification was used, with pounds per customer as the dependant variable. Cross price effects were obtained by including an aggregate price for Pork and Poultry. Prices were assumed to be exogenous and a seemingly unrelated regression (SUR) method was used for estimation. Neither homogeneity nor symmetry conditions were imposed or tested. Except for ground beef and ham, all own price elasticities were significant and negative and all except roast beef were price inelastic. Most cross-price elasticities were significant and positive. Missing from this study was any socioeconomic data such as income (considered random), family size, age, and gender and other data such as prices for foods other than meat.

Jones, Mustiful and Chern (1994) estimated demand elasticities for cereal products using scanner data. A national supermarket chain in Columbus, Ohio provided approximately 19,110 observations from each of six stores. To make the large data set more manageable, the data were classified into five product groups. Socioeconomic data were obtained from the 1990 census (for tracts surrounding each store) including population, race and average age, family income, and education level. The model specification used was similar to that of Capps (1989). The results of this study included significant, negative, and elastic own-price elasticities in all but one cereal category. Income elasticities were significant and positive in each category. There were mixed results in terms of the socioeconomic variables.

CHAPTER 3

DATA AND VARIABLES

This study is unique in that price and quantity scanner data are linked to individual transactions from individual consumers for whom additional household specific socioeconomic data were obtained. The data were obtained from a computerized point-of-sale (POS) system at the Community Food Co-op in Bozeman, Montana, and from two survey mailings. The POS system has several categories, two of which were utilized for this research–the electronic journal and the membership information component.

The electronic journal records every transaction made at the POS (check out) terminals in great detail. Information recorded for each transaction includes date, time, POS number, transaction number, total expenditure, number of items purchased, discount, and prices and quantities purchased of each item. The membership information section includes contact information about each member such as address and phone number, as well as purchase information including the date, POS number, transaction number of each purchase, the total amount of each purchase, the total amount to-date of purchases made by an individual, and accounts receivable information concerning purchases charged to a member's account.

Quantity Data

The quantity of purchases data were obtained using both the electronic journal and the membership information components of the POS system. First, a random sample of 200 members was selected from the membership roster. The names and addresses of these members were printed for collecting additional data as discussed later in the socioeconomic data set section. To maintain member confidentiality, the names and addresses of members were separated from the membership numbers by Co-op staff and only the membership numbers were used to extract purchase data. By matching the date, POS number, and transaction number from the membership section with the analogous variables in the electronic journal, every purchase made by each individual in the random sample was available in itemized format (including prices and quantities).

Organic and non-organic (conventional) bananas, garlic, onions, and potatoes were chosen for analysis because they were (at the co-op) the most widely purchased produce items with both organic and corresponding conventional choices available to consumers every day during the range of the research. Data were collected for 132 of the 200 randomly selected members who returned an initial survey (a return rate of 66%) which provided permission to use their purchase data for this study. Each member's purchases were tracked for nineteen weeks from February 13, 1998 through June 26, 1998.

To increase the proportion of non-zero purchases, both quantities purchased and total expenditures (for each consumer) were aggregated from single transactions into weekly purchases. Since many Co-op shoppers make frequent shopping trips, the number of weekly shopping trips (1367) is about one-half the number of total transactions (2589). The descriptive statistics for the raw data (weekly transactions) are reported in table 1.

The quantity data does not include a measure of produce quality. While quality is an important factor in consumer demand for produce, a quality-price adjustment is far less important when commodities have minimal quality variations. The produce manager of the Co-op, Grant McGuire, explained that produce sold by the Co-op is relatively homogenous in terms of quality because the Co-op has a goal of consistently supplying their members with high quality produce (8/27/98 Interview). For this study, it is assumed that quality is constant over time for three reasons. First, the Co-op has the right to refuse any shipment not meeting its desired quality. When produce is received with any observed sensory defects, shipment is refused and the items are reordered. Second, the Co-op receives shipments in small batches (three per week for most items). With this rapid turnover of produce items, spoilage is limited. Third, in the unlikely event of items becoming overripe or bruised, they are removed from stock and disposed of immediately.

Table 1: Quantity Data Descriptive Statistics (Weekly Purchase Averages)

Variable	Observation	Mean	Std Dev	Min	Max
Discount (%)	1379	2.90	6.90	0.00	25.00
Total Expenditure ($)	1379	23.23	49.65	0.85	433.76
Organic Banana (Lbs.)	1379	0.37	1.14	0.00	11.80
Conventional Banana (Lbs.)	1379	0.27	0.75	0.00	5.30
Organic Garlic (Lbs.)	1379	0.01	0.04	0.00	0.54
Conventional Garlic (Lbs.)	1379	0.01	0.05	0.00	0.50
Organic Onion (Lbs.)	1379	0.07	0.35	0.00	3.85
Conventional Onion (Lbs.)	1379	0.06	0.30	0.00	4.00
Organic Potato (Lbs.)	1379	0.07	0.44	0.00	6.54
Conventional Potato (Lbs.)	1379	0.06	0.39	0.00	4.85

Price Data

Price data were obtained directly from the electronic journal. The electronic journal records prices for all items purchased by consumers each week. Prices for the eight items were recorded from the Friday of each of the nineteen weeks included in the study because the produce manager makes all weekly pricing changes each Friday morning (before the store opens). The prices used in the modeling process are indexed by dividing the weekly price for each item by that item's price in week one, then multiplying by 100. This is done because the calculated variable (described later), "price of all other foods purchased," used in the analysis is, by construction, an index. In order to be consistent throughout the analysis, all prices are indexed in the same manner.

The Consumer Price Index for "All Foods Eaten at Home" was obtained for February through June 1997 (monthly data). These data are used to calculate an index price for "all other foods eaten at home" and will be discussed further in chapter 4. Table 2 gives descriptive statistics for the price data. The prices in table 2 are not adjusted for inflation. Since the data for this study were obtained during a short period of time (19 weeks), at a time when inflation was very low (1-2%), little would be gained by deflating the prices and further complicating the modeling process.

The general manager of the Co-op, Kelly Wiseman, referred to their stable pricing (no change over a nineteen-week period) of organic bananas and non-organic garlic as a "quasi-loss leader" marketing technique (2/12/99 Interview). According to him, if consumers know in advance what the price will be on certain important produce items, they will be more likely to revisit the store. The margin on such products is set such that the average marketing margin is positive and adequate to ensure some profit. This technique is also referred to by the USDA Bureau of Agricultural Economics (1953) as a pricing policy where retailers hold their produce at one price for a considerable amount of time. From past experience with seasonal price fluctuations, the retailer can calculate the price which will return the profit margin desired. If a major cost change does occur, a new selling price can be established and continued indefinitely. Unfortunately, this technique renders econometrics useless in estimating own-price elasticities for organic bananas and non-organic garlic because of a lack of price variability. Consequently, these two commodities were dropped from the study.

