

## **ABSTRACT**

CARPIO, CARLOS. Two-Constraints Models of Consumer Demand: An Application to the Demand for Agritourism in the United States. (Under the direction of Michael Wohlgenant.)

This dissertation comprises three essays analyzing the economic behavior of customers visiting farms with recreational purposes in the United States. The first essay uses the Travel Cost method with data from the 2000 National Survey on Recreation and the Environment to determine and quantify the effect of the different factors affecting customers' decisions to visit United States farms for recreational purposes. The estimates of the own price elasticity and income elasticity of farm recreational trips are -0.13 and 0.06, respectively. The total consumer surplus generated from the agricultural landscape was estimated in 24.6 billion dollars, which is about one half of the last 10 years average of the US total net farm income, calculated in around 50 billion dollars.

The second and third essays develop two different methods to analyze consumer behavior of individuals when time is an important component of the decision process. The inclusion of the time dimension into the consumer problem is motivated by the analysis of consumer behavior of one specific type of agritourism: pick-your-own (PYO) activities. The inclusion of the time dimension is necessary in this context since the purchase of PYO fruit involves both time and money costs. Moreover, the time spent harvesting the fruit is perceived by most of the customers as a recreational activity.

The second essay develops a fully structural econometric consumer demand model. The third essay considers the problem from a different perspective and assumes a deterministic decision framework. Based in the comparative statics of the solutions to this

optimization problem, a theoretical consistent incomplete demand system of equations is proposed.

The models are used to analyze customers' decision to buy pick-your-own versus pre-harvested fruit at North Carolina pick-your-own fruit operations. The empirical application distinguishes the double effect of time as a resource constraint and also providing utility. Elasticity estimates show that strawberries sold at pick-your-own operations are price elastic, with pick-your-own fruit being less price elastic than pre-harvested fruit.

Two-Constraints Models of Consumer Demand: An Application to the Demand for  
Agritourism in the United States

by  
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DEDICATION

A mi familia  
(To my family)

## BIOGRAPHY

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## TABLE OF CONTENTS

|   | Pages |
|---|-------|
| List of Tables . . . . .  | vii   |
| <br>  |       |
| <b>1. Introduction</b>  |       |
| 1.1. General Trends in the Demand and Supply of Agritourism . . . . .                         | 2     |
| 1.2. Importance of Pick-your-own Marketing . . . . .  | 3     |
| 1.3. Objectives . . . . .   | 5     |
| 1.4. Dissertation Overview . . . . .  | 6     |
| References . . . . .  | 8     |
| <br>  |       |
| <b>2. The Demand for Agritourism in the United States</b>                                     |       |
| 2.1. Introduction . . . . .   | 10    |
| 2.1.1. Agritourism: Definition and Trends . . . . .   | 11    |
| 2.1.2. The Non-market Value of Rural Landscape . . . . .                                      | 13    |
| 2.2. Economic Framework . . . . .   | 14    |
| 2.2.1. Value of the Rural Landscape . . . . .   | 15    |
| 2.3. Econometric and Empirical Model . . . . .  | 16    |
| 2.3.1. Consumer Surplus Calculations . . . . .  | 20    |
| 2.4. Data . . . . .   | 22    |
| 2.5. Results and Discussion . . . . .   | 23    |
| 2.5.1. Probit Model . . . . .   | 23    |
| 2.5.2. Count Regression Model . . . . .   | 25    |
| 2.5.3. Consumer Surplus . . . . .   | 27    |
| 2.5.4. Robustness of Results to Model Assumptions . . . . .                                   | 28    |
| 2.6. Summary and Conclusions . . . . .  | 30    |
| References . . . . .  | 32    |
| <br>  |       |
| <b>3. A Structural Econometric Model of Consumer Demand at Pick-Your-Own Fruit Operations</b> |       |
| 3.1. Introduction . . . . .   | 37    |
| 3.1.1. Importance of Direct Marketing in the U.S. Agriculture . . . . .                       | 38    |
| 3.1.2. Literature on the Demand for Pick-your-own Fruit . . . . .                             | 40    |
| 3.2. Theoretical Framework . . . . .  | 43    |
| 3.3. Data and Estimation Procedures . . . . .   | 50    |
| 3.3.1. Data . . . . .   | 50    |
| 3.3.2. The Income Variable . . . . .  | 50    |
| 3.4.3. Opportunity Cost of Time Variable . . . . .  | 51    |
| 3.4. Estimation Procedures . . . . .  | 52    |
| 3.4.1. Estimation of the Parameters of the Discrete Choice Probability . . . . .              | 53    |
| 3.4.2. Estimation of the Parameters of the Continuous Choice . . . . .                        | 55    |
| 3.5. Results . . . . .  | 57    |
| 3.5.1. Discrete Choice Model . . . . .  | 57    |
| 3.5.2. Continuous Choice Models . . . . .   | 60    |
| 3.6. Summary and Conclusions . . . . .  | 63    |

|  |     |
|--|-----|
| References   | 64  |
| Appendices   | 73  |
| Appendix 3.1. Derivation of Solutions to Maximization Problem                                  | 73  |
| Appendix 3.2. Parameters of Reduced Form Discrete Choice Model<br>and Auxiliary Time Equations | 74  |
| Appendix 3.3. Log-Income Equation Estimation Results   | 75  |
| Appendix 3.4. Derivation of the Elasticities for the Aggregate Goods                           | 76  |
| <b>4. The Theory of the Economics of Time Revisited</b>  |     |
| 4.1. Introduction  | 77  |
| 4.2. Consumer Problem  | 78  |
| 4.2.1. Comparative Statics of Solutions  | 81  |
| 4.2.2. Slutsky-Hicks Equation  | 83  |
| 4.2.3. Roy's Identity  | 85  |
| 4.2.4. Negative Semidefiniteness and Symmetry Conditions                                       | 86  |
| 4.2.5. Homogeneity   | 92  |
| 4.2.6. Comparison of Properties of Demand Functions  | 92  |
| 4.3. Implications for Empirical Analysis   | 93  |
| 4.4. An Incomplete Demand System Consistent with the Theory                                    | 96  |
| 4.5. Empirical Application   | 99  |
| 4.5.1. Data  | 99  |
| 4.5.2. Estimation Procedures   | 101 |
| 4.6. Empirical Results   | 104 |
| 4.7. Summary and Conclusions   | 107 |
| References   | 109 |
| <b>5 Dissertation Summary and Conclusions</b>  | 114 |



## List of Tables

|  |     |
|--|-----|
| 1.1. Number of Farmers Participating in Pick-your-own (PYO) Marketing and Value of Sales of Fruit and Berries in the State of New York (1980, 1987 and 2000) | 9   |
| 2.1. Summary Statistics of the Variables used in the Probit Analysis   | 34  |
| 2.2. Results of the Probit Analysis for the Decision to Visit Farm Operations with Recreational Purposes   | 34  |
| 2.3. Summary Statistics of the Variables used in the Count Regression Model of Number of Trips to Farms  | 35  |
| 2.4. Results of the Poisson Regression for the Number of Recreational Trips to Farms   | 36  |
| 2.5. Consumer Surplus of Farm Trips  | 36  |
| 3.1. Summary Statistics of Characteristics of Customers Visiting Pick-your-own Fruit Operations in North Carolina  | 67  |
| 3.2. Maximum Likelihood Estimation of Structural Parameters of Discrete Choice (Probability of buying Pick-your-own Strawberries)                            | 68  |
| 3.3. OLS Structural Parameters of Continuous Choice (Conditional Quantities Demanded)  | 69  |
| 3.4. Marginal Effects of Variables: Unconditional Demand for Pick-your-own Strawberries  | 70  |
| 3.4. Marginal Effects of Variables: Unconditional Demand for Pre-harvested Strawberries  | 71  |
| 3.5. Elasticities Estimates  | 72  |
| 4.1. Comparison of the properties of the demand functions for alternative consumer optimization problems   | 111 |
| 4.2. Tests of the Demand Restrictions  | 111 |
| 4.3. Parameters Estimates of the Demand Equations  | 112 |
| 4.4. Marginal Effects and Elasticities   | 113 |

## **Chapter 1**

# **Introduction**

Agritourism refers to those activities that include visiting a working farm or any agricultural operation to enjoy, to be educated or to be involved in what is happening on the operation. Visit to farms with recreational purposes is also referred in the literature as agricultural tourism or farm recreation. Examples of agritourism activities are pick-your-own produce, Christmas tree sales, hayrides, children's educational programs, petting zoos, and on-farm festivals.

This dissertation comprises three essays analyzing the economic behavior of customers visiting farms with recreational purposes in the United States. Previous studies about agritourism have mainly focused on the motivations of farmers to start agritourism enterprises. In this study we focus on the factors affecting consumers' participation in agritourism.

The first part of the dissertation (Chapter 2) analyzes the factors affecting U.S. customers' decisions to visit farms with recreational purposes. This is an analysis done at the national level using a representative sample of the U.S. population. The second part

(Chapters 3 and 4) analyzes consumer purchasing behavior in a particular type of agritourism activity, pick-your-own (PYO) fruit operations in North Carolina.

### **1.1. General Trends in the Demand and Supply of Agritourism**

Agritourism is a segment within the larger sector of rural tourism. Rural tourism is based on the rural environment in general whereas agritourism is based on the farm and the farmer (Fleischer and Tchetchik, 2005). The recent growth in agritourism is both demand and supply driven. Several factors are believed to be increasing the demand for agritourism. First, the demand for outdoor recreation in general is rising due to increases in discretionary income. Second, people are doing more traveling as a family, traveling by car and looking for more activities involving experiences (Randall and Gustke, 2003). Finally, there is evidence of a growing concern by the public to support local farmers (Govindasamy, Italia and Adelaja, 2002).

Several reasons have also led farm families to explore the viability of alternative economic strategies in an effort to preserve the family farm, among others: a declining labor force, changing farm structure, increased intensification and specialization of farming activities, poor agricultural commodity prices, rising production costs, globalization, industrialization, the encroachment of suburban development, loss of government-supported agriculture programs, and the elasticity of commodities markets (Rickard, 1983; Fleischer and Pizam, 1997).

As mentioned previously, agritourism includes several types of activities. One of these activities is pick-your-own products. Since in the second part of the dissertation we

analyze the behavior of customers visiting this type of operations, the next section presents an overview of the importance of PYO marketing as part of U.S. agriculture.

## **1.2. Importance of Pick-your-own Marketing**

In addition of being a recreation activity, PYO activities constitute a form of farmer to consumer direct marketing. Moreover, the marketing dimension of the activity has been the focus of most of the previous studies on the subject. Direct marketing alternatives for farmers include PYO operations, farmers' markets, farm stands and roadside stands. More recently, internet marketing and niche markets have also appeared as direct marketing alternatives for farmers.

In the United States PYO marketing dates back at least some 80 years. One of the earliest documented experiences of PYO marketing is from producers in Wisconsin in the early 1920's (Morris, 1979). In recent years, the rise in popularity of direct marketing has been attributed mostly to the growing consumer interest in obtaining fresh products directly from the farm. From the farmers' perspective, small to medium size growers can increase the profitability of the farm by selling their products at higher prices directly to the consumer.

Only very few surveys have gathered state level data on the number of pick-your own operations and the value of the products sold using this marketing channel. This makes it difficult to gauge the importance of these operations and its evolution through time in different states.

One of the most extensive efforts to measure the extent of the different direct marketing alternatives in the U.S was carried out by USDA in 1978, 1979 and 1980 (Henderson and Linstrom, 1980; 1982). Twenty two states were included in the surveys. These surveys show that, on average, 8.5 % of the farmers in these states sold their products using PYO marketing and an average of 8.5% of their direct sales were done using this marketing alternative. For fruits and nuts the share of total direct sales was higher, averaging 30% in the 22 states.

New York is probably one of the few states that has available data on the number and volume of sales of PYO farms in several years. Table 1.1 shows the number and percentage of farmers participating in PYO marketing in the state. This table also shows the value of products sold using this marketing alternative. Both the number of farmers as well as the percent of farmers using PYO to market their products increased during the period from 1979 to 2000. The number of farmers shows an increase of 150%. On the other hand, the importance of PYO assessed as the share of total direct of sales decreased in the period from 1979 to 1987, but increased from 1987 to 2000.

A problem when trying to assess the importance of direct marketing is that the data provided by the USDA Census of Agriculture is not consistent with data obtained at the state level. For example, for New York, the USDA Census of Agriculture 2002 report that 4,651 farmers participate in direct marketing and the value on direct sales is estimated around \$60 million. On the other hand, the NYASS (2002) reports 6,667 farmers participating in direct marketing and a value of \$230 million for direct sales from which around \$60 million corresponds to PYO marketing.

Even though at the aggregate level PYO marketing is small compared with other marketing channels, for some states and agricultural products PYO marketing is relatively more important. A recent survey carried out by the University of Kentucky Cooperative Extension Service shows that more than half of vegetables and fruit producers participate in direct marketing. Sixteen percent reported using PYO to market their products and 31% said they are interested in using PYO marketing in the future (Ernst and Woods, 2004). Also, from Table 1.1 we can see that in the year 2000, in the state of New York the value of PYO sales of fruit and berries was about 25% of the value of total direct sales.