Table 2: Price Data Descriptive Statistics

Variable	Observations	Mean	Std Dev	Min	Max
Price Org. Banana ($)	19	1.19	0.00	1.19	1.19
Price Conv. Banana ($)	19	0.93	0.05	0.89	0.99
Price Org. Garlic ($)	19	6.94	0.78	5.99	7.99
Price Conv. Garlic ($)	19	2.99	0.00	2.99	2.99
Price Org. Onion ($)	19	1.32	0.34	0.99	1.89
Price Conv. Onion ($)	19	0.71	0.08	0.59	0.79
Price Org. Potato ($)	19	1.40	0.26	1.19	1.99
Price Conv. Potato ($)	19	0.91	0.19	0.49	0.99
Consumer Price Index[2]	19	160.35	0.24	160.00	160.70

Socioeconomic Data

The socioeconomic data were obtained by sending two separate surveys to each of the randomly selected members. The first survey asked for information about family characteristics and household income. Questions asked included the number of adults in each household, the age of each adult, the number of children, the annual income of the

[2] CPI for all other foods eaten at home

household, and the percent of produce bought at the Co-op versus other area stores. From the initial mailing, 97 of 200 surveys were returned (48.5% return rate). After a second mailing to non-respondents, a total of 132 surveys were returned (66% return rate), of which 123 (61.5% of total) contained enough information to be usable, and 115 (57.5% of total) contained all relevant information.

With further review of organic produce related literature, it became apparent that two additional household characteristics might be important factors for inclusion in the data set. A second survey was mailed to the same random sample of members with questions asking about the educational level and employment characteristics of the primary grocery shopper. For these questions, respondents were asked to choose from several alternatives, and indicator variables were created to facilitate the analysis. Of these 200 supplemental questionnaires, 54 were returned (27% return rate). A copy of each questionnaire is included in Appendix A. Table 3 provides descriptive statistics for the socioeconomic data set.

Table 3: Socioeconomic Data Descriptive Statistics

Variable	Observations	Mean	Std Dev	Min	Max
Number of Adults	129	1.76	0.61	1.00	5.00
Average Age of Adults	123	41.66	11.91	19.00	74.50
Number of Children	130	0.49	0.91	0.00	5.00
Annual Household Income ($)	115	38,370.43	24,613.93	2,000.00	150,000.00
Percent of Produce Bought at the Co-op (%)	130	45.80	37.90	0.00	100.00
Stay at Home Care giver (indicator)	54	0.11	0.31	0.00	1.00
Employed Part Time (indicator)	54	0.46	0.50	0.00	1.00
Employed Full Time (indicator)	54	0.30	0.46	0.00	1.00
Retired (indicator)	54	0.04	0.19	0.00	1.00
Full Time Student (indicator)	54	0.10	0.30	0.00	1.00
Education: High School (indicator)	54	0.03	0.17	0.00	1.00
Education: Some College (indicator)	54	0.22	0.41	0.00	1.00
Education: College Degree (indicator)	54	0.21	0.41	0.00	1.00
Education: Post Graduate (indicator)	54	0.54	0.50	0.00	1.00

The co-op members who returned surveys appear to be representative of the population of Gallatin County[3] in the categories of persons per household (2.25 versus 2.5 for Gallatin County) and proportion employed (76% versus 73% for Gallatin County). However, on average, the sub-group in this research had higher incomes ($38,370 per

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[3] The statistical information referred to for Gallatin County is taken from 1990 Census of Housing and Population. For this reason, comparisons to the research population (1998 Co-op survey) may not be entirely reliable.

household versus $23,345 for Gallatin County) and was more highly educated (75% with a bachelors degree or higher versus 33% for Gallatin County) then the county population.

Additional Variables

Table 4 is a list of variables and descriptions including the computer-calculated variables included in the regressions, as well as temporary variables used in the calculation of regression variables. All variables are calculated using all produce items in the study, i = {non-organic bananas, organic garlic, non-organic onions, organic onions, non-organic potatoes, and organic potatoes}.

Table 4: Calculated Variable List

Variable	Description/Calculated By
$Quantity_i$	quantity of good i
$Price_i$	price of good i
Indexed $Price_i$	$Price_{ij}$ / $Price_{i1}$ for all goods i, for all weeks j
Total $Expenditure_t$	Tot_Exp_t = total expenditure for each transaction t
Expenditure $Share_{ij}$	XS_i = $(Price_j)$ * $(Quantity_{ij})$ / Total $Expenditure_{ij}$ for all items purchased i, per week $_j$
CPI	consumer price index for price of all foods eaten at home
Expenditure Share for All-Other-Foods purchased from the Co-op (items purchased not included in the study)	XS_AOG = 1-(Σ expenditure $share_i$)
Price of All-Other-Foods bought from the Co-op	P_AOG = (CPI - (Σ ($Price_i$ * Expenditure $share_i$)) / XS_AOG_j for all items purchased i, per week $_j$
Quantity of All-Other-Foods bought from the Co-op	Quantity_AOG = (XS_AOGj*Tot_Expj)/P_AOGj for each week j
Stone's Quantity Index (Expenditure)	LnQ = Σ (Expediture $share_i$ * Ln($Qauntity_i$)) + Σ (XS_AOG * Ln(quantity_AOG))

CHAPTER 4

THEORETICAL AND EMPIRICAL FRAMEWORK

General Theoretical Model

The model used for this analysis closely follows Theil's (1965) Rotterdam model (level version) as specified by Gao, Wailes, and Cramer (1994). The Rotterdam model is an approximate demand system model based on consumer demand theory. It is a flexible functional form that is linear in parameters and allows for the imposition of homogeneity, symmetry, and adding-up restrictions.

The basic model in most demand analyses is one in which the quantity of a good purchased by consumers is a function of the price of that good (P_{own}), the prices of other goods (P_{subst}), consumer income (M), and tastes and preferences (T): $Q = f(P_{own}, P_{subst}, M, T)$. A double-logarithmic demand function is often used as a starting point in demand analysis because taking the natural log of price and income variables makes it easier to obtain (and later impose restrictions on) elasticity estimates. The descriptive statistics of quantities purchased (Table 1) also support taking logs of the quantities. The initial model has the form:

(1) $$Ln(q_i) = \alpha_1 + \eta_i Ln(M) + \sum_j \mu_{ij} Ln(p_j)$$

In this general specification, q_i is the quantity of the ith good, p_j is the price of the jth good, M is income (or expenditure), α_1 is the constant (intercept) term, η_i is the income elasticity, and μ_{ij} are the Marshallian price elasticities.

In order for a demand system to be consistent with consumer demand theory, homogeneity, symmetry and Engel aggregation (adding-up) restrictions must be imposed. These restrictions stem from three basic assumptions which are fundamental components (axioms) of consumer theory. These assumptions are based on the belief that consumers are rational as defined by: reflexivity, completeness, and transitivity. Reflexivity means that any consumption bundle (X) is at least as good as itself: $X \succeq X$. Completeness means that any two bundles (X and Y) can be compared: $X \succ Y$, $Y \prec X$ or $X \sim Y$; In the latter case a consumer is indifferent between X and Y. Transitivity means that if a consumer prefers bundle X to Y and prefers Y to Z, the consumer must prefer X to Z: if $X \succeq Y$ and $Y \succeq Z$ then $X \succeq Z$.