Despite the growing interest by U.S. customers and farmers to participate in agritourism activities, the literature review indicated a paucity of studies dealing with the demand for these activities. Therefore, there is need for further research to try to understand the factors affecting consumers' demand for these activities. This information can be helpful to farmers considering an agritourism enterprise and also to development planners who are considering agritourism as an option to promote regional economic development.

### **1.3. Objectives**

The general objective of this dissertation is to analyze the behavior of customers participating in on-farm recreation activities. The specific objectives are:

- (1) To determine and quantify the factors affecting U.S. consumers' decisions to visit farms with recreational purposes.

- (2) To develop theoretical and empirical models of consumer behavior when utility is a function of the commodities and the time allocated to them and the consumer is subject to two budget constraints.
- (3) To analyze empirically the factors affecting the behavior of consumers attending pick-your-own fruit operations.

Given the unique characteristics of the demand for PYO fruit, the empirical analysis of consumer behavior at PYO operations motivated the analysis of the inclusion of time (both as a resource constraint and as source of utility) into the consumer demand problem. This was necessary since traditional economic models of consumer behavior assume that the demand for goods originates from an optimization problem where consumers are maximizing utility from the consumption of goods subject to a budget constraint. The effect of time in the utility function and as a resource constraint (time constraint) has received little attention in the context of the demand for goods.

#### **1.4. Dissertation Overview**

This dissertation has a three essay format and each essay stands alone and can be read separately. The first essay (Chapter 2) looks at the issue of the demand for agritourism at the national level. The second and third essays (Chapter 3 and 4) study the economic behavior of customers participating in a specific type of agritourism: pick-your-own fruit. The three essays are complementary since they focus on different choice margins. The first essay looks at the decision to visit or not visit farms and also the total

number of visits to farms. The second and third essays study the buying behavior of individuals visiting PYO farm operations.



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**Table1.1. Number of Farmers Participating in Pick-your-own (PYO) Marketing and Value of Sales of Fruit and Berries in the State of New York (1980, 1987 and 2000)**

| Year | Farmers participating in PYO marketing |         | Value of sales  | Value of sales of fruits and berries                  |
|------|--|---------|---|---|
|      | Number                                 | Percent | (Percent of sales in relation to total direct sales ) | (Percent of sales in relation to total direct sales ) |
| 1979 | 592                                    | 5.8     | 6.7   | 31  |
| 1987 | 748                                    | 12.0    | 3.7   | 19  |
| 2000 | 1475                                   | 22.0    | 7.4   | 26  |

Sources:

Henderson, P.L., and H.R. Linstrom. Farmer to Consumer Direct Marketing, Selected States, 1979-1980. National Economics Division, Economic Research Service, U.S. Department of Agriculture. Statistical Bulletin No. 681. February, 1982.

New York Agriculture Statistics Service (NYASS). "2000 Direct Market Survey Highlights." December 16, 2002. (<http://www.nass.usda.gov/ny/DirectMktng2001/DirectMarketing2000.pdf>, February 15, 2005).

## **Chapter 2**

# **The Demand for Agritourism in the United States**

### **2.1. Introduction**

In addition to producing food and fiber, farms provide other rural amenities to the public. Some of these amenities can be marketed as private goods, whereas others are public goods and do not have a market. One of the marketed amenities is on-farm recreation, also called agritourism or agrotourism. Besides the market goods or services obtained at the farm operations, visitors to farms also obtain benefits derived from the scenic beauty generated by the rural landscape.

The objectives of this study are two-fold: 1) To determine and quantify the effects of different factors influencing customers' decisions to visit farms, and 2) To provide an estimate of the recreational value of the rural landscape in the United States.

Previous studies about agritourism have mainly focused on the motivations of farmers to start agritourism enterprises. The literature on the subject of demand for farm recreation is limited; therefore, there is a need for further research in this area. The

assessment of the nonmarket benefits of the rural landscape in the United States has not received much attention either. Most of the work in this area has been done for a small region and has focused exclusively on the benefits received by rural residents. The focus of this study is the recreational value of the rural landscape to farm visitors.

### **2.1.1. Agritourism: Definition and Trends**

Agritourism refers to those activities that include visiting a working farm or any agricultural operation to enjoy, to be educated or to be involved in what is happening on the operation. Agritourism is a segment within the larger sector of rural tourism. Rural tourism is based on the rural environment in general whereas agritourism is based on the farm and the farmer (Fleischer and Tchetchik, 2005). Examples of agritourism activities are pick-your-own produce, christmas tree sales, hayrides, children's educational programs, petting zoos, and on-farm festivals.

The recent growth in agritourism is both demand and supply driven. On the supply side, economic pressures have forced farmers and ranchers to augment their income through diversification, both within agriculture itself, and through non-agricultural pursuits. On the demand side, people's interest in farm activities has increased in the last years.

It has been estimated that 62 million Americans visited farms one or more times in 2000, which corresponds to almost 30% of the population (Barry and Hellerstein, 2004). Several factors are believed to be increasing the demand for agritourism. First, the demand for outdoor recreation in general is rising due to increases in discretionary income. Trends and future projections indicate continued increases in the number of

participants, trips, and activity days for outdoor recreation as well as the increase of multi-activity but shorter trips (English et al., 1999). Second, people are doing more traveling as a family, traveling by car and looking for more activities involving experiences (Randall and Gustke, 2003). Finally, there is evidence of growing concern by the public to support local farmers (Govindasamy, Italia and Adelaja, 2002). This growing interest for rural life has also been observed since the early 1990s in other developed countries such as Japan (Ohe, 2002).

Several factors have led farm families to explore the viability of alternative economic strategies in an effort to preserve the family farm, among others: a declining labor force, changing farm structure, increased intensification and specialization of farming activities, poor agricultural commodity prices, rising production costs, globalization, industrialization, the encroachment of suburban development and the loss of government-supported agriculture programs (Rickard, 1983; Fleischer and Pizam, 1997). Agritourism brings diversification opportunities to farms and ranchers that can help buffer fluctuating markets. It can increase farm revenue and increase community economic activity. It can provide economically feasible ways to care for natural habitats, natural scenic areas, national resources, and special places (Keith et al., 2003).

Income from agritourism provides farmers with approximately \$800 million per year. Even though the percentage of farms with income from agritourism at the national level is only about 2%, in some Midwest states 7% of farms receive income from this activity (Barry and Hellerstein, 2004).

Previous studies about agritourism have mainly focused on the motivations of farmers to start agritourism enterprises. In this study we focus on the factors affecting the demand for agritourism in the United States. This information can be helpful to farmers considering an agritourism enterprise and also to development planners who are considering agritourism as an option to promote regional economic development.

### **2.1.2. The Non-market Value of Rural Landscape**

The public environmental amenity benefits of rural land have long been recognized. These amenities include wildlife habitats, open spaces, aesthetic scenery and cultural preservation (Fleischer and Tsur, 2000). However, given their characteristics of nonexclusivity (available to the general public) and nonrivalry (consumption by one person does not affect consumption by another person), rural land amenities escape adequate consideration by private markets (Bergstrom et al., 1985). Therefore there might be the need for some sort of policy intervention which, in turn, requires measurement of the value of this public good.

Several researchers have assessed the nonmarket benefits of rural land in the United States, Canada and Europe. Most of these studies have focused on the valuation of the rural landscape by residents (e.g., Bowker and Didychuck, 1994; Bergstrom et al., 1985; Bateman et al., 1994). For example, Bowker and Didychuck (1994) estimate the nonmarket benefits of land retention in Eastern Canada using the contingent valuation method. The extra-margin benefit of retaining farmland was estimated at about \$97 per acre or about 6 to 16 percent of land prices. Bergstrom et al. (1985) estimated the

willingness to pay for the environmental amenity benefits of agricultural land in Greenville County, South Carolina. Aggregate amenity benefits of prime agricultural land were estimated at approximately \$13 per acre.

The valuation of the non-market benefits of the rural landscape to rural visitors has received less attention. Fleischer and Tsur (2000) measured the recreational use value of agricultural landscape for two regions in Israel combining the travel cost (TC) method with contingent based information regarding the influence of the agricultural landscape in the visitation decisions. These authors found that the landscape value of farmland is higher than the returns to farming. In the United States, Rosenberger and Loomis (1999) studied the benefits to tourists associated with ranch open space in a resort area in Colorado. To estimate the benefits these authors use the TC method and the Contingent Behavior (CB) where respondents are asked how their current visitation would change with a change in site quality. These authors found that there was no net effect from converting the existing ranchland to urban and resort development uses.

## **2.2. Economic Framework**

The decision making behavior of individuals visiting farms can be analyzed using a two stage framework. The first stage is the decision to visit farm operations. The second stage involves the number of subsequent visits to farms.

The decision to visit or not visit farms can be analyzed using a random utility model. Under this framework the observed choice between two alternatives is the one providing the higher level of utility (Greene, 2003). Therefore binary choice models such

as the logit or probit formulations can be used to model household decisions to visit or not visit farms with recreational purposes. The choice of this framework for the discrete choice has also has an empirical justification since the price or cost of the trips for non farm visitors is unknown.

For farm visitors, the demand for farm trips can be formulated using the TC method. This method specifies the demand for trips as a function of travel costs, income and other socio-demographic characteristics of the individual. This framework is justified by the fact that the total price of visiting a farm includes travel expenses and expenditures at the farm locations plus the opportunity costs of traveling to the farm. The demand for visits to farms can be represented by a general travel cost model:

$$ntrips = f(Tc, y, d, q) \quad (1)$$

where  $ntrips$  is the number of trips to farms with recreational purposes,  $Tc$  is the implicit price or travel cost to the farms,  $y$  is the household income,  $d$  is a vector of demographic characteristics of the group or its representative, and  $q$  is a vector of characteristics of the site.

### **2.2.1. Value of the Rural Landscape**

The method used to value the rural landscape follows closely the method proposed by Fleischer and Tsur (2000). Specifically, this procedure allows measuring the recreational use value of the rural landscape. Other use and non-use values of the rural landscape are not considered in this paper. The following assumptions are necessary in this procedure:



- (1) Assume that different levels of the rural landscape can be represented by an index  $R_q$ . This index can be thought to represent a weighted sum of the shares of land covered by different landscapes characteristics (e.g., land in pasture, farmsteads, orchards, residential areas, etc.).
- (2) The rural landscape affects the demand for farm trips as a demand curve shifter. Therefore, the recreational use value can be defined and measured by changes in consumer surplus associated with varying levels of the agricultural landscape index  $R_q$ .

### **2.3. Econometric and Empirical Model**

An econometric specification that allows us to model farm visitors' behavior in the proposed two part decision process is the hurdle count model. The hurdle count data model combines a dichotomous model for the binary outcome being above or below the hurdle, and a truncated count model for outcomes above the hurdle. In our application the hurdle is the visit or not visit to farms during the last year. Because of the discrete nature of the number of trips to farms, a count model is necessary for the outcomes above the hurdle (Winkelmann, 2003).

The general formulation of a hurdle count model assumes that  $f_1(0)$  is the probability of a zero outcome, and that  $f_2(k)$ ,  $k=1,2,3\dots$  is the probability function for positive integers. The probability function of the hurdle-at-zero model is given by:

$$\begin{aligned}
P(Y = 0) &= f_1(0) \\
P(Y = k) &= (1 - f_1(0)) \frac{f_2(k)}{1 - f_2(k)} \quad k = 1, 2, \dots
\end{aligned} \tag{2}$$

The term  $\frac{f_2(k)}{1 - f_2(k)}$  corresponds to the truncation of  $f_2(k)$  at zero since most of the count data distributions have support over the nonnegative integers. In our application we use the univariate probit model to model the probability of the binary outcome (visit vs. non-visit) and a Poisson model for the number of trips. The probability function of a Poisson distribution is:

$$P(Y = k) = \frac{\exp^{-\lambda} \lambda^k}{k!} \quad \lambda \in R^+, k = 0, 1, 2, \dots \tag{3}$$

Since the distributions are conditional on the explanatory variables, a common assumption in the context of the Poisson regression model is to make the parameter  $\lambda$  a function of the explanatory variables. The most common formulation for  $\lambda$  is the loglinear model (Greene, 2003):

$$\ln \lambda = x' \beta \tag{4}$$

where  $x$  is the vector of explanatory variables and  $\beta$  is a parameter vector. The probability function of the probit-poisson regression model is then:

$$P(Y_i = 0 | x_i) = \Phi(x_i' \beta) \tag{5.1}$$

$$P(Y_i = y_i | x_i) = (1 - P(Y_i = 0 | x_i)) \frac{\exp(-\exp(w_i' \theta)) (\exp(y_i w_i' \theta))}{y_i! (1 - \exp(-\exp(w_i' \theta)))} \quad y_i = 1, 2, \dots \tag{5.2}$$

where  $x_i$  is the vector of covariates explaining the binary choice and  $\beta$  is the corresponding parameter vector,  $w_i$  is the vector of covariates determining the conditional probabilities in the Poisson process and  $\theta$  is the corresponding parameter vector. The

subscript  $i$  is included to indicate that the observation corresponds to the  $i$ th household.

$\Phi(\cdot)$  is the cumulative density function of a standard normal distribution.