If consumer behavior follows these relatively weak assumptions, the theoretical restrictions of symmetry, homogeneity, and adding-up should be imposed on demand systems. But, in order to do so, equation (1) must be transformed into a weighted-elasticity functional form, utilizing the Slutsky equation in elasticity form defined as:

$$(2) \qquad \varepsilon_{ij} = \mu_{ij} + \eta_i w_j$$

where the ε_{ij}'s are the income constant (Marshillian) price elasticities, the μ_{ij}'s are utility constant (Hicksian) price elasticities, η_i represents the income elasticity for good i, and w_j

are budget shares. Solving equation (2) for the μ_{ij}'s, and substituting into equation (1), and multiplying both sides by w_i we get:

$$(3) \qquad w_i Ln(q_i) = \alpha_i w_i + \theta_i Ln(M) - \theta_i \sum_j w_j Ln(p_j) + \sum_j s_{ij} Ln(p_j)$$

where:

$$\theta_i = w_i \eta_i = \frac{p_i q_i}{M} \bullet \frac{\partial q_i}{\partial M} \bullet \frac{M}{q_i} = \frac{p_i \partial q}{\partial M}$$

are marginal shares, and $s_{ij} = w_i \varepsilon_{ij}$ are weighted Hicksian elasticities. Upon estimation the desired elasticities (η_i and ε_{ij}) are calculated by dividing each (θ_i and s_{ij}) through by the appropriate budget shares.[4] The Slutsky aggregation condition requires that for each i^{th} good:

$$\sum_j s_{ij} = \sum_j w_i \varepsilon_{ij} = 0$$

meaning the sum of the Slutsky coefficients and the sum of the weighted elasticities are both equal to zero. The Engel aggregation condition requires:

$$\sum_i w_i \eta_i = \sum_i \theta_i = 1$$

where the sum of the weighted income elasticities must sum to one, indicating that a consumer's budget constraint is binding. Summing both sides of equation (3), over all i goods yields:

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[4] Recall that the elasticities are weighted by budget share before estimation to allow for the imposition of cross-equation restrictions implied by consumer choice theory.

$$(4) \qquad \sum_i w_i Ln(q_i) = \sum_i \alpha_i w_i + Ln(M)\sum_i \theta_i - \sum_i \theta_i \sum_j w_j Ln(p_j) + \sum_j Ln(p_j)\sum_i s_{ij}$$

or:

$$(5) \qquad LnQ = \sum_i \alpha_i w_i + Ln(M) - \sum_j w_j Ln(p_j)$$

where: $LnQ = \sum_j w_j Ln(q_j)$. Substituting equation (5) into equation (3) yields:

$$(6) \qquad w_i Ln(q_i) = \alpha_{0i} + \theta_i LnQ + \sum_j s_{ij} Ln(p_j)$$

where: $\alpha_{0i} = \alpha_i w_i - \theta_i \sum_i \alpha_i w_i$, and

$$\sum_i \alpha_{0i} = 0.$$

LnQ is the Stone's quantity index used as a proxy for income. A Stone's quantity index can be used in place of the income variable because it represents the consumer's total budget. As long as a complete system is estimated, the adding up restriction requires the total budget be exhausted. Equation (6) is a level version Rotterdam model with parameters (θ_i and s_{ij}) having the same interpretation as in the original Rotterdam specification. These parameters-- marginal budget shares (θ_i), and weighted Slutsky elasticities (s_{ij})-- are assumed constant for estimation purposes.

With the model properly specified, homogeneity and symmetry can easily be imposed on the weighted own- and cross-price elasticity matrix. The homogeneity condition for the model is derived by summing equation (2) using $\sum_j s_{ij} = \sum_j w_i \varepsilon_{ij}$ and imposing: $\sum_j \mu_{ij} = -\eta_i$

then:

$$\sum_j s_{ij} = w_i \Big[\sum_j \mu_{ij} + \eta_i \sum_j w_j\Big] = w_i(-\eta_i + \eta_i) = 0$$

The symmetry condition is $s_{ij} = s_{ji}$. The adding up restriction is imposed after estimation as described in the next section.

The underlying utility function for this model is assumed to be weakly separable. Weak separability specifies utility as a function of different categories of goods. An example of a weakly separable utility function (in general form) is given by:

$$V(x_1, x_2, x_3, x_4) = U(f(x_1, x_2), g(x_3, x_4))$$

where x_1 and x_2 are categorized as foods (for example), and x_3 and x_4 are categorized as clothing (for example). The marginal rate of substitution (MRS) between any two goods in the same category is a function only of the goods in that category (Silberberg 1990, 345). The MRS between x_1 and x_2 is

$$-\frac{\partial V / \partial x_1}{\partial V / \partial x_2} = -\frac{U_1 f_1}{U_1 f_2} = -\frac{f_1(x_1, x_2)}{f_2(x_1, x_2)} = -\frac{p_1}{p_2}.$$

However, the total expenditure on a given category does depend on the prices of all goods, not just the goods in that category (i.e., the prices of individual articles of clothing have an effect upon the amount of "food" the consumer purchases).

A weakly separable utility assumes that a two-stage budgeting process is followed by consumers. If consumers first decide on total expenditure on food out of their total income, then food (or in this case, food purchased from a specific store) can be modeled as a system of demand equations. Thus, the demand elasticities generated from this model are conditional, based upon the initial decision as to the amount of income budgeted for purchases at the Co-op.

Multivariate System Estimation

The model is estimated as a system of equations because of the desire to impose cross-equation restrictions and because of the potential for contemporaneously correlated errors in optimization. The specific empirical form of this model adds the socioeconomic variables mentioned in Chapter 3, and an error term, but is based on equation (6) and its theoretical formulation. The system to be estimated is given by:

$$w_{it}Ln(q_{it}) = \alpha_{it} + \theta_{it}LnQ_t + \sum_j s_{ij}Ln(p_j) + \sum_t \delta_{it}D_t + U_{it} \tag{7}$$

$$i = 1,2,3,4,5,6,7 \qquad j = 1,2,3,4,5,6,7 \qquad t = 1,2,\ldots,T$$

In the empirical model, w_{it} represents the weekly expenditure share for each good (i) per consumer/week (t). $Ln(q_{it})$ represents the seven dependent variables which are the natural log of the quantities where i indexes non-organic bananas, organic garlic, organic onions, non-organic onions, organic potatoes, non-organic potatoes, and "all other foods purchased." As previously discussed, consumer transactions were aggregated into weekly totals. The parameter α_i is an intercept term. The parameter θ_i gives the estimated (weighted elasticity) coefficients on expenditure. The variable LnQ_t (Stone quantity index) is a measure of (the natural log of) the consumers total weekly budget spent on food (proxy for income/expenditure). The parameter s_{ij} gives the estimated expenditure share weighted Slutsky (Hicksian) elasticities. When i = j, the estimated coefficient is the own-price (weighted) elasticity, and when i $\neq$ j, the coefficients are cross-price (weighted) elasticities. $Ln(p_j)$ represents the natural log of the price for each item including a calculated price for "all other foods purchased." The price variables are constant over consumers for each week in the study. D_t is a vector of socioeconomic variables including the number of adults and children per household, the ages of each adult, and indicator variables for occupation and educational level. These socioeconomic variables are constant for each individual consumer (t) over the span of the study. Finally, U_{it} are the equation errors.

The system is estimated using iterated seemingly-unrelated regressions (ITSUR). ITSUR improves the efficiency of parameter estimates by accounting for contemporaneous correlation of errors across equations. Efficiency is gained by first estimating the system using ordinary least squares (OLS), then taking this information into account when final parameter coefficients are estimated. In addition, ITSUR parameter estimates converge to the maximum likelihood estimates and are invariant to the choice of deleted equation.

The model is estimated for six equations (rather than all seven) because of an empirical complication inherent in any over-identified system of equations. When all the cross-equation restrictions (symmetry, homogeneity, and adding-up) are imposed on a system of equations, the final equation has no unknown parameter values (i.e., the system is over-identified). While parameter estimates can be obtained, such estimates are not unique. It is possible to obtain unique parameter values without dropping the final equation estimate using maximum likelihood (ML) but the complexity of the likelihood function makes this option less attractive than using ITSUR to get identical coefficients. Therefore, the seventh equation representing "Quantity of All Other Foods" purchased at the Co-op is deleted for estimation purposes. Since the variable "Price of All Other Foods" is still included in the regressions, the parameter estimates of the dropped equation can be recovered using the homogeneity, symmetry, and adding-up restrictions imposed on the model.

CHAPTER 5

EMPIRICAL RESULTS

A six commodity (non-organic bananas, organic garlic, non-organic onions, organic onions, non-organic potatoes, and organic potatoes) system of Hicksian demand equations was estimated under the Rotterdam model by iterated seemingly unrelated regressions (ITSUR) using (the Proc-Model function in) SAS version 7.0. Because of some missing observations in the socioeconomic data (due to a smaller rate of return on the supplemental survey), parameter estimates are first presented with the employment and education variables omitted.[5] Parameters are also presented for a model in which the sample size is reduced but employment and education variables are included. The sample size for the model excluding employment and education variables is 1272 (from 1379 total observations) while the sample size for the model including employment and education is reduced to 626.

Model Excluding Employment and Education Variables

Table 5 presents all of the parameters estimated including both the weighted price (s_{ij}) and income (θ_i) coefficients as well as the socioeconomic coefficients.

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[5] The SAS system automatically excludes the entire record (row) from the estimation if there is any missing data. Therefore, for each Co-op member who did not return the second (employment, education) survey, each record (row) of purchases is excluded from estimation when employment or education variables are used as independent (RHS) variables.

Table 5: Estimated Regression Coefficients of the Model Without Employment/Education Variables (n = 1272)

Coefficients with respect to independent variables (t-statistics) * = significant at the .10 level of significance ** = significant at the .05 level of significance						
	Equations: Dependant Variable =					
Parameters Estimated	Non-organic Bananas	Non-organic Onions	Non-organic Potatoes	Organic Garlic	Organic Onions	Organic Potatoes
Intercept	0.004 (1.22)	-0.0001 (-0.20)	-0.001 (-0.95)	-0.01 (-5.14)**	0.001 (1.16)	0.003 (1.66)*
Price of Non-org Bananas	-0.004 (-0.22)					
Price of Non-org Onions	-0.001 (-0.41)	-0.0006 (-0.28)				
Price of Non-org Potatoes	-0.005 (-1.87)*	-0.00004 (-0.07)	0.002 (1.63)			
Price of Org Garlic	-0.002 (-0.34)	0.0009 (0.58)	-0.0009 (-0.49)	-0.001 (-0.15)		
Price of Org Onions	-0.002 (-0.82)	-0.0001 (-0.10)	0.002 (1.79)*	0.002 (1.05)	0.0008 (0.67)	
Price of Org Potatoes	0.003 (0.69)	0.002 (1.88)*	0.002 (1.92)*	0.004 (1.58)	0.0005 (0.45)	0.003 (1.59)
Stone's Quantity Index (Expenditure)	0.001 (1.79)*	0.00003 (0.33)	-0.00002 (-0.06)	-0.0006 (-1.47)	0.0004 (1.82)*	0.0009 (3.21)**
Average Age of Adults in household	0.00 (0.10)	0.00 (-0.31)	0.00002 (0.77)	0.00009 (2.54)**	0.00001 (0.63)	-0.00001 (-0.38)
Number of Adults in Household	0.0008 (0.85)	0.0002 (1.20)	0.0005 (1.16)	0.001 (2.07)**	-0.0004 (-1.01)	-0.0005 (-1.02)
Number of Children in Household	0.0006 (0.89)	0.0001 (0.95)	0.001 (3.19)**	0.001 (2.73)**	-0.0001 (-0.40)	0.0009 (2.55)**

This section will discuss the socioeconomic characteristics in the model. Own- and cross-price and income elasticities will be discussed in the following section after the non-weighted (Hicksian) elasticities are presented.

In the non-organic potato equation, the number of children in the household helps determine the quantity of potatoes purchased. As the number of children increases, more non-organic potatoes are purchased. In the organic-garlic equation, the average age of adults, the number of adults, and the number of children in the household are each significant, and positively related to the amount of organic garlic purchased. Finally, in the organic potato equation, the number of children in the household has a significant, positive relationship to the quantity of organic potatoes purchased.

For these three goods, it seems family composition is an important consideration in determining purchasing patterns. These family characteristics may, in fact, be quantitatively more important than prices (for the small price changes observed) for making purchase decisions regarding many of the goods in this study.

Table 6 presents the conditional (Hicksian) price elasticities (ε_{ij}) and the income (expenditure) elasticities (η_i) for the larger sample (N=1272) when education and employment variables excluded from the set of explanatory variables. The systems Hicksian elasticities are calculated using equations (8) and (9)

$$(8) \qquad \varepsilon_{ij} = s_{ij} / [(\sum_{t=1}^{T} w_{it}) / T]$$

$$(9) \qquad \eta_i = \theta_i / [(\sum_{t=1}^{T} w_{it}) / T]$$

where the s_{ij}'s and the θ_i's are the weighted elasticities presented in tables 5, 7, and 9 and the w_{it}'s are the expenditure share weights (i = goods 1,2,3...I, t = weeks 1,2,3...T), and thus the bracketed terms are average expenditure share weights.