Tables 2.1 and 2.3 present the description of the variables included in the binary choice model for the decision to visit or not visit to farms and the variable considered in the Poisson model for the annual number of trips to farms. The demographic variables are the same for both models. However, given that no information is available about farm trips for non-visitors, the variables related to farm trips are not included in the binary choice model. The specification of the mean in the probit model can be interpreted as a reduced form of a model in which prices represent quality differences caused by heterogeneous commodity aggregation and the household characteristics are a proxy for household preferences over unobservable quality characteristics (e.g., Davis and Wohlgenant, 1993).

The log-likelihood function for probit-poisson regression model is given by:

$$L(\beta, \theta | x_i, w_i) = \sum_{i=1}^N d_i \ln \Phi(x_i' \beta) + (1 - d_i) \ln[1 - \Phi(x_i' \beta)] \\ + (1 - d_i)[- \exp(w_i' \theta) + y_i w_i' \theta - \ln(y_i!) - \ln(1 - \exp(- \exp(w_i' \theta)))] \quad (6)$$

where  $d_i = 1 - \min\{y_i, 1\}$ . The first two terms correspond to the log-likelihood of the hurdle step and the third term is the log-likelihood for positive counts. Therefore, this log-likelihood is separable and maximizing can be simplified by maximizing the probit model log-likelihood using all observations, and then the log-likelihood for the truncated variable using the subset of observations for which the counts are possible. Both models can be maximized using Newton's optimization method.

Phanuef and Smith (2004) argue that hurdle models use different data generating process to explain the likelihood of consumers being one of three types: nonusers, potential users and users. Potential users' utility function contain trips to the recreational sites but the trip site is equal or above their choke price. On the other hand, nonusers will never visit a site regardless of the price. The use of this rationality to classify consumers gives alternative interpretations to the hurdle model results. From this perspective, the truncated count model can be seen as recovering the parameters of the demand for trips by users and potential users using only a sample of users. To make this point clear, consider the mean of the truncated poisson distribution which is (Winkelmann, 2003):

$$E(y_i | \lambda_i, y_i > 0) = \frac{\lambda_i}{1 - \exp(-\lambda_i)} \quad (7)$$

This equation represents the mean quantity demanded by users. On the other hand, under the assumption that the number of trips follows the Poisson distribution, if the mean of interest is the mean quantity demanded by both users and potential users, then this mean is estimated by:

$$E(y_i | \lambda_i) = \lambda_i, \quad (8)$$

and the truncated model is only used as a mean to recover the parameters of the mean of the untruncated distribution.

If the mean quantity demanded of interest is the whole population demand (users, potential users and non-users) then the mean demand is equals the probability of crossing the hurdle times the expected value of the truncated at zero Poisson distribution:

$$E(y_i | \lambda_i) = \Phi(x_i' \beta) \frac{\lambda_i}{1 - \exp(-\lambda_i)} \quad (9)$$

However, this formulation implicitly assumes that all the households with zero trips belong to the non-users group. Unfortunately, there is not enough information to identify the groups of potential users and non-users and therefore the probability of crossing the hurdle is underestimated. The survey only identified consumers with zero trips and consumers with at least one trip. Therefore this mean quantity demanded can be seen as a lower bound of the mean quantity demanded by the population.

### 2.3.1. Consumer Surplus Calculations

If the consumer surplus of interest is the consumer surplus of the groups of uses and potential users, then the consumer surplus equals  $\lambda_i / \beta_{TC}$  where  $\beta_{TC}$  is the parameter corresponding to the total cost of the trip variable (Creel and Loomis, 1990). On the other hand, if the consumer surplus of interest is the population consumer surplus, it can be shown that the consumer surplus equals:

$$\int \Phi(x_i' \beta) \frac{\lambda_i}{1 - \exp(-\lambda_i)} dTC = \frac{\Phi(x_i' \beta)}{\beta_{TC}} (\lambda_i + \ln(1 - e^{-\lambda_i})) \quad (10)$$

As mentioned previously since it is not possible to differentiate non-users from potential users, equation (10) does not include the price effect in the potential-users group.

The consumer surplus expressions presented previously measure the benefit of the recreational trips to the farms as a whole, of which only part originates from the rural

scenery. The calculation of the benefit derived from the rural scenery requires the evaluation of the demand without (or at different levels) of the rural landscape. However, the loss of the agricultural landscape is a future contingency for which no actual visitation data are available. Therefore, we follow Fleischer and Tsur (2000) and use a hypothetical question regarding the importance of the rural landscape in the decision to visit farms.

The question asked to farm visitors was “In general, when deciding to visit the farm, how important was it to enjoy the rural scenery around the farm?” (such as the variety of animal life, the mixture of crops, or the appearance of farm barns and silos) The interviewees had to select between “important,” “somewhat important,” and “not at all important.” Hence, we define the variable  $V_{ij}=2$  if the individual response was “important,”  $V_{ij}=1$  if the individual response was “somewhat important,” and  $V_{ij}=0$  if the answer was “not at all important.” The component in (4) corresponding to the effect of the rural landscape in the demand for trips can then be written as  $V_{ij}Rq\beta_{Rq}$ , where  $Rq$  is the rural landscape index as explained previously and  $\beta_{Rq}$  is the corresponding parameter. Without loss of generality we can use the normalizing assumption that the level of the rural landscape is a number between 0 and 1. The actual level of the rural landscape can be set to 1, i.e.,  $Rq=1$  and the index can be set to zero when the rural landscape vanishes<sup>1</sup>.

The effect of the rural landscape in the decision to visit can be measured by the effect in the predicted mean of the number of trips and consequently in the consumer surplus per visitor per year. This can be done by calculating the predicted mean at the current level and the predicted mean assuming that the rural landscape vanishes, i.e.,

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<sup>1</sup> This is a first approximation to the value. In practice, every state and even every region will have a different value for the index of the agricultural landscape.

$Rq=0$  for all the observations. The change in the consumer surplus under the two assumptions can be seen as a measure of the benefit of the rural landscape.

## 2.4. Data

The data for the estimation of the model come from the 2,000 National Survey on Recreation and the Environment (NSRE). This National Survey is administered through a partnership between the Forest Service Research Group on the University of Georgia campus in Athens, and the Human Dimensions Research Laboratory at the University of Tennessee in Knoxville. The NSRE's main purpose is to describe and explore participation in a wide range of outdoor recreation activities by people 16 years or older in the United States. More information about the survey can be found in Cordell (2004).

The NSRE is one of the few nationwide surveys that includes information about Americans visiting farms. Out of the 25,010 NSRE respondents, 7,820 reported visiting a farm which represents about 31% of the sample. Of the 7,820 "farm visitors", 1,604 were interviewed about farm recreation.<sup>2</sup> A very detailed presentation of the results of the survey can be found in Barry and Hellerstein (2004).

The random sample of farm visitors who were interviewed about agritourism comprises only 21% of the total of respondents reporting visiting farms the previous year, therefore for the probit analysis a proportional random sample was obtained from the non-visitors group. Since observations with missing values were deleted from the sample, a total of 1,524 visitors and 3,411 non-visitors were included in the probit analysis.

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<sup>2</sup> Our numbers differ slightly with those presented by Barry and Hellerstein (2004).

For the count regression model only a subsample of 1,033 individuals was used for the analysis. The observations excluded from this subsample included observations with missing values and observations of individuals who traveled more than 500 miles and spent more than a \$1,000 during the trip. These observations were deleted to ensure that the travel was done by car. Moreover, the results were robust to the exclusion of these observations.

The total cost variable ( $T_c$ ) includes the monetary costs of the trip plus the opportunity cost of time. The opportunity cost of time variable was obtained by dividing the distance traveled by an average speed of 55 miles/hour and multiplying this value by one third of the hourly wage (annual family income divided by 1,800 hours) (Phaneuf and Smith, 2004, p. 29). Travel costs were estimated by multiplying the distance traveled times the per mile cost of traveling by car. The AAA estimated that in 2,000 the average cost per mile of driving a car was 49.1 cents.

## **2.5. Results and Discussion**

### **2.5.1. Probit Model**

Table 2.1 presents the summary statistics of the variables used in the probit analysis. Even though we have not tested for statistical differences, the values of the variables in the farm visitors and non visitors groups are very similar. When comparing the average farm visitor and the average non-visitor, the average farm visitor is more educated, has a higher family income, is younger and belongs to a household with more family members than the average non-visitor. The group of farm visitors included a



higher percent of visitors that were white, males, living in the rural area, employed and with children under six years old.

Table 2.2 presents the results of the probit analysis which models the decision to visit a farm or not visit farms. The results indicate that white households are more likely to visit farm operations whereas Hispanic households are less likely to visit farm operations. People living in rural areas and with children under six years old are also more likely to visit farms with recreational purposes. An increase in the age of the individual decreases the probability of visiting a farm. On the other hand, an increase in the family income and the number of members in the family increases the probability of becoming a farm visitor. The final specification of the probit model in Table 2.2 did not include years of education since it is highly correlated with family income. When the two variables are included together in the model, only years of education is statistically significant.

In the probit model, the coefficients are not the marginal effects. Table 2.2 also displays the marginal effects of the explanatory variables in the probit model. The marginal effects of the parameters corresponding to dummy variables are the effects in relation to an individual with characteristics of the dummy variables not included in the model (unemployed; race other than white, black and Hispanic; female; living in the rural area; with no children under 6 years old; and which is not a student, retired or homemaker). Relative to this type of respondent a respondent who is white is almost 10% more likely to visit farms. On the other hand a customer who is Hispanic is 13% less likely to visit farm operations. Someone living in the urban area is 5% less likely to visit

a farm. Finally, the presence of children under six years old makes a household 4% more likely to visit a farm.

The marginal effects of the continuous variables represent the change in the probability of choosing an alternative for a one unit change in the variable. Each additional person in the household increases the probability that the person will visit farms by about 1%. An increase in one year in the age of the respondent decreases the probability of visiting farms by only 0.2%. The marginal effect corresponding to income implies that a 1% increase in income increases the probability of visiting a farm around 0.07%. The marginal effects of the other variables included in the model are not statistically significant, nor are they economically important.

### **2.5.2. Count Regression Model**

Table 2.3 presents the summary statistics of the variables used in the count regression model of the number of trips to farms. The average number of trips to farms by visitors is 10.32 with an average cost of about \$41.5 per trip and an average distance traveled to the farm of 61.8 miles. The values of the socioeconomic characteristics of the visitors are similar to those presented in the probit model.

Table 2.4 shows the results of the Poisson count regression model. As expected the cost of the trip has a negative effect on the number of trips. The effect of the travel cost variable expressed in elasticity terms indicates that a 1% percent increase in travel costs causes a 0.13% reduction in the number of trips.

The marginal effect of income translated to elasticity indicates that a 1% increase in income increases the average number of trips by 0.06%. Age and years of education have a quadratic effect on the number of trips. This indicates that the number of trips increases as the age and years of education increases, reaches a maximum and then the number of trips decreases with further increases in age or years of education. The age at which the number of trips is maximum is 40 years and the years of education at which the number of trips is maximum is 14 years of education.

The variable corresponding to the importance of rural landscape indicates that people who consider the rural landscape as an important factor when deciding to visit a farm operation make more trips to farms than people who consider the rural landscape unimportant. Specifically, people who consider enjoying the rural scenery around the farm as “somewhat important” make on average 0.8 more trips than people who think that enjoying the rural scenery is “not at all important.” People who consider enjoying the rural landscape as “important” make on average 1.6 more trips compared to the latter group of people.

The marginal effects of the parameters corresponding to dummy variables in this model are also the effects in relation to an individual with characteristics of the dummy variables not included in the model (unemployed; race other than white, black and Hispanic; female; living in the rural area; with no children under 6 years old; and which is not a student, retired or homemaker). Relative to this type of respondent a respondent who is white will make 3.7 more trips whereas a respondent who is Hispanic will make 2.4 less trips. People living in the rural area will make on average about 7 more trips to

farms than those living in urban areas. Male respondents make on average 3.5 more trips than females. Retired people make on average almost 2 more trips to farms. Being a student and homemaker have also a positive effect on the number of trips relative to the baseline respondent, making around 1 more trip to farms compared to the baseline respondent. Other variables were not statistically significant nor economically important, except for the dummy variable for black respondent which indicates that on average black visitors make 2 less trips compared to the baseline respondent.

### **2.5.3. Consumer Surplus**

The results of the calculations of consumer surplus are presented in Table 2.5. The estimated consumer surplus for the average consumer in the group of visitors and potential visitors is \$312.5/trip, of which \$38.4 is due to the rural landscape. This value indicates that around 12% of the consumer surplus would be generated by the rural landscape. The consumer surplus for the average person in the U.S. population is \$96.9/trip, of which \$11.6 is due to the rural landscape<sup>3</sup>. In Israel, Fleischer and Tsur (2000) estimated values of \$167 and \$49 for the per trip agricultural landscape induced-surplus in two regions of that country.

Using the estimated 62 millions of visitors to farm operations and the predicted 10.4 visits per individual, the total consumer surplus derived from the rural landscape was estimated as 24.9 billions dollars per year. This value is about half of the last 10 years average total net farm income in the United States, which is around 50 billion dollars. Fleischer and Tsur (2000) and Drake (1992) found that the landscape value of

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<sup>3</sup> The average probability of a becoming a farm visitor was estimated in 0.31.

farmland is far in excess of returns to farming in Israel and Sweden, respectively. The value of farms trips to the average household in the U.S. is around \$1,000, of which \$120 corresponds to the rural landscape. The economic value of farmland for residents has not been considered in this study.