Since the equation representing consumption of all other foods was deleted prior to estimation, the parameters for this equation are recovered using the symmetry ($s_{ij} = s_{ji}$), homogeneity ($\sum_i s_{ij} = \sum_i w_i \varepsilon_{ij} = 0$), and adding-up ($\sum_i w_i \eta_i = \sum_i \theta_i = 1$) restrictions presented in Chapter 4. Because the parameters of the deleted equation are linear combinations of random variables, their standard errors (and thus t-statistics) can be calculated.[6]

[6] The parameter values for the "all other foods" equation are calculated using the Slutsky aggregation (homogeneity) conditions and the Engle aggregation (adding-up) conditions discussed at length in Chapter 4. The variance of each parameter in the "all other foods" equation is calculated by adding the variance of each parameter and two times the co-variance between each parameter used in the aggregation conditions to calculate these "all other foods" parameter values.

Table 6: Expenditure and Price Elasticities for the Estimation Without Education/Employment Variables (n = 1272)

Elasticities with respect to independent variables (t-statistics) * = significant at the .10 level of significance ** = significant at the .05 level of significance							
	Percentage Change in the Quantity of:						
with respect to a 1% change in the price of:	Non-organic Bananas	Non-organic Onions	Non-organic Potatoes	Organic Garlic	Organic Onions	Organic Potatoes	All Other Foods
Non-org. Bananas	-0.52 (-0.22)	-1.56 (-0.41)	-3.13 (-1.87)*	-1.28 (-0.34)	-0.91 (-0.82)	1.76 (0.69)	0.01 (0.64)
Non-org. Onions	-0.21 (-0.41)	-0.69 (-0.28)	-0.02 (-0.07)	0.50 (0.58)	-0.04 (-0.10)	0.99 (1.88)*	-0.0002 (-0.06)
Non-org. Potatoes	-0.76 (-1.87)*	-0.04 (-0.07)	1.24 (1.63)	-0.51 (-0.49)	0.61 (1.79)*	1.39 (1.92)*	0.0003 (0.08)
Org. Garlic	-0.33 (-0.34)	0.95 (0.58)	-0.54 (-0.49)	-0.44 (-0.15)	0.67 (1.05)	2.37 (1.58)	-0.003 (0.23)
Org. Onions	-0.36 (-0.82)	-0.12 (-0.10)	0.97 (1.79)*	1.01 (1.05)	0.30 (0.67)	0.31 (0.45)	-0.003 (-0.50)
Org. Potatoes	0.41 (0.69)	1.70 (1.88)*	1.32 (1.92)*	2.13 (1.58)	0.18 (0.45)	2.09 (1.59)	-0.002 (-2.72)**
All Other Foods	1.77 (0.64)	-0.24 (-0.06)	0.16 (0.08)	-1.42 (0.23)	-0.80 (-0.50)	-8.91 (-2.72)**	0.01
with respect to a 1% change in Expenditure (Stone's quantity index)	0.15 (1.79)*	0.04 (0.33)	-0.01 (-0.06)	-0.33 (-1.47)	0.15 (1.82)*	0.61 (3.21)**	1.01 (1.01)

The elasticities presented here are the same in sign as the weighted parameters presented in table 5 (because all the average expenditure share weights are positive), and have identical t-values because the weights are constants (no variance).

For this model there are no own-price elasticities significantly different from zero. A few cross-price elasticities appear significant. The most interesting cross-price elasticities are the price of organic potatoes in the non-organic potato equation and the price of non-organic potatoes in the organic potato equation. These elasticities are positive, significant at the 10% level, and relatively large indicating that organic potatoes and non-organic potatoes are fairly strong substitutes. The price of "all other foods" at the co-op has a significant and complementary relationship with organic potatoes.

The lack of significant own-price elasticities implies that consumers are not very price sensitive to changes in prices of the goods in this study. One possible explanation for these results is that the items in this study are considered staples to many consumers, where small price changes do not alter purchasing behavior. In addition there is not much variability in prices during the course of the study (see Table 2 in Chapter 3). Another possible explanation for these results is that of a possible "zero purchase" bias on the own-price coefficients. This problem is discussed in the third section of this chapter.

In the non-organic banana, organic onion, and organic potato equations, the expenditure elasticities are each significantly different from zero and positive, indicating that consumers treat these items as normal goods. In each equation, the expenditure elasticities are significantly different from one.

Model Including Employment and Education Variables

For completeness, the system was also estimated using a smaller sample size including the supplemental survey data on education and employment. This estimation has roughly one-half as many observations as the first system estimated. These variables are added to the model because employment and educational characteristics were important factors in previous research by Huang (1996), and Thompson and Kidwell (1998).

Table 7 presents the estimated coefficients for the model. The model includes seven employment and educational RHS variables.

Table 7: Estimated Regression Coefficients of the Model with Employment/Education Variables (n = 626)

Coefficients with respect to independent variables (t-statistics)
* = significant at the .10 level of significance
** = significant at the .05 level of significance

	Equations: Dependant Variable =					
Parameters Estimated	Non-organic Bananas	Non-organic Onions	Non-organic Potatoes	Organic Garlic	Organic Onions	Organic Potatoes
Intercept	0.01 (0.99)	0.0008 (0.69)	0.001 (0.23)	-0.02 (-2.56)**	-0.05 (-2.55)**	0.003 (0.65)
Price of Non-org Bananas	-0.02 (-0.79)					
Price of Non-org Onions	-0.002 (-0.47)	0.002 (0.63)				
Price of Non-org Potatoes	-0.003 (-0.62)	-0.001 (-1.42)	0.003 (1.35)			
Price of Org Garlic	-0.002 (-0.15)	0.0006 (0.36)	-0.0003 (-0.07)	0.0007 (0.07)		
Price of Org Onions	0.003 (0.58)	-0.001 (-0.72)	0.003 (1.86)*	0.003 (0.99)	-0.005 (-2.45)**	
Price of Org Potatoes	0.005 (0.71)	0.001 (1.25)	0.001 (0.80)	0.006 (1.54)	0.0007 (0.43)	0.0007 (0.23)
Stone's Quantity Index	0.0009 (0.81)	0.0002 (1.64)*	-0.0004 (-0.61)	-0.0005 (-0.62)	0.001 (2.33)**	0.0009 (1.76)*
Average Age of Adults in Household	-0.0002 (-1.37)	0.00 (0.35)	0.00001 (0.26)	0.0002 (1.98)**	0.0001 (2.75)**	-0.00003 (-0.61)

Coefficients with respect to independent variables (t-statistics) * = significant at the .10 level of significance ** = significant at the .05 level of significance						
	Equations: Dependant Variable =					
Parameters Estimated	Non-organic Bananas	Non-organic Onions	Non-organic Potatoes	Organic Garlic	Organic Onions	Organic Potatoes
Number of Adults in Household	0.003 (1.31)	0.0002 (0.78)	0.0007 (0.62)	0.003 (1.97)**	-0.0005 (-0.71)	-0.0001 (-0.13)
Number of Children in Household	0.001 (0.90)	0.00008 (0.60)	0.0008 (1.37)	0.001 (1.60)	0.00003 (0.09)	0.0007 (1.35)
Primary Grocery Shopper works Part-time	0.004 (1.26)	-0.001 (-3.26)**	-0.005 (-2.63)**	0.0003 (0.12)	-0.0001 (-0.10)	-0.007 (-0.44)
Primary Grocery Shopper works Full-time	0.001 (0.35)	-0.001 (-2.97)**	-0.005 (-2.77)**	-0.005 (-1.66)*	0.002 (1.32)	-0.002 (-1.31)
Primary Grocery Shopper is Retired	0.02 (3.54)**	-0.0007 (-0.93)	-0.004 (-1.21)	-0.002 (-0.35)	-0.004 (-1.82)*	-0.001 (-0.41)
Primary Grocery Shopper is a Full-Time Student	-0.002 (-0.37)	-0.001 (-2.16)**	-0.006 (-2.44)**	0.001 (0.31)	0.0005 (0.28)	-0.003 (-1.37)
Primary Grocery Shopper has Some College	-0.009 (-1.61)	0.0002 (0.33)	0.002 (0.53)	0.002 (0.42)	0.003 (1.39)	0.001 (0.53)
Primary Grocery Shopper has a Four- Year Degree	-0.003 (-0.61)	-0.00006 (-0.10)	0.002 (0.88)	-0.0006 (-0.15)	0.0002 (0.11)	0.001 (0.41)
Primary Grocery Shopper has Post Graduate Education	-0.005 (-1.04)	-0.0002 (-0.32)	0.002 (0.76)	0.00004 (0.01)	0.00001 (0.01)	0.002 (0.83)

Again, significance of the model's socioeconomic variables is examined first; Price and income elasticities will be discussed in the section following the calculated elasticity table.

The additional independent variables in this model (employment and education variables) are indicator variables meaning they take a value of 1 if "true" and 0 if "false." When using indicator variables in a multiple regression framework, one indicator from each category (employment and education) must be dropped or the sum of the vectors within that category will be a linear combination, and the independent variable matrix sum of squares (X`X) will not be invertible. The coefficients of the indicators left in the system, are interpreted as the differential impact between that indicator and the omitted variable. In other words, the omitted variable is used as a basis for comparison. "Stay-at-home care giver" is omitted from the employment category, and "high school only" is omitted from the education category. Therefore, the estimated coefficients for the remaining variables are differences in purchasing behavior for a member with specified employment or educational characteristics from a member who is a "stay-at-home care giver" with a "high school" education.

In the non-organic banana equation, the primary grocery shopper being retired, has a positive significant effect on the quantity of non-organic bananas purchased. Working part-time or full-time, and being a full-time college student each have negative and significant effects on the quantity of non-organic onions and non-organic potatoes purchased. In the organic garlic equation, both the average age of adults, and the number of adults in the household have significant and positive effects, while the primary grocery shopper being retired has a negative effect on the quantity of organic garlic purchased. Finally, in the organic onion equation, the average age of adults in the household is significant, and positively related to the amount of organic onions purchased, while the primary grocery shopper being retired has a significant and negative relationship.

Table 8 presents the price and income elasticities for this system. The elasticities for this system are likewise calculated using equations (8) and (9).

Table 8: Expenditure and Price Elasticities for the Estimation with Education/Employment Variables (n = 626)

Elasticities with respect to independent variables (t-statistics) * = significant at the .10 level of significance ** = significant at the .05 level of significance							
	Percentage Change in the Quantity of:						
with respect to a 1% change in the price of:	Non-organic Bananas	Non-organic Onions	Non-organic Potatoes	Organic Garlic	Organic Onions	Organic Potatoes	All Other Foods
Non-org Bananas	-2.71 (-0.79)	-2.18 (-0.47)	-1.51 (-0.62)	-0.56 (-0.15)	0.94 (0.58)	2.85 (0.71)	0.02 (0.64)
Non-org Onions	-0.25 (-0.47)	1.84 (0.63)	-0.49 (-1.42)	0.21 (0.36)	-0.33 (-0.72)	0.71 (1.25)	0.0004 (0.08)
Non-org Potatoes	-0.38 (-0.62)	-1.08 (-1.42)	1.54 (1.35)	-0.08 (-0.07)	0.95 (1.86)*	0.89 (0.81)	-0.003 (-0.44)
Org Garlic	-0.22 (-0.15)	0.72 (0.36)	-0.13 (-0.07)	0.23 (0.07)	0.98 (0.99)	3.75 (1.54)	-0.009 (-0.49)
Org Onions	0.35 (0.58)	-1.07 (-0.72)	1.40 (1.86)*	0.94 (0.99)	-1.56 (-2.45)**	0.44 (0.43)	-0.004 (-0.55)
Org Potatoes	0.60 (0.71)	1.31 (1.25)	0.74 (0.81)	2.02 (1.54)	0.24 (0.43)	0.43 (0.23)	-0.02 (-1.96)**
All Other Foods	2.61 (0.64)	0.46 (0.08)	-1.56 (-0.44)	-2.75 (-0.49)	-1.22 (-0.55)	-9.08 (-1.96)**	0.01
with respect to a 1% change in							
Expenditure (Stone's quantity Index)	0.12 (0.80)	0.25 (1.64)*	-0.18 (-0.61)	-0.17 (-0.62)	0.32 (2.33)**	0.54 (1.76)*	1.02 (0.88)

The own price elasticity for organic onions is significant and negative implying the demand for organic onions is negatively sloped, as expected. No additional own-price elasticities are significantly different from zero. As mentioned in the prior section, there may be several reasons for this lack of significant own-price elasticities.

Only two commodity cross-price elasticities are significantly different from zero. These elasticities imply organic onions may be somewhat substitutable with non-organic potatoes. While it is possible that consumers substitute these goods for each other, it is not an expected result. Consistent with the first model presented, the price of "all other foods" at the co-op has a significant and negative relationship with the quantity of organic potatoes purchased implying organic potatoes are compliments to "all other foods."

A lack of significant, positive, cross-price elasticities, between like organic and non-organic items (onions and potatoes) may be the result of the random sample under consideration containing two distinct subgroups of consumers who shop at the co-op. One subgroup may be more inclined to buy organic products, while the other group normally purchases non-organic products. This would limit the amount of substitutability between organic and non-organic potatoes and between organic and non-organic onions.

In the non-organic onion, organic onion, and organic potato equation the expenditure elasticities are significant and positive. Except for differences between non-organic onions (in this model) for non-organic bananas (in the first model presented), these results are similar to those of the model excluding employment and education variables.

Especially in the case of the own-price elasticity for organic onions, the own- and cross-price elasticities presented for this model do differ in significance and magnitude from those presented in table 6. This implies that the employment variables may be important factors in determining the demand characteristics of organic produce.