#### **2.5.4. Robustness of Results to Model Assumptions**

A critical assumption of the surplus calculations is that the calculated trip costs are average costs of all the trips to farm operations. The survey only asked respondents about the distance traveled for the last recreational trip to a farm. The sensitivity of the surplus calculations to this assumption requires further investigation. An alternative econometric procedure might take into account the measurement error in the trip cost variable. For example, the formulation for the parameter  $\lambda$  in the Poisson model could be specified as

$$\ln \lambda = x'\beta + \varepsilon \quad (11)$$

where  $\varepsilon$  represents the measurement of the cost variable and which can be assumed to follow for example a normal distribution with mean zero and variance  $\sigma^2$ . This type of model is very similar to models proposed to account for unobserved heterogeneity in count data models. In our specific application, this would require the estimation of a truncated Poisson regression model with the parameter  $\lambda$  specified as in equation (11). A model including equation (11) in untruncated Poisson and untruncated Negative Binomial regression models yielded parameter estimates very similar to the ones presented in Table 2.4.

The calculation of the consumer surplus measure using the parameter estimates of a demand model including income is theoretically dubious since the consumer surplus measure is not path independent. Path dependence implies that the measure of consumer surplus is not unique. However, given the fact that the percentage of income spent on farms trips is very small (less than 1% in average) and the income elasticity is also small, the errors incurred in using consumer surplus as a measure of the more theoretically appealing equivalent or compensating variations are minor (Just, Hueth and Schmitz, 2004).

The robustness of the socioeconomic variables was evaluated estimating models with and without the trip costs variables. Most of the parameter estimates were robust to the exclusion of the trip costs variables, except for the parameters corresponding to income and years of education, which by construction are correlated with the opportunity cost of time variable.

The survey also included a question where people were asked if they would change the number of trips taken to the farm if the cost of the trip were to increase by a given amount (different values for different respondents). They were given the option to choose between: no change, 1 less trip, 2 less trips, taken no trips and other. An estimate of the change in the number of trips taken by a dollar increase in the trip cost can be obtained by dividing the stated change in the number of trips by the assumed change in the trip costs. Mathematically this can be expressed as follows:

$$\Delta \text{ in the \# of trips by a dollar increase in trip costs} = \frac{\Delta \text{ Number of Trips Taken}}{\Delta \text{ Cost of the trip}} \quad (12)$$

The calculated average of this variable was estimated as 0.030, which is very close to the estimated marginal effect of travel costs in the travel cost demand model.

## **2.6. Summary and Conclusions**

Using data from the 2,000 National Survey on Recreation and the Environment this study has explore two main issues: the factors affecting American population visits to farms and the economic value of the rural landscape for farm visitors.

The average quantity of trips to farms demanded by visitors is 10.4 trips per year whereas the quantity demanded by the average person in the U.S. population is 3.2 trips per year. The analysis of the factors influencing people decision to become farms' visitors found race and location of residence as the most important characteristics explaining this decision. The number of farm recreational trips visits was determined to be not very sensitive to change in its own price (elasticity of -0.13). The income elasticity was estimated in 0.06. Location of residence, race and gender were found to be important determinants of the number of farm trips. This information might be useful to farmers considering to start an agritourism enterprise and also to development planners who are considering agritourism as an option to promote regional economic development. However, given the fact that agritourism comprise a variety of activities, further work is required to identify the factors affecting the decisions to visit specific types of agritouristic activities.

Given their characteristics of nonexclusivity and nonrivalry, rural land amenities might escape adequate consideration by private markets. This might cause the loss of

farmland beyond of what is socially optimum. Therefore, there could be the need for some sort of policy intervention which, in turn, requires measurement of the value of this public good. Previous studies about rural amenities have mainly focused on the economic value for residents. In this study we estimate the economic value of the rural landscape to farm visitors. The calculated consumer surplus per visitor per trip is estimated as \$312.5/trip, of which \$38.4 is due to the rural landscape. The total consumer surplus generated from the agricultural landscape was estimated to be 24.6 billion dollars, which is about half of the last 10 years U.S. net total farm income average, calculated to be around 50 billion dollars.



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**Table 2.1. Summary Statistics of the Variables used in the Probit Analysis**

| Variable                           | Visitors<br>(n=1,524)     | Non-Visitors<br>(n=3,411) |
|------------------------------------|---------------------------|---------------------------|
| Years of education                 | 14.05 (2.62) <sup>1</sup> | 13.61 (2.75)              |
| Black                              | 0.05 (0.21)               | 0.08 (0.27)               |
| White                              | 0.93 (0.25)               | 0.89 (0.32)               |
| Hispanic                           | 0.05 (0.22)               | 0.08 (0.28)               |
| Male                               | 0.45 (0.50)               | 0.42 (0.49)               |
| Age                                | 42.84 (15.50)             | 46.05 (17.65)             |
| Family Income                      | 58,014 (34,525)           | 53,879 (34,897)           |
| Live in Urban Area                 | 0.62 (0.49)               | 0.67 (0.47)               |
| Household size                     | 2.89 (1.53)               | 2.64 (1.54)               |
| Presence of children under 6 years | 0.23 (0.42)               | 0.16 (0.37)               |
| Student                            | 0.09 (0.29)               | 0.09 (0.29)               |
| Retired                            | 0.16 (0.37)               | 0.23 (0.42)               |
| Homemaker                          | 0.17 (0.37)               | 0.19 (0.39)               |
| Employed                           | 0.70 (0.46)               | 0.63 (0.48)               |

<sup>1</sup> Numbers in parenthesis are standard errors

**Table 2.2. Results of the Probit Analysis for the Decision to Visit Farm Operations with Recreational Purposes**

| Variable                           | Parameter              |            | Marginal Effect |            |
|------------------------------------|------------------------|------------|-----------------|------------|
|                                    | Coefficient            | Std. Error | Coefficient     | Std. Error |
| Intercept                          | -0.600*** <sup>a</sup> | 0.162      | -0.210***       | 0.056      |
| Employed                           | 0.074                  | 0.062      | 0.026           | 0.021      |
| Black                              | -0.095                 | 0.141      | -0.032          | 0.047      |
| White                              | 0.303**                | 0.121      | 0.098***        | 0.036      |
| Hispanic                           | -0.408***              | 0.079      | -0.128***       | 0.021      |
| Male                               | 0.220                  | 0.040      | 0.008           | 0.014      |
| Age                                | -0.006***              | 0.002      | -0.002***       | 0.000      |
| Family Income (\$1,000 )           | 1.114*                 | 0.573      | 0.389*          | 0.200      |
| Live in Urban Area                 | -0.130***              | 0.040      | -0.046***       | 0.014      |
| Presence of children under 6 years | 0.114**                | 0.579      | 0.040*          | 0.021      |
| Household size                     | 0.034**                | 0.015      | 0.012**         | 0.005      |
| Student                            | -0.104                 | 0.079      | -0.036          | 0.026      |
| Retired                            | -0.019                 | 0.079      | -0.006          | 0.027      |
| Homemaker                          | -0.006                 | 0.061      | -0.002          | 0.021      |

<sup>a</sup>Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

**Table 2.3. Summary Statistics of the Variables used in the Count Regression Model of Number of Trips to Farms**

| <b>Variable</b>                    | <b>Mean<br/>(n=1,033)</b> | <b>Standard error</b> |
|------------------------------------|---------------------------|-----------------------|
| Number of trips                    | 10.32                     | 15.43                 |
| Cost of the trip (\$)              | 41.47                     | 63.56                 |
| Distance to the farm (miles)       | 61.83                     | 91.63                 |
| Years of education                 | 14.16                     | 2.58                  |
| Black                              | 0.04                      | 0.19                  |
| White                              | 0.94                      | 0.24                  |
| Hispanic                           | 0.04                      | 0.20                  |
| Male                               | 0.46                      | 0.50                  |
| Age                                | 42.77                     | 14.95                 |
| Family Income (\$)                 | 56,645.46                 | 34,560.40             |
| Live in Urban Area                 | 0.60                      | 0.49                  |
| Household size                     | 2.95                      | 1.53                  |
| Presence of children under 6 years | 0.26                      | 0.44                  |
| Student                            | 0.08                      | 0.26                  |
| Retired                            | 0.16                      | 0.36                  |
| Homemaker                          | 0.18                      | 0.38                  |
| Employed                           | 0.71                      | 0.45                  |

**Table 2.4. Results of the Poisson Regression for the Number of Recreational Trips to Farms**

| Variable                           | Parameter              |            | Marginal Effect |            |
|------------------------------------|------------------------|------------|-----------------|------------|
|                                    | Coefficient            | Std. Error | Coefficient     | Std. Error |
| Intercept                          | -0.231                 | 0.291      | -2.371          | 3.240      |
| Trip Cost                          | -0.003*** <sup>a</sup> | 0.000      | -0.032***       | 0.001      |
| Importance of Rural Landscape      | 0.076***               | 0.018      | 0.785***        | 0.199      |
| Family Income (\$1,000 )           | 0.001***               | 0.000      | 0.011***        | 0.038      |
| Years of Education                 | 0.246***               | 0.039      | 2.525***        | 0.000      |
| Years of Education <sup>2</sup>    | -0.009***              | 0.001      | -0.088***       | 0.015      |
| Employed                           | 0.002                  | 0.034      | 0.025           | 0.383      |
| Black                              | -0.185*                | 0.103      | -1.905          | 1.166      |
| White                              | 0.356***               | 0.076      | 3.654***        | 0.880      |
| Hispanic                           | -0.235***              | 0.058      | -2.411***       | 0.633      |
| Male                               | 0.341***               | 0.021      | 3.501***        | 0.292      |
| Age                                | 0.035***               | 0.004      | 0.357***        | 0.052      |
| Age <sup>2</sup>                   | -0.001***              | 0.000      | -0.005***       | 0.001      |
| Live in Urban Area                 | -0.666***              | 0.020      | -6.837***       | 0.395      |
| Presence of children under 6 years | -0.050*                | 0.027      | -0.515*         | 0.307      |
| Household size                     | -0.004                 | 0.008      | -0.040          | 0.092      |
| Student                            | 0.093**                | 0.045      | 0.951*          | 0.514      |
| Retired                            | 0.171***               | 0.047      | 1.752***        | 0.534      |
| Homemaker                          | 0.083**                | 0.032      | 0.852**         | 0.370      |

<sup>a</sup> Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

**Table 2.5. Consumer Surplus of Farm Trips**

|  | Visitors and Potential Visitors | Population |
|--|---------------------------------|------------|
| Trips quantity demanded  | 10.4                            | 3.2        |
| Consumer surplus for the average person (\$ per visit )                            | 312.5                           | 96.9       |
| Consumer surplus for the average person due to rural landscape only (\$ per visit) | 38.4                            | 11.6       |
| Total consumer surplus per year for the average person (\$ )                       | 3250                            | 1008       |
| Estimated number of visitors per year (millions)                                   | 64                              |            |
| Total consumer surplus due to rural landscape (billions \$ per year)               | 24.9                            |            |
| Total net farm income (1990-2000 average) (billions \$ per year)                   | 48.2                            |            |

## **Chapter 3**

# **A Structural Econometric Model of Consumer Demand at Pick-Your-Own Fruit Operations**

### **3.1. Introduction**

Pick-your-own (PYO) fruit operations are farms where customers harvest their product from farmers' fields. PYO farms constitute a marketing alternative that allows farmers to sell their product directly to the consumer. A better understanding of the way these markets work can help farmers participating in PYO to make more informed production and marketing decisions.

This paper analyzes the economic behavior of customers visiting pick-your-own (PYO) fruit operations. In order to study this problem, a fully structural econometric consumer demand model is developed. This model is appropriate for situations in which the goods consumed have time and monetary costs, and where time spent consuming/obtaining the goods also enters into the utility function. Moreover, the use of

the structural discrete-continuous choice model allows considering the problem of zero expenditures in a theoretically consistent manner.

Traditional economic models of consumer behavior assume that the demand for goods is originated from an optimization problem where consumers are maximizing utility from the consumption of goods subject to a budget constraint. The effect of time in the utility function and as a resource constraint (time constraint) has not been explored previously in the context of the demand for goods. The simultaneous consideration of these aspects have mainly been restricted to the areas of environmental and transportation economics.

Two constraint models of consumer behavior without considering the effect of time in the utility function have received some attention in the economics literature (e.g. Larson and Shaikh, 2001; Hanemann, 2004). However, the time spent obtaining (consuming) the goods is not assumed to provide utility. Time is only seen as a scarce resource constraining the problem. Most of these models have been done using the deterministic type of behavior and only interior (non-zero) solutions are considered.

### **3.1.1. Importance of Direct Marketing in the U.S. Agriculture**

Even though the food sector in the United States is moving towards consolidation which implies bigger farms and store outlets, farmers' direct marketing alternatives are also growing in importance. Direct marketing alternatives for farmers include PYO operations, farmers' markets, farm stands and roadside stands. More recently, internet

marketing and niche markets have also appeared as direct marketing alternatives for farmers.

The main factors affecting the increase in importance of direct marketing are the consumer's growing interest in fresh products and farm recreation, and the difficult financial situation of small farmers that is compelling them to look for alternatives to market their products. Given the limited availability of data, it is difficult to quantify the importance of direct marketing and PYO marketing in particular. Results from the US Census of Agriculture indicate that the value of agricultural products sold directly to individuals for human consumption more than doubled from 1992 to 2002, going from \$404 million to \$812 million. The number of farms selling products directly to the consumer also increased in the same period from 86,432 to 116,733 farms (USDA, 2002 Census of Agriculture).

A problem when trying to assess the importance of direct marketing is that the data provided by the USDA Census of Agriculture is not consistent with data obtained at the state level. For example, for New York, the USDA 2002 Census of Agriculture reports that 4,651 farmers participate in direct marketing and the value on direct sales is estimated at around \$60 million. On the other hand, the New York Agricultural Statistical Service (NYASS, 2002) reports 6,667 farmers participating in direct marketing and a value of \$230 million for direct sales from which around \$60 million corresponds to PYO marketing.

An alternative assessment of the economic importance of direct marketing can be obtained by using the information reported by consumers about expenditures on farm



products. The 2000 National Survey on Recreation and the Environment (NSRE) is one of the few nationwide surveys that include information about Americans visiting farms (Barry and Hellerstein, 2004). In the survey, out of the 25,010 NSRE respondents 7,820 reported visiting a farm. Extrapolated to the U.S. population, this result indicates that 62 million Americans visited farms one or more times in 2000. About 20% of the individuals interviewed about farm recreation reported buying agricultural products, which represents around 12 million customers. With an average number of 10 farm trips per year and an average of \$28 in expenditures in farm products per trip, this represents a market of more than 3 billion dollars per year.

### **3.1.2. Literature on the Demand for Pick-Your-Own Fruit**

The literature review identified 12 studies carried out in the U.S. during the last 20 years in the subject of the demand for PYO products. Most of the studies have been done from the perspective of PYO operations as another consumer outlet and very few have considered the recreational aspects of the activity. The majority of the samples for the surveys are random samples from visitors to PYO farms. Only two surveys sample the entire population of the state or county.

The main objectives of these studies have been: 1) To characterize the type of customers visiting PYO operations, and 2) To study the motivations and shopping behavior of customers to PYO farms. With regard to the type of customers visiting the operations, these studies have consistently found that customers visiting PYO farms have higher income and education than the average of the population. The majority of customers come from a ratio of around 20-25 miles. During the 80's the average age was

about 35-45 years, but in the last surveys the average age is around 50 years. Finally, most of the shoppers are females, but couples and children are very often part of the shopping parties.

With regard to the motivations of the customers, the studies consistently report that the main factors motivating the visits are freshness of the products, quality of the produce, prices and the farm experience. The variability of the relative importance of these factors seems to depend on the way the survey was conducted. Some surveys for example ask for the most important reason whereas others ask to select all the important reasons.

The majority of the studies only report the results of the surveys and in general lack analysis correlating factors or quantifying the effect of several factors affecting customers' decisions. The literature review only identified one study exploring the links between customers' characteristics and motivations, only one study quantifying the effect of customers' characteristics and motivations and the decision to visit or not the operation. Even though four of the studies analyze the effect of socioeconomic characteristics on the amount of fruit purchased, only one of these studies intends to quantify the effects.

The only study exploring the connections between customers' characteristics and motivations is Ott et al. (1988) survey of customers visiting a PYO blueberry farm in Georgia. For example, these authors report that higher income customers and small size families are more likely to select fruit quality as an important reason for picking blueberries. They also found females to be more likely to select price as an important

reason for picking fruit. These links might be important for the establishment of marketing segments and the targeting of potential customers.

Govindasamy and Nayga (1997) analyze the factors affecting the decision to visit different types of direct market facilities in New Jersey. These authors use logit analysis to determine and quantify the effect of several socioeconomic and demographic characteristics on the decision to visit PYO operations in New Jersey. They find that those customers who expect more variety and lower prices at PYO operations than in supermarkets are around 12% more likely to visit a PYO farm. Individuals who buy produce for canning, freezing or preserving are around 20% more likely to visit PYO operations than those who do not. Customers with only high school diploma are 15% less likely to visit the operations compared to customers with college education. Finally, they report that customers with incomes of \$60,000 or above are 10% more likely to patronize PYO operations than those with lower incomes.

Toensmeyer and Ladzinski (1983) studying direct market customers in Delaware analyze the relationship between the amount spent on each visit to the outlet and income. They compare income categories and expenditures categories by means of a contingency table but do not find any relationship between the variables.

Safley et al. (1999) and Safley et al. (2001) studying PYO strawberry and muscadine grapes customers in North Carolina explore the relation between customer expenditures and socioeconomic characteristics (household income, age, number of hours adults work in the household). The analysis is carried out by comparing the socioeconomic characteristic categories and the average expenditure in the category and

identifying groups with the highest average expenditures. Customers are divided between PYO and pre-picked fruit customers.

PYO strawberry customers with lower incomes have the largest average expenditures and pre-picked strawberry customers with higher incomes have the largest average expenditures. On the other hand, middle to higher income customers are the customers with the highest expenditures at the muscadine grapes farms for both PYO and pre-picked fruit.

The only study that has intended to determine the impact of various customer characteristics on the quantity of fruit picked is Ott et al. (1988). These authors use regression analysis with quantity of blueberries picked at a Georgia farm as the dependent variable. As independent variables they include age, income, education, family size, sex of the picker, if the picker stored or processed any fruit, and distance traveled to the farm. They only find one statistically significant variable: family size. The results indicate that for every additional family member the amount picked would increase by 2.91 pounds.

### **3.2. Theoretical Framework**

A microeconomic model of fruit demand at pick-your-own operations must be able to explain the type of fruit chosen by the household, and explain the quantity of fruit purchased. It is important to point out that the choice margin we focus on is the decision

to buy PYO fruit versus pre-harvested fruit<sup>4</sup>. Therefore, a discrete/continuous choice model seems to be appropriate for this situation. This framework allows modeling the choice between different types of a good and the quantity of the good to buy. Dubin and McFadden (1984) used this framework to study the demand for appliance and the demand for electricity. Chintagunta (1993) and Chiang (1991) analyzed purchased incidence, brand choice and purchase quantity decisions of households.

The structural econometric model of consumer behavior proposed in this study is an extension of Hanemann's (1984) work on discrete/continuous choice modeling. This model of choice assumes a random utility. The model arises when one assumes that although a utility function is deterministic for the consumer, it also contains elements that are unobservable to the investigator. The utility of the consumer is defined over the quantity of the goods, the time spent obtaining the goods and their perceived characteristics. The inclusion of time into preferences is a novel characteristic of this model. The utility function is defined over two goods. The first good is available in R alternative forms which can represent different brands or varieties of a product. The second is a numeraire. The utility function has the following form:

$$u(x, z, o, q, T, \psi, b, s, \varepsilon) \quad (1)$$

where  $\psi = [\psi_1, \psi_2, \dots, \psi_R]$  is a R-dimensional vector and  $\psi_i$  represents the consumer's evaluation of quality for the  $i^{\text{th}}$  alternative,  $x = [x_1, x_2, \dots, x_R]$  is a R-dimensional vector and  $x_i$  represents the quantity of the  $i^{\text{th}}$  variety of the first good,  $z$  represents the quantity

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<sup>4</sup> Data limitations preclude us from studying households' participation decision to visit or not visit the operation. The first essay in this dissertation looks at the households' participation decision in various types of on-farm recreational activities.

of a good numeraire,  $o$  represents the quantity of a time numeraire,  $T = [T_1, T_2, \dots, T_R]$  is a  $R$ -dimensional vector and  $T_i$  represents the time spent obtaining the  $i^{\text{th}}$  variety. It is assumed that  $b_i = [b_{i1}, b_{i2}, \dots, b_{iK}]$  is a  $k$ -dimensional vector defining  $k$  different dimensions of quality, where  $b_{i1}$  is the amount of the  $k^{\text{th}}$  characteristic associated with a unit of consumption of variety  $i$ . The  $R$ -dimensional vector  $\varepsilon = [\varepsilon_1, \varepsilon_2, \dots, \varepsilon_R]$  is a random vector representing the unobservable characteristics of the consumer and/or attributes of the commodities. Finally,  $s = [s_1, s_2, \dots, s_L]$  is an  $L$ -dimensional vector with observed characteristics of the consumer.

The consumer's problem is to choose  $x$ ,  $z$  and  $o$  to maximize utility subject to a budget constraint and a time constraint:

$$\sum_{i=1}^R p_i x_i + z = y, \quad (2)$$

$$\sum_{i=1}^R T_i(x_i) + o + T_w = T \quad (3)$$

In equation (2)  $y$  is income and in equation (3)  $T_w$  represents the number of hours worked and  $o$  the time numeraire. Total income can be assumed to be the product of the wage rate  $w$  and the number of hours worked,

$$y = T_w w, \quad (4)$$

and the total amount of time required to obtain each variety can be assumed to be a linear function of the amount obtained:

$$T_i = t_i x_i \quad (5)$$

Using these assumptions, the two constraints can be merged into a single constraint:

$$\sum_{i=1}^R \pi_i x_i + q = I \quad (6)$$

where  $\pi_i = p_i + wt_i$ ,  $q = z + wo$  and  $I = y + wT$ . Equation (6) indicates that time is valued at the wage rate. However, the assumption of a flexible number of hours seems to be unrealistic since in practice most of the people work a fixed number of hours. If we use  $\lambda$  as the Lagrangian multiplier corresponding to the budget constraint (2) and  $\mu$  as the Lagrangian multiplier corresponding to the time constraint (3), a parameter  $\theta = \mu/\lambda$  can be defined to merge the two constraints into a single constraint as follows:

$$\sum_{i=1}^R \pi_i x_i + k = I \quad (7)$$

where  $\pi_i = p_i + \theta t_i$ ,  $k = z + \theta o$  and  $I = y + \theta T$ . Notice that  $\theta$  corresponds to an endogenously determined value of time since both  $\mu$  and  $\lambda$  are functions of the endogenous variables.

In order to devise a structural econometric model of brand choice, specific assumptions regarding the functional form of the direct utility function and the distribution of the errors are necessary. The following utility model can be used:

$$\begin{aligned} u(x, z, T, \psi, b, s, \varepsilon) &= u^*(\sum x_j, k + \sum \psi_j(b_j, s, \varepsilon_j)x_j + \xi T_j) \\ &= u^*(\sum x_j, k + \sum (\psi_j(b_j, s, \varepsilon_j) + \xi_j)x_j) \end{aligned} \quad (8)$$

where  $u^*$  is a bivariate utility function. In this model the different varieties are perfect substitutes. Maximization of (8) subject to (7) leads to a corner solution where only one of the brands is selected. Equation (8) extends Hanemann's perfect substitution model to

include the time spent obtaining the  $i^{\text{th}}$  variety in the utility function. In this model  $\xi$  is a parameter that measures the effect of time on the utility function.

Given that a consumer has selected brand  $j$ , her conditional direct utility function is  $\bar{u}_j(x_j, \psi_j, t_j, q) = \bar{u}_j(x_j, k + (\psi_j + \xi t_j))$ . Then, it can be shown (see Appendix 3.2) that the conditional ordinary demand functions and indirect utility functions associated with  $\bar{u}_j$  have the form:

$$\bar{x}_j(\pi_j, \psi_j, t_j, I) = \bar{x}_j(\pi_j - \psi_j - \xi t_j, I), \quad (9)$$

$$\bar{v}_j(\pi_j, \psi_j, t_j, I) = \bar{v}_j(\pi_j - \psi_j - \xi t_j, I). \quad (10)$$

Since  $\bar{v}_j$  is decreasing in its first argument, it follows from (10) that the single brand selected is the one for which  $\pi_j - \psi_j - \xi t_j$  (quality-time effect adjusted price) is lowest. In equation form, alternative  $j$  would be preferred to alternative  $i$  if:

$$\pi_j - \psi_j - \xi t_j < \pi_i - \psi_i - \xi t_i, \quad \forall i = 1, \dots, R \text{ and } i \neq j. \quad (11)$$

The function  $\psi_j$  can be seen as an index of the overall quality of the  $j$ th brand which depends on the quality characteristics of the brand  $b_j$ , the characteristics of the individual, and the error term  $\varepsilon_j$ . The following form can be assumed:

$$\psi_j(b_j, s, \varepsilon_j) = \alpha_j + \gamma' b_j + \varphi_i' s + \varepsilon_j, \quad (12)$$

where  $\alpha_j$ ,  $\gamma$  and  $\varphi$  are parameters.