Exploring a Possible Zero Purchase Bias in Own-Price Elasticities

As noted earlier, the lack of significant own-price elasticities in the models presented may be a result of the large number of zero purchases. People who are not buyers of a given item, at any price, exhibit a zero purchase. With several members showing zero purchases, it is impossible for the system to differentiate between the members who are not buying an item because the price is high, and the members who are not buying because they are not "in the market" for the item. A problem arises from leaving these zero purchase observations in the study. Specifically, leaving these zero purchasers in the estimation causes the intercept term to be biased downward and thus the slope of the relevant demand curve to be biased toward zero.

To explore the magnitude of the problem arising from zero purchasers, the system was also estimated excluding any member who did not purchase at least one item from each pair of organic and non-organic items (bananas, garlic, onions, potatoes). For example, if a consumer did not purchase either organic or non-organic bananas during the course of this research (nineteen weeks), it was concluded that this person was not "in the market" for bananas and was excluded from the study. This process was repeated for each member, for each pair of goods. Because the estimation is in system form, if a member is removed for one pair of items, they are removed for all items. This process significantly reduced the number of observations available for estimation. The model without the employment and education variables is estimated using 268 observations of which 251 contain no missing data and are used in the estimation.[7]

Table 9 presents each estimated coefficient including weighted price and income coefficients and household characteristic included as independent variables in the model.

[7] The model including employment and education variables was also estimated but there were only 165 observations (of 268) without missing data. The model converged with biased estimates likely because the sample size was too small. These biased results are not reported.

Table 9: Estimated Regression Coefficients of the Model without Employment/Education Variables Excluding Zero Purchasers (n = 251)

	Coefficients with respect to independent variables (t-statistics) * = significant at the .10 level of significance ** = significant at the .05 level of significance					
	Equations: Dependant Variable =					
Parameters Estimated	Non-organic Bananas	Non-organic Onions	Non-organic Potatoes	Organic Garlic	Organic Onions	Organic Potatoes
Intercept	0.03 (3.09)**	-0.0005 (-0.43)	-0.01 (-1.59)	-0.006 (-1.26)	0.001 (0.56)	0.009 (1.60)
Price of Non-org Bananas	0.02 (0.41)					
Price of Non-org Onions	-0.005 (-0.86)	0.0001 (0.03)				
Price of Non-org Potatoes	-0.009 (-1.13)	0.0002 (0.18)	0.003 (0.70)			
Price of Org Garlic	0.01 (0.71)	0.0008 (0.28)	-0.002 (-0.62)	-0.004 (-0.39)		
Price of Org Onions	0.005 (0.74)	-0.0004 (-0.22)	0.002 (1.39)	0.007 (2.39)**	0.0006 (0.35)	
Price of Org Potatoes	0.009 (0.81)	0.003 (1.85)*	0.008 (2.35)**	0.005 (0.91)	0.0009 (0.44)	-0.003 (-0.46)
Stone's Quantity Index (Expenditure)	0.001 (0.71)	0.00004 (0.18)	-0.004 (-2.53)**	0.0007 (0.76)	0.0006 (1.51)	0.002 (2.17)**
Average Age of Adults in household	-0.0004 (-2.77)**	-0.00001 (-0.83)	0.0001 (1.13)	-0.00005 (-0.86)	0.00005 (1.92)*	-0.00003 (-0.46)
Number of Adults in Household	-0.005 (-1.25)	0.0004 (0.90)	0.004 (1.14)	0.0008 (0.42)	-0.001 (-1.25)	-0.002 (-0.88)
Number of Children in Household	-0.002 (-0.88)	0.0006 (2.51)**	0.002 (1.31)	0.0009 (1.07)	-0.0002 (-0.45)	0.001 (1.09)

In the non-organic banana equation, the average age of adults in a household is significant and has a negative relationship with the quantity of bananas purchased. The number of children in a household has a significant and positive relationship with the quantity of non-organic onions purchased. Finally, the average age of adults in the household has a significant and positive relationship with the amount of organic onions purchased. This estimation had only three socioeconomic coefficients significantly different from zero. Again, the smaller number of usable observations may be adversely affecting the accuracy of these results.

The parameter estimates presented for this model varied only slightly from those presented in table 5. This indicates that removing zero purchasers does not substantially affect the estimation. Table 10 presents the Hicksian price and income elasticities for this estimation.

Table 10: Expenditure and Price Elasticities for the Estimation without Education and Employment Variables Excluding Zero Purchasers (n = 251)

Elasticities with respect to independent variables (t-statistics) * = significant at the .10 level of significance ** = significant at the .05 level of significance							
	Percentage Change in the Quantity of:						
with respect to a 1% change in the price of:	Non-organic Bananas	Non-organic Onions	Non-organic Potatoes	Organic Garlic	Organic Onions	Organic Potatoes	All Other Foods
Non-org Bananas	2.72 (0.41)	-5.80 (-0.86)	-5.42 (-1.13)	6.58 (0.71)	1.78 (0.74)	6.03 (0.81)	-0.03 (-0.60)
Non-org Onions	-0.78 (-0.86)	0.13 (0.03)	0.11 (0.18)	0.45 (0.28)	-0.16 (-0.22)	1.79 (1.85)*	0.002 (0.28)
Non-org Potatoes	-1.32 (-1.13)	0.21 (0.18)	2.09 (0.71)	-1.37 (-0.62)	0.84 (1.39)	5.25 (2.35)**	-0.003 (-0.25)
Org Garlic	1.68 (0.71)	0.85 (0.28)	-1.44 (-0.62)	-2.42 (-0.39)	2.71 (2.39)**	3.04 (0.91)	-0.02 (-0.95)
Org Onions	0.69 (0.74)	-0.46 (-0.22)	1.34 (1.39)	4.12 (2.39)**	0.24 (0.35)	0.59 (0.44)	-0.02 (-2.11)**
Org Potatoes	1.39 (0.81)	3.08 (1.85)*	4.97 (2.35)**	2.74 (0.91)	0.35 (0.44)	-1.76 (-0.46)	-0.02 (-2.59)**
All Other Foods	-4.38 (-0.60)	1.99 (0.28)	-1.65 (-0.25)	-10.11 (-0.95)	-5.76 (-2.11)**	-14.94 (-2.59)**	0.09
with respect to a 1% change in							
Expenditure (Stone's quantity index)	0.21 (0.71)	0.04 (0.18)	-2.20 (-2.53)**	0.39 (0.76)	0.21 (1.51)	1.45 (2.17)**	1.01 (1.24)

Again, no own-price elasticities are significant. As mentioned earlier, it is possible that co-op shoppers are not price sensitive (over small changes in price) for the goods in this research. It is also possible that reducing the number of observations from nearly 1300, to less than 300, decreased the robustness and the consistency of the results.

The cross-price elasticities between organic and non-organic potatoes are significant and positive, indicating that the two types of potatoes are substitutes. Two additional cross-price elasticities are significantly different from zero. Organic potatoes in the in the non-organic onion equation (and vice versa), and organic onions in the organic garlic equation (and vise versa) are each positive and significant.