By substituting (12) into (11), and rearranging terms we can rewrite the condition specifying the choice of the  $j^{\text{th}}$  alternative as:

$$\alpha_j + \gamma' b_j + \varphi_i' s + \xi t_j - \pi_j + \varepsilon_j > \alpha_i + \gamma' b_i + \varphi_i' s + \xi t_i - \pi_i + \varepsilon_i \quad (13)$$



If we denote  $\text{Pr}_j$  as the probability of selecting variety  $j$ , and make

$\lambda_j = \alpha_j + \gamma' b_j + \varphi_i' s + \xi t_j - \pi_j$  then,

$$\text{Pr}_j = \Pr(\varepsilon_i < \varepsilon_j + \lambda_j - \lambda_i) \quad (14)$$

The functional form of  $\text{Pr}_j$  depends on the assumption regarding the distribution of the  $\varepsilon_j$ 's. If the  $\varepsilon_j$ 's are assumed to be multivariate normal with mean zero and some covariance  $\Sigma \equiv \{ \sigma_{ij} \}$ , then  $\text{Pr}_j$  follows a R-1 multivariate probit model. Denote the R dimensional multivariate normal density of the  $\varepsilon_j$ 's by  $\varphi_T(\cdot; \mu, \Sigma)$  and the corresponding c.d.f. by  $\Phi_T(\cdot; \mu, \Sigma)$ . In this study only two brands (types of goods) are considered, therefore the choice probability for the two goods case takes the following form:

$$\text{Pr}_j = \Phi_1(\bar{\lambda}_j - \bar{\lambda}_i; 0, 1) \quad j=1,2; i=1,2 \quad (15)$$

where  $\bar{\lambda}_j = \lambda_j / w_{ij}^{1/2}$ ,  $\bar{\lambda}_i = \lambda_i / w_{ij}^{1/2}$ ,  $w_{ji} = \sigma_j^2 + \sigma_i^2 - 2\sigma_{ij}$ .

In order to develop formulas for the probabilities of the continuous choices, a specific functional form for the indirect utility function (10) needs to be selected. The following model can be used (Hanemann, 1984):

$$\bar{v}_j(\pi_j, \psi_j, t_j, I) = -\frac{e^{-\eta I}}{\eta} + \frac{\kappa}{\rho} e^{-\rho(\pi_j - \psi_j - \xi t_j)}, \quad \kappa > 0, \eta \neq 0. \quad (16)$$

Using Roy's identity, the corresponding demand function to (14) is then:

$$\bar{x}_j(\pi_j, \psi_j, t_j, I) = \kappa e^{-\rho(\pi_j - \psi_j - \xi t_j) + \eta I} \quad (17)$$

or using the definition of the  $\lambda_j$ 's:

$$\bar{x}_j(\pi_j, \psi_j, t_j, I) = \kappa e^{\rho \lambda_j + \eta I} e^{\rho \varepsilon_j} \quad (18)$$

Given the distributional assumption about the errors, the density of  $\bar{x}_j$ ,  $f_{x_j|\varepsilon \in A_j}(x)$  can be derived. The conditional mean quantity of brand j demanded can be obtained by integrating the density of  $\bar{x}_j$ , or from (18) using the mean and generating functions of a truncated normal distribution. For estimation purposes it is more convenient to work with the mean of the conditional distribution of  $\ln(x_j)$ :

$$\begin{aligned} E\{\ln(x_j) | \varepsilon \in A_j\} &= \ln \kappa + \rho \lambda_j + \eta I + \rho E\{\varepsilon_j | \varepsilon \in A_j\} \\ &= \ln \kappa + \rho \lambda_j + \eta I - \rho \rho_j [\phi_1(\bar{\lambda}_j - \bar{\lambda}_i; 0, 1) / \Phi_1(\bar{\lambda}_j - \bar{\lambda}_i; 0, 1)] \end{aligned} \quad (19)$$

where  $\rho_j = Cov(\varepsilon_j, \varepsilon_j - \varepsilon_i) = (\sigma_j^2 - \sigma_{ji}) / w_{ji}$ .

The density of the unconditional demand functions can be written as follows:

$$f_{x_j}(x) = \begin{cases} 1 - \Pr_j, & x = 0 \\ \Pr_j f_{x_j|\varepsilon \in A_j}(x), & x > 0 \end{cases} \quad (20)$$

The mean of the unconditional demand functions is then:

$$\begin{aligned} E[x_j] &= \Pr ob(x_j = 0)E[x_j | x_j = 0] + \Pr ob(x_j > 0)E[x_j | x_j > 0] \\ &= (1 - \Pr_j)0 + \Pr_j E[x_j | \varepsilon \in A_j] \\ &= \Pr_j \theta e^{\rho \lambda_j + \eta I} E\{e^{\rho \varepsilon_j} | \varepsilon \in A_j\} \\ &= \Pr_j \theta e^{\rho \lambda_j + \eta I} e^{\rho^2 \sigma_j^2 / 2} [\Phi_1(\bar{\lambda}_j - \bar{\lambda}_i - \rho \rho_j; 0, 1) / \Phi_1(\bar{\lambda}_j - \bar{\lambda}_i; 0, 1)] \end{aligned} \quad (21)$$

Equation (21) shows that the mean unconditional demand function for the  $i^{\text{th}}$  type is the product of the probability of buying that type times the mean of the conditional demand function. This equation can also be used to calculate marginal effects of the explanatory variables on the mean unconditional quantity demanded.

### **3.3. Data and Estimation Procedures**

#### **3.3.1. Data**

This data is from a consumer survey conducted by the North Carolina Strawberry Association in cooperation with the North Carolina Department of Agriculture and Consumer Services, and the Department of Agricultural and Resource Economics at N.C. State University. The survey was conducted at direct market strawberry operations throughout the state during the spring of 1999. Each operation offered customers two options for buying strawberries: they could either pick their own strawberries (PYOS) for the growers' field or they could buy pre-picked strawberries (PPS) at the grower's fruit stand. The survey was divided into two segments. The first segment was administered when the consumer arrived to the direct market operation and the second, when the consumer left the operation. A total of 1701 customers were interviewed.

In our sample, most of the customers purchased one brand but there were a few that behaved differently. In the survey, out of 1,701 observations, 2 customers did not buy any type of fruit and 18 bought two types of fruit. Given the small proportion of customers buying both types of fruit or none of them, we drop these observations for the analysis and use the model where the customers only choose one type of fruit.

#### **3.3.2. The Income Variable ( $y$ )**

Both surveys reported income in intervals (discrete) form rather than continuous form. The income variable falls only in a certain interval, with both end intervals being open-ended. Transforming the data from discrete to continuous saves degrees of freedom

in the estimation and facilitates the interpretation of the coefficients. A procedure developed by Stewart (1983) can be used to transform the variables. This method assigns each observation its conditional expectation:

$$E(I_i | A_{k-1} < I \leq A_k, x_i) = x_i\beta + \sigma \left[ \frac{\phi(Z_{k-1}) - \phi(Z_k)}{\Phi(Z_{k-1}) - \Phi(Z_k)} \right], \quad (22)$$

where  $I_i$  is the natural logarithm of unobserved income for the  $i^{\text{th}}$  household,  $x_i$  and  $\beta$  are both  $k \times 1$  vectors representing regressors and unknown parameters respectively,  $A_k$  and  $A_{k-1}$  are the natural logarithms of the boundary values for the  $k^{\text{th}}$  interval,  $Z_k = (A_k - x_i\beta)/\sigma$ ,  $\sigma$  is the standard deviation, and  $\Phi$  and  $\phi$  are the normal cumulative and normal probability density functions. Parameter estimates for  $\beta$  and  $\sigma$  can be obtained by using maximum likelihood estimation procedures. Expressions for the log-likelihood functions of this model can be found in Bhat (1994). The vector of regressors,  $x_i$ , included in the income models for the strawberry customers and the results of the estimation of the models are displayed in Appendix 3.2.

### 3.3.3. Opportunity Cost of Time Variable ( $\theta t$ )

The opportunity cost of time variables was constructed by multiplying the per minute wage times minutes per pound spent in the operation ( $\theta t = k.w.t$ ). To calculate the per minute wages it was assumed a total of 1,800 hours of work per year. Therefore, the parameter estimated in the probit model is the proportion of the wage at which people value time. To take into account the fact that the opportunity cost of time may differ depending on the working status of the household members, interactions between the

hourly wage and the working status of the household members were also included in the estimation. Three variables define the working status of the household members: number of household members working more than 40 hours a week, number of household members working less than 40 hours a week, and number of household members that are retired.

### 3.4. Estimation Procedures

Estimation of the parameters of the discrete/continuous choice model can be carried out by using maximum likelihood estimation procedures. A simpler two step estimation procedure which yields consistent parameters estimates can also be used. In a first step, the parameters of  $Pr_j$  are estimated using maximum likelihood estimation on the probit model of discrete choice. This model yields consistent estimates of the  $\lambda_j$ 's and  $w_{ij}$ . Using these estimates and equation (19) the rest of the parameters of the continuous choice can be recovered using regression analysis. Using (20) the following regression models can be estimated:

$$\ln(x_j) = \ln \kappa + \rho \lambda_j + \eta I - \rho \rho_j [\phi_1(\bar{\lambda}_j - \bar{\lambda}_i; 0, 1) / \Phi_1(\bar{\lambda}_j - \bar{\lambda}_i; 0, 1)] \quad (23)$$

Using (23) consistent estimates of  $\kappa$ ,  $\rho$  and  $\eta$  can be obtained using OLS or nonlinear least squares, depending on the functional form selected for  $\kappa$ . The continuous choice model can also be made a function of the socioeconomic characteristics of the individuals by making the parameter  $\kappa$  depend on these characteristics. Since  $\kappa > 0$ , an appropriate choice for the parameters is  $\kappa = \exp(\iota' \omega)$  where  $\iota$  is a vector of parameters and  $\omega$  is a vector of socioeconomic characteristics of the individuals.

The approach outlined would be possible if the times spent picking the fruit were observed for the entire sample; however, because of the selectivity problem the procedure to recover the parameters is more complex. The following section explains in detail the procedure used to estimate the parameters of the choice probability and the continuous choice.

### 3.4.1. Estimation of the Parameters of the Discrete Choice Probability ( $\Pr_j$ )

In the analysis only the times spent picking the fruit were considered. The times spent buying the fruit were assumed fixed for each operation and were not considered in the analysis. Therefore, the hypothetical likelihood function contribution for person  $n$  choosing variety two (PYO fruit) that could be formed if the picking times ( $t_2$ ) were observed for the whole sample is given by

$$\Pr_{2n} = \Phi_1(\bar{\lambda}_{2n} - \bar{\lambda}_{1n}; 0, 1) \quad (24)$$

where  $\bar{\lambda}_{2n} - \bar{\lambda}_{1n} = (\bar{\alpha}_2 - \bar{\alpha}_1) + \bar{\gamma}'(b_{2n} - b_{1n}) + \bar{\varphi}_l' s_n + \bar{\xi}(t_2) - (1/w_{12}^{1/2})(\pi_{2n} - p_1)$ ,

and the hypothetical contribution of person  $n$  choosing variety one would be:

$$\Pr_{1n} = 1 - \Pr_{2n} = 1 - \Phi_1(\bar{\lambda}_{1n} - \bar{\lambda}_{2n}; 0, 1) \quad (25)$$

However, since picking times are only observed if the PYO variety is chosen, the likelihood expressions cannot be formed. Given that times enter the  $\bar{\lambda}_{2n} - \bar{\lambda}_{1n}$  function in a linear form, the most convenient specification for  $t_2$  is a linear regression model:

$$t_2 = X\beta_2 + u_2 \quad (26)$$

where the  $X$  is a vector of explanatory variables,  $\beta_2$  are parameter vectors and

$u_2 \sim N(0, \sigma_2^2)$  is a random disturbance. Previous studies where prices have been missing

have assumed that the mean of the distribution of prices is a function of household characteristics, arguing that price represents quality differences caused by heterogeneous commodity aggregation and the household characteristics are a proxy for household preferences over unobservable quality characteristics (e.g., Davis and Wohlgenant, 1993). In this study, times spent picking the fruit can also be assumed to be a function of the households' characteristics but also make the time equations a function of the characteristics of the farm. If  $u_2$  and  $r = \varepsilon_2 - \varepsilon_1$  are mutually dependent, together they form a bivariate normal distribution with mean vector zero and covariance matrix

$$\Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{21} & \sigma_2^2 \end{pmatrix}$$

This system of equations is similar to the binary choice model with limited dependent variables shown in Lee (1979). This author proposes the following multi-step approach to obtain estimates of the choice probability  $\text{Pr}_j$ . In the first stage, obtain a reduced form for the binary choice by substituting the time equations  $t_2$  into the choice equation. The above model can be written as:

$$I_t = 1 \text{ iff } X\Pi\sigma_{\Pi}^{-1} > [(\varepsilon_2 - \varepsilon_1) + (\xi - \theta)(t_2)]\sigma_{\Pi}^{-1} \quad (28)$$

$$I_t = 0 \text{ iff } X\Pi\sigma_{\Pi}^{-1} < [(\varepsilon_2 - \varepsilon_1) + (\xi - \theta)(t_2)]\sigma_{\Pi}^{-1} \quad (29)$$

Where  $X\Pi$  represents the reduced form of  $\bar{\lambda}_{2n} - \bar{\lambda}_{1n}$ ,  $I_t$  defines the choice of PYO fruit (variety 2) and  $\sigma_{\Pi}$  is the variance of  $(\varepsilon_2 - \varepsilon_1) + (\xi - \theta)(t_2)$ . Therefore the parameters  $\Pi$  can be estimated consistently by probit analysis.

To estimate the parameters  $\beta_2$  in the time equations, the estimated  $I$  is used to form the appropriate inverse Mill's ratios to correct for selectivity bias in the time equation. The following equation has to be estimated:

$$t_2 = X\beta_2 - \sigma_{\Pi u_2} \frac{\phi_1(X\hat{\Pi}\sigma_{\Pi}^{-1})}{1 - \Phi_1(X\hat{\Pi}\sigma_{\Pi}^{-1})} + \eta_2 \quad (30)$$

where  $\eta_i$  is a disturbance and  $\sigma_{\Pi u_i}$  is the covariance between  $u_2$  and  $[(\varepsilon_2 - \varepsilon_1) + (\xi - \theta)(t_2)]\sigma_{\Pi}^{-1}$ . To obtain the structural parameters from the discrete choice probability  $\Pr_2$ , predicted times  $\hat{t}_2 = X\hat{\beta}_2$  are used in (25) instead of the  $t_2$  values to estimate the second stage probit model. As shown in Lee (1979), these two stage probit estimates are consistent. However, the asymptotic covariance matrix is complicated. A simpler approach is to use bootstrapping to obtain an asymptotic covariance matrix of the estimator (Greene, 2003). The bootstrapping approach utilized in this study is outlined in the next section.

### 3.4.2. Estimation of the Parameters of the Continuous Choice

Estimation of the parameters of the continuous choice in equation (23) can be achieved by writing the two demand equations as one and estimating the parameters in the pooled sample. This approach allows for testing the equality of the parameters between the two equations. Using this approach, equation (22) can be rewritten as:

$$\ln(x) = \delta_1 \ln \kappa + \delta_2 \ln \kappa + \rho(\delta_2 \lambda_2 + \delta_1 \lambda_1) + \eta I - 0.5\rho(\chi_2 \delta_2 + \chi_1 \delta_1) + \eta_x \quad (31)$$

where the  $\delta_i$ 's are dummies indicating that the  $i^{\text{th}}$  alternative has been selected,

$\chi_1 = \phi_1(\bar{\lambda}_2 - \bar{\lambda}_1; 0, 1) / \Phi_1(\bar{\lambda}_2 - \bar{\lambda}_1; 0, 1)$ ,  $\chi_2 = \phi_1(\bar{\lambda}_2 - \bar{\lambda}_1; 0, 1) / (1 - \Phi_1(\bar{\lambda}_2 - \bar{\lambda}_1; 0, 1))$ ,  $\eta_x$  is an



error term.  $\lambda_1$  and  $\lambda_2$  are the terms used to correct for the selection bias.  $\lambda_2$  and  $\lambda_1$  are replaced by the predicted values calculated using the estimated parameters of the discrete choice probabilities  $Pr_1$  and  $Pr_2$  which are known to be consistent. However, since the parameters of the socio-demographic characteristics in the probit model represent only differences in marginal utilities (i.e., these parameters can not be identified) only the parameters related to price, opportunity cost of time and time were used to identify the parameter  $\rho$ . The parameters corresponding to the socio-demographic characteristics in the continuous choice model can then be interpreted as reduced form parameters comprising the effect of these variables in the continuous choice through  $\kappa$ , and their effect on the discrete choice through the  $\lambda_i$ 's.

As in other sample selection models, the errors  $\eta_x$  in the continuous choice equation are heteroskedastic. To take into account this problem and the use of imputed regressors in the estimation of the continuous choice equation, the asymptotic covariance matrix of the parameters was approximated using a non-parametric bootstrapping procedure as outlined by Wooldridge (2002, p.379).

The bootstrapping procedure is as follows. Let  $S = \{w_1, w_2, \dots, w_N\}$  denote the sample used for estimation purposes and  $\hat{\theta}$  the estimated parameter. At each bootstrap iteration,  $b$ , a random sample of size  $N$  is drawn with replacement from the original sample. Denote the sample at iteration  $b$  as  $S^{(b)} = \{w_1^{(b)}, w_2^{(b)}, \dots, w_N^{(b)}\}$ . This bootstrap sample is used to obtain the  $\hat{\theta}^{(b)}$  MLE estimates (in the case of the probit model) and OLS estimates (in the case of the continuous choice model). The procedure has to be

iterated B times, to obtain  $\hat{\theta}^{(b)}$ ,  $b=1,2,\dots,B$ . The sample variance of the  $\hat{\theta}^{(b)}$ 's was used to obtain standard errors for  $\hat{\theta}$ , the parameter estimates of the original sample. A total of  $B=1000$  replications were used in the procedure.

### **3.5. Results**

Slightly more than half of the customers (51%) bought pre-picked-strawberries (PPS), while 49% bought pick-your-own strawberries (PYOS). On average, PPS customers paid 52 cents more than PYOS customers. However, PPS customers spent only one third of the time that PYOS customers spent. Around 70% of the buyers were repeat customers. The average customer traveled 17 miles, and was 51 years old. About half of the customers lived in rural areas (52%). Females shopping alone made up the largest population of shoppers followed by males shopping alone, couples, and females with children. A more detailed description of the characteristics of the households visiting North Carolina strawberry operations obtained from this survey can be found in Safley et al. (1999).

#### **3.5.1. Discrete Choice Model**

The structural parameters of the discrete choice are shown in Table 3.2. The reduced form parameters of the discrete choice and the parameters of the time equations are shown in Appendix 3, but we only focus our discussion on the structural parameters. Conventional standard errors and the standard errors obtained using bootstrapping are

presented for both models. For the marginal effects only bootstrapping standard errors are shown.

Table 3.2 only presents the results corresponding to the decision to buy PYOS. Because of the way in which prices enter into the equations, these parameters are equal in sign and magnitude for both equations. The rest of the parameters are equal in absolute value but with different signs for both alternatives.

The parameters of the main economic variables (price, opportunity cost of time and time) in the discrete choice model all have the expected signs. Following the structural econometric discrete choice model, the ratio of the opportunity cost of time parameter and the price parameter represents the proportion of the wage at which consumers value their time. The estimated value is around 4% which is lower than the values of around 10-30% commonly reported in the literature (Phaneuf and Smith, 2004, p. 29). With an average wage of 50 cents per minute this transforms into an opportunity cost value of 2.2 cents per minute or \$1.32/hour for the average household. However, this value varies depending on the working status of the household members. Each additional member in the household working more than 40 hours per week increases the household's opportunity cost of time by 0.7% of the wage, each additional member in the household working less than 40 hours per week decreases the household's opportunity cost of time by around 1.3% of the wage. Finally each additional member in the household who is retired decreases the household's opportunity cost of time in 0.3%.

For the time variable, a quadratic effect was included in the empirical specification of the discrete choice model. The estimation results indicate that the utility

function obtained by picking strawberries increases as the time increases, reaches a maximum at 5.79 minutes/lb and then decreases with further increases in time. At the average time spent by the households picking strawberries (3.31 minutes/lb), the monetary value of the benefit obtained from picking strawberries is about 0.10 cents per minute or \$6/hour. Therefore, there is, in general, a positive effect of time in the discrete choice decision.

In the probit model, the coefficients are not the marginal effects. Expressions for the marginal effects and standard errors in this model can be found in Greene (2003). Marginal effects of parameters corresponding to dummy variables are easier to interpret and compare than those corresponding to continuous variables. The marginal effects of these parameters are the effects in relation to an individual with characteristics of the dummy variables not included in the model (Central region, currently living in the rural area and visiting during the weekend). Relative to this type of customer, a customer in the Central Region and one in the Eastern region are, respectively, -73% and -11% less likely to buy PYOS. This indicates a very important effect of location in the decision to buy PYOS or PPS. This effect might be capturing characteristics of the individuals living in that area and also of the farms located in that region. Unfortunately, the characteristics of the operations were not considered in the survey. Relative to the baseline customer, people living in urban areas are 5% more likely to buy PYOS and people visiting during the weekday are 7% more likely to buy PYOS.

The marginal effects of the continuous variables represent the change in the probability of choosing an alternative for a one unit change in the variable. Each

additional female in the shopping party increases the probability that the household will buy PYOS by about 8% and each additional child in the household increases the probability of buying PYOS by 5%. The effect of income is very small. A \$10,000 increase in income increases the probability of buying PYOS by only 2%. The marginal effects of the other continuous variables included in the model are not economically important.

### **3.5.2. Continuous Choice Results**

The results of the estimation of the parameters of the conditional continuous choice equations, that is the mean quantity demanded conditional on having previously selected a type of fruit, are shown on Table 3.3. Following the structural econometric model, the parameter  $\rho$  which measures the effect of price in the quantity demanded, is estimated in 0.157. This parameter corresponds to the marginal effect of the adjusted price on the natural log of the conditional quantity demanded. The rest of the parameters can be interpreted as the marginal effect of the variables on the natural log of the conditional quantity demanded. When comparing the effects of the socio-demographic characteristics on the discrete choice and the continuous choice it can be seen that even though some variables increase the probability of buying one type of fruit, their effect on the conditional quantity demanded can have the opposite effect. For example, even though the number of females in the shopping party decreases the probability of buying PPS, this variable increases the conditional quantity demanded of both types of fruit. This is an interesting feature of this model since it allows analyzing the effects of the variables on both the discrete choice and the continuous choice separately. This information might

be important if for example the marketing efforts are directed to obtain more customers interested in one type of fruit or customers who are likely to buy more fruit.

The marginal effects of the variables on the unconditional demands are presented in Tables 3.4 and 3.5. These marginal effects were obtained using equation (21). From this expression, it can be seen that these marginal effects can also be decomposed into the effects corresponding to the discrete choice and the effects corresponding to the conditional quantity demanded.

Price, time, location of the operations, number of males and females in the shopping party and number of children in the household are the more important determinants of the quantity demanded of PYOS. As in the case of the probit model, the marginal effects of the dummy variables are the effects in relation to an individual with characteristics of the dummy variables not included in the model (Central region, currently living in the rural area and visiting during the weekend). Relative to this type of customer, customers in the Western region demand 5 fewer pounds of PYOS. Each additional male or female in the shopping party increases the quantity demanded of PYOS by 1.2 pounds. Each additional child in the household increases the demand for PYOS by 0.7 pounds. The effect of prices can be analyzed using the elasticity estimates (Table 7). The own price elasticity of PYOS is estimated in -1.30. The cross price elasticity is 1.90. The overall effect of own time in the demand for PYOS is positive but small with an estimated elasticity value of 0.09.

Price, location of the operations, location of residence, the variable indicating if the visit was done during the weekday, the number of members in the household and the

numbers of members in the shopping party are the more important determinants of the quantity demanded of PPS. Relative to the baseline customer, customers in the Western region demand 7 more pounds of PPS and customers living in the Eastern region demand 1 fewer pounds of PPS. Customers visiting the operations during the weekdays demand 1 fewer pounds of PPS. The own price elasticity of PPS is estimated to be -2.98. The cross price elasticity is 1.79.

Previous studies estimating elasticities for strawberries report elasticity values ranging from -0.26 to -2.8. Richards and Patterson (1999) estimate a price elasticity of -2.8 for this commodity. Carter et al. (2005) report elasticities between -1.2 and -2.7. You, Epperson and Huang (1998) estimate an own price elasticity of -0.26. To be able to compare our elasticity estimates with those of previous authors, the elasticity of the aggregate commodity composed by PYOS and PPS was also estimated (see equations in Appendix 3.4). This elasticity measures the effect of a proportional change in the price of the two types of fruit on the aggregate quantity demanded. The elasticity for the aggregate good is estimated to be -0.32.

As we expected the own price elasticities for PPS are much higher than the own price elasticity for PYOS. This result has to do with the fact that strawberries at the store are closer substitutes for PPS than PYOS. Therefore, even though the time effects were found to be very small, the differences in price elasticities seem to be capturing the intrinsic differences between buying pre-harvested fruit versus picking the fruit from the field.

### **3.6. Summary and Conclusions**

This paper developed a fully structural econometric consumer demand model for goods which have time and monetary costs, and where time spent obtaining the goods also enters into the utility function. The assumed framework allows for obtaining closed form solutions for the probability that the person will choose every alternative and the demand function for the continuous good. The derived demand functions and indirect utility functions differentiate the effect of time as a resource constraint forming the full price of the good and the effect of time in the utility function.

The model was used to analyze customers' decision to buy pick-your-own versus pre harvested fruit at North Carolina pick-your-own fruit operations. The empirical application distinguishes the double effect of time as a resource constraint and also providing utility. However, the effect of time is found to be relatively small compared to the price effect.

Elasticity estimates show that strawberries sold at pick-your-own operations are price elastic, with PYOS being less price elastic than PPS. However, the elasticity of the aggregate commodity composed by PYOS fruit and PPS was found to be inelastic. This information has implications for the pricing policies used by farmers engaged in PYO marketing. The effect of the socio-demographic characteristics of the individuals could also be used for the design of marketing strategies.