For this estimation, two income elasticities are significantly different from zero. The expenditure elasticity in the non-organic potato equation is significant and negative, indicating that non-organic potatoes act as an inferior good in this estimation. In the organic potato equation the expenditure elasticity is significant and positive indicating that organic potatoes are a normal good. As in each of the other models presented, all expenditure elasticities are significantly different from one.

Additional Considerations

An additional reason for the lack of negative and significant own-price elasticities was further investigated. The potatoes included in the study may have important purchase choices not included in the data. For all of the other produce items in the study, there are no additional varieties available at the co-op. However, there are two additional varieties of organic potatoes available to consumers. In addition to the organic and non-organic red potatoes used in this research, the co-op also provides organic russet potatoes (5 pound bag), and organic Yukon gold potatoes (bulk).

For this reason, the model was estimated removing both the organic and non-organic potato equations from the model.[8] The results of this estimation were nearly identical to the original estimation except a small number of coefficients lost some significance. Since no own-price parameters gained significance with the exclusion of the two potato equations, it does not appear that the potato equations are distorting the results.

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[8] Each model presented in this chapter was estimated with the two potato equations removed. In the model including employment and education variables and excluding zero purchasers, the estimation converged with biased estimates. In each of the other three models (with education and employment including zero purchasers, without education and employment including zero purchasers, and without education and employment excluding zero purchasers) the estimation results were nearly identical to the original models, except for fewer significant expenditure elasticities.

CHAPTER 6

CONCLUSION

As organic produce sales continue to grow at increasing rates, estimates of own- and cross-price elasticities to aid in retail, wholesale, and farm level decision making are essential. Also essential, with the expanding use of point-of-sale scanner systems, are methods of using this attractive source of data to increase the efficiency of pricing and production decisions. The number of stores using "club membership" or "preferred customer" programs, and the number of transactions with debit or credit cards are steadily increasing. With this innovation, huge sources of consumer-level retail scanner data coupled with socioeconomic data are being created. This data can be used to reveal extensive amounts of information about consumer purchasing behavior.

Organic and non-organic bananas, garlic, onions, and potatoes were selected for this research for because they each had organic and non-organic varieties available to consumers on a daily basis. Also, they are each among the most popular goods at this store in terms of gross sales. Prices and quantities purchased for each of these items were obtained from the point-of-sale scanner system at a co-op food store.

A sample population of 200 members was drawn at random from the membership roster at the Community Food Co-op in Bozeman, Montana. An initial survey was sent to this sample to obtain household income, number of adults and children per household, age of adults, and percent of produce purchased at the co-op. The response rate for this survey was 66%. A second survey was then sent to the same sample members. This survey asked for educational and employment characteristics and had a response rate of 27%.

This study used a level version Rotterdam model to estimate price and income elasticities for a system of organic and non-organic commodities using retail level scanner data. Advantages of the Rotterdam model include straightforward elasticity estimation and the relative ease at which cross- and own-equation restrictions can be imposed. The model is estimated using iterative seemingly unrelated regressions (ITSUR) to account for a contemporaneously correlated error structure.

Empirical results of the study are mixed. Only one own-price elasticity appears significant. The (compensated) demand elasticity for organic onions is negative and significant (at the 5% level of significance) in the model including employment and education variables. A few cross-price elasticities were significant. Organic potatoes and non organic potatoes are substitutes in the model without employment and education variables. Organic potatoes and non-organic onions appear, unexpectedly, to be substitutes in one of the estimations while non-organic potatoes and organic onions are substitutes in two of the estimations.

The absence of significant and negative own-price elasticities was one problem encountered during the course of this research. This lack of significance implies that consumers are non-responsive to small price changes, possibly because they regard the goods in question as staples. Other possible explanations include a lack of price variability over the span of the research and/or a possible zero purchase bias arising from a large number of items not purchased by a given consumer in a given week.

Many of the socioeconomic characteristics included in the estimation are important in making purchasing decisions. Average age of adults, number of adults, and number of children are significant in several equations. Employment characteristics appear very important in making purchasing decisions while educational status does not significantly change consumption patterns for those with any college education relative to those with only a highschool education.

Difficulties others may encounter with using retail-level scanner data for demand analysis include problems arising from the sheer volume of transactions recorded. Even at the relatively small co-op food store in this study, there are over 700 transactions per day recorded by the point-of-sale system. This large volume of data creates data management challenges. Additionally, with every transaction being recorded, individual items are often not purchased by a given consumer during a given trip to the store. This relatively large number of zero purchases may bias demand equation and elasticity estimation.

Features of this study include being one of few existing studies related to organic produce demand. In addition, this research also constitutes a pilot study for the use of scanner data, coupled with socioeconomic data from membership, preferred customer, or debit card users on a larger scale. With the availability of accurate consumer level price and quantity data as well as socioeconomic data, scanner data may be a useful data source for retail level demand analysis.

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APPENDIX A

SURVEY QUESTIONNAIRES

COMMUNITY FOOD COOP
908 W. Main Bozeman, MT 59715
phone: 406-587-4039
fax: 406-587-7955
bozocoop@imt.net

April 10, 1998

Dear Co-op member:

The Co-op, in association with the Economics Department at MSU, is interested in using our new computer system to help develop economic demand information on organic produce. This information will help our produce department in pricing decisions, but also will help the organic produce industry as a whole understand the demand for organic produce.

You were selected at random to participate in this project. If you agree to participate, your purchases of organic produce will be used to compile data for analysis. Of course, complete confidentiality will be maintained.

Please consider participating in this study. If you agree to participate, we need you to complete the survey below and return it in the self addressed, stamped envelope enclosed by April 30th. If you have any questions or concerns please call Dana at the Co-op.

Your member number: __________

The number of adults in your household: ______; their ages: ______, ______, ______, ______.

The number of children (17 and under) in your household: _____.

What percent of the produce you buy is from the Co-op? _____%

What is your annual household income? $___________

Where do you buy produce other than the Co-op?

- ☐ Safeway
- ☐ Buttrey
- ☐ County Market (IGA)
- ☐ Albertsons
- ☐ Town & Country
- ☐ Other: _____________

Thank you for participating in this study.

Dear Coop Customer:

Thank you for responding to our organic produce demand survey last April. We have become aware that some additional information would be helpful in completing our study. Please answer the following three questions to help us improve the quality and availability of organic products here at the Community Coop.

What is your membership number?

Is the primary grocery shopper? (please check one)

❒ A stay-at-home care giver
❒ Employed part-time outside the home
❒ Employed full-time outside the home
❒ Retired

What is the educational level of the primary grocery shopper? (please check highest level)

❒ High school
❒ Some college or other post secondary education
❒ A four-year college degree
❒ Some post graduate education

Please drop this postage-paid postcard in any mail box. Feel free to call Dana at 587-4039 with any questions. Thanks again for your assistance.