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**Table 3.1. Summary Statistics of Characteristics of Customers Visiting Pick-your-own Fruit Operations in North Carolina**

| <b>Variable</b>   | <b>Pick-your-own strawberries (PYOS) customers</b> | <b>Pre-picked strawberries (PPS) customers</b> | <b>All customers</b> |
|---|--|--|----------------------|
| Number of customers                                       | 502  | 511  | 1013                 |
| Price of PPS \$/lb  | 1.39 (0.27)  | 1.39 (0.27)                                    | 1.39 (0.27)          |
| Price of PYOS \$/lb                                       | 0.87 (0.10)  | 0.87 (0.10)                                    | 0.87 (0.10)          |
| Time PPS min/lb   | -  | 1.69 (3.20)                                    | -                    |
| Time PYOS min/lb  | 4.64 (4.61)  | -  | -                    |
| Amount purchased lb                                       | 10.88 (8.93)                                       | 7.34 (6.48)                                    | 9.07 (7.97)          |
| New customers   | 0.37 (0.48)  | 0.25 (0.43)                                    | 0.30 (0.46)          |
| Age   | 48.89 (16.25)                                      | 53.47 (15.92)                                  | 51.22 (16.24)        |
| Miles traveled  | 14.34 (47.47)                                      | 19.52 (50.52)                                  | 16.98 (49.09)        |
| Number of members in household working more than 40 hours | 1.11 (1.12)  | 1.09 (1.09)                                    | 1.10 (1.10)          |
| Number of members in household working less than 40 hours | 0.37 (1.37)  | 0.18 (0.46)                                    | 0.27 (1.01)          |
| Retired people in household                               | 0.48 (0.78)  | 0.61 (0.96)                                    | 0.55 (0.88)          |
| Current residence in urban area                           | 0.50 (0.50)  | 0.46 (0.50)                                    | 0.48 (0.50)          |
| Residence of parents in urban area                        | 0.38 (0.48)  | 0.37 (0.48)                                    | 0.37 (0.48)          |
| Eastern region  | 0.25 (0.43)  | 0.52 (0.50)                                    | 0.39 (0.49)          |
| Central Region  | 0.37 (0.48)  | 0.11 (0.32)                                    | 0.24 (0.43)          |
| Western Region  | 0.38 (0.49)  | 0.36 (0.48)                                    | 0.24 (0.43)          |
| Visit during weekdays                                     | 0.76 (0.43)  | 0.74 (0.44)                                    | 0.75 (0.45)          |
| Income  | 53,690 (30,650)                                    | 56,898 (32,512)                                | 55,456 (31,645)      |

**Table 3.2. Maximum Likelihood Estimation of Structural Parameters of Discrete Choice  
(Probability of buying Pick-your-own Strawberries)**

| Variable   | Parameters             | ML<br>Std.<br>Errors | Boot.<br>Std.<br>Errors <sup>b</sup> | Marginal<br>Effects | ML<br>Std.<br>Errors | Boot.<br>Std.<br>Errors |
|--|------------------------|----------------------|--------------------------------------|---------------------|----------------------|-------------------------|
| Intercept  | -4.098*** <sup>a</sup> | 0.707                | 1.022                                | -1.231***           | 0.282                | 0.299                   |
| Price ( $P_{pyo} - P_{pre}$ )  | -5.348***              | 0.953                | 1.562                                | -1.606***           | 0.380                | 0.444                   |
| Opportunity Cost of Time   | -0.199*                | 0.136                | 0.145                                | -0.060*             | 0.054                | 0.041                   |
| Opportunity Cost of Time<br>( $w \cdot t_{pyo}$ ) x Number of<br>members in household<br>working > 40 h/week | -0.036                 | 0.025                | 0.033                                | -0.011              | 0.010                | 0.010                   |
| Opportunity Cost of Time<br>( $w \cdot t_{pyo}$ ) x Number of<br>members in household<br>working < 40 h/week | 0.072                  | 0.041                | 0.062                                | 0.022               | 0.016                | 0.017                   |
| Opportunity Cost of Time<br>( $w \cdot t_{pyo}$ ) x Number of<br>retired people in<br>household              | 0.018                  | 0.033                | 0.049                                | 0.005               | 0.013                | 0.014                   |
| Time ( $t_{pyo}$ )   | 0.765***               | 0.223                | 0.242                                | 0.230***            | 0.089                | 0.075                   |
| Time <sup>2</sup> ( $t_{pyo}^2$ )  | -0.066***              | 0.019                | 0.023                                | -0.020***           | 0.007                | 0.007                   |
| Income (\$10,000)  | 0.062                  | 0.055                | 0.059                                | 0.019               | 0.022                | 0.018                   |
| West   | -2.419***              | 0.286                | 0.486                                | -0.726***           | 0.114                | 0.134                   |
| East   | -0.375*                | 0.167                | 0.228                                | -0.113*             | 0.067                | 0.074                   |
| Number of males in the<br>shopping party   | 0.131                  | 0.115                | 0.149                                | 0.039               | 0.046                | 0.046                   |
| Number of females in the<br>shopping party   | 0.272***               | 0.082                | 0.088                                | 0.082***            | 0.033                | 0.025                   |
| Number of children in the<br>shopping party  | 0.078                  | 0.026                | 0.205                                | 0.023               | 0.011                | 0.060                   |
| Urban  | 0.166*                 | 0.093                | 0.106                                | 0.050*              | 0.037                | 0.031                   |
| Weekday visit  | 0.237                  | 0.186                | 0.225                                | 0.071               | 0.074                | 0.067                   |
| Miles  | 0.001                  | 0.001                | 0.002                                | 0.000               | 0.000                | 0.001                   |
| Number of males in the<br>household  | -0.004                 | 0.026                | 0.089                                | -0.001              | 0.010                | 0.026                   |
| Number of females in the<br>household  | 0.160*                 | 0.103                | 0.121                                | 0.048*              | 0.041                | 0.036                   |
| Number of children in<br>household   | 0.168**                | 0.068                | 0.086                                | 0.051**             | 0.027                | 0.024                   |
| Age  | -0.008**               | 0.004                | 0.004                                | -0.002**            | 0.002                | 0.001                   |
| Ben/Lerman R <sup>2</sup>  | 0.64                   |                      |                                      |                     |                      |                         |
| Cramer R <sup>2</sup>  | 0.27                   |                      |                                      |                     |                      |                         |

<sup>a</sup>Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

<sup>b</sup>Standard errors and statistical tests were calculated using the asymptotic covariance obtained using bootstrapping.

**Table 3.3. OLS Structural Parameters of Continuous Choice (Conditional Quantities Demanded)**

| Variable                                | PYOS                  |               |                              | PPS       |               |                 |
|---|-----------------------|---------------|------------------------------|-----------|---------------|-----------------|
|   | Parameter             | OLS Std Error | Boot. Std Error <sup>b</sup> | Parameter | OLS Std Error | Boot. Std Error |
| Intercept                               | 2.372*** <sup>a</sup> | 0.132         | 0.163                        | 2.372***  | 0.132         | 0.163           |
| Adjusted Price                          | -0.157**              | 0.067         | 0.079                        | -0.157**  | 0.067         | 0.079           |
| Income (\$10,000)                       | -0.012                | 0.010         | 0.010                        | 0.010     | 0.009         | 0.008           |
| West                                    | 0.262***              | 0.067         | 0.065                        | 0.036     | 0.100         | 0.109           |
| East                                    | 0.024                 | 0.080         | 0.079                        | -0.525*** | 0.079         | 0.081           |
| Number of males in the shopping party   | 0.110**               | 0.051         | 0.061                        | -0.062    | 0.042         | 0.050           |
| Number of females in the shopping party | 0.067**               | 0.020         | 0.034                        | 0.067**   | 0.020         | 0.034           |
| Number of children in the household     | -0.030                | 0.017         | 0.034                        | 0.022     | 0.008         | 0.062           |
| Urban                                   | -0.106***             | 0.043         | 0.042                        | -0.106*** | 0.043         | 0.042           |
| Weekday visit                           | -0.081**              | 0.050         | 0.050                        | -0.081**  | 0.050         | 0.050           |
| Miles                                   | 0.000                 | 0.000         | 0.001                        | 0.000     | 0.000         | 0.001           |
| Number of males in the household        | -0.026                | 0.039         | 0.044                        | 0.012     | 0.009         | 0.032           |
| Number of females in the household      | -0.020                | 0.028         | 0.035                        | -0.020    | 0.028         | 0.035           |
| Number of children in household         | 0.037*                | 0.020         | 0.028                        | 0.037*    | 0.020         | 0.028           |
| Age                                     | -0.002                | 0.002         | 0.002                        | -0.002    | 0.002         | 0.002           |
| R <sup>2</sup>                          | 0.19                  |               |                              |           |               |                 |
| Adj. R <sup>2</sup>                     | 0.17                  |               |                              |           |               |                 |

<sup>a</sup>Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

<sup>b</sup>Standard errors and statistical tests were calculated using the asymptotic covariance obtained using bootstrapping.

**Table 3.4. Marginal Effects of Variables: Unconditional Demand for Pick-your-own Strawberries**

| Variable  | Discrete Choice Effects |                               | Conditional Mean Effects |                  | Total Unconditional Mean Effects |                  |
|---|-------------------------|-------------------------------|--------------------------|------------------|----------------------------------|------------------|
|   | Parameter               | Boot. Std. Error <sup>a</sup> | Parameter                | Boot. Std. Error | Parameter                        | Boot. Std. Error |
| Price   | -14.079*** <sup>a</sup> | 3.975                         | -2.283**                 | 1.337            | -16.362***                       | 4.630            |
| Opportunity Cost of Time  | -0.525**                | 0.360                         | -0.085*                  | 0.066            | -0.610*                          | 0.417            |
| Opportunity Cost of Time (w.t <sub>pyo</sub> ) x Number of members in household working > 40 h/week | -0.095                  | 0.080                         | -0.015                   | 0.016            | -0.111                           | 0.093            |
| Opportunity Cost of Time (w.t <sub>pyo</sub> ) x Number of members in household working < 40 h/week | 0.188                   | 0.158                         | 0.031                    | 0.036            | 0.219                            | 0.185            |
| Opportunity Cost of Time (w.t <sub>pyo</sub> ) x Number of retired people in household              | 0.048                   | 0.122                         | 0.008                    | 0.022            | 0.055                            | 0.141            |
| Time (t <sub>pyo</sub> )  | 2.015***                | 0.624                         | 0.327***                 | 0.128            | 2.342***                         | 0.726            |
| Time <sup>2</sup> (t <sub>pyo</sub> <sup>2</sup> )  | -0.173***               | 0.059                         | -0.028***                | 0.012            | -0.201***                        | 0.068            |
| Income (\$10,000)   | 0.163                   | 0.147                         | -0.055                   | 0.064            | 0.108                            | 0.181            |
| West  | -6.369***               | 1.206                         | 0.990**                  | 0.486            | -5.378***                        | 1.400            |
| East  | -0.987*                 | 0.608                         | 0.050                    | 0.524            | -0.937                           | 0.894            |
| Number of males in the shopping party   | 0.345                   | 0.381                         | 0.702**                  | 0.408            | 1.047**                          | 0.612            |
| Number of females in the shopping party   | 0.717***                | 0.222                         | 0.473**                  | 0.233            | 1.190***                         | 0.333            |
| Number of children in the shopping party  | 0.206                   | 0.514                         | -0.162                   | 0.228            | 0.043                            | 0.612            |
| Urban   | 0.438*                  | 0.268                         | -0.601**                 | 0.288            | -0.163                           | 0.415            |
| Weekday visit   | 0.624                   | 0.609                         | -0.430*                  | 0.325            | 0.194                            | 0.746            |
| Miles   | 0.002                   | 0.004                         | 0.000                    | 0.004            | 0.001                            | 0.005            |
| Number of males in the household  | -0.010                  | 0.223                         | -0.157                   | 0.311            | -0.167                           | 0.405            |
| Number of females in the household  | 0.422*                  | 0.313                         | -0.083                   | 0.236            | 0.339                            | 0.458            |
| Number of children in household   | 0.443**                 | 0.221                         | 0.266*                   | 0.186            | 0.709**                          | 0.323            |
| Age   | -0.020**                | 0.011                         | -0.014*                  | 0.011            | -0.034**                         | 0.017            |

<sup>a</sup>Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

<sup>b</sup>Standard errors and statistical tests were calculated using the asymptotic covariance obtained using bootstrapping.

**Table 3.5. Marginal Effects of Variables: Unconditional Demand for Pre-harvested Strawberries**

| Variable  | Discrete Choice Effects |                               | Conditional Mean Effects |                  | Total Unconditional Mean Effects |                  |
|---|-------------------------|-------------------------------|--------------------------|------------------|----------------------------------|------------------|
|   | Parameter               | Boot. Std. Error <sup>b</sup> | Parameter                | Boot. Std. Error | Parameter                        | Boot. Std. Error |
| Price   | - 9.240*** <sup>a</sup> | 2.627                         | -6.391***                | 1.931            | -15.631***                       | 4.488            |
| Opportunity Cost of Time  | 0.344*                  | 0.236                         | 0.215*                   | 0.155            | 0.559*                           | 0.391            |
| Opportunity Cost of Time (w.t <sub>pyo</sub> ) x Number of members in household working > 40 h/week | 0.063                   | 0.053                         | 0.039                    | 0.035            | 0.102                            | 0.087            |
| Opportunity Cost of Time (w.t <sub>pyo</sub> ) x Number of members in household working < 40 h/week | -0.124                  | 0.104                         | -0.077                   | 0.069            | -0.201                           | 0.172            |
| Opportunity Cost of Time (w.t <sub>pyo</sub> ) x Number of retired people in household              | -0.031                  | 0.080                         | -0.020                   | 0.053            | -0.051                           | 0.133            |
| Time (t <sub>pyo</sub> )  | -1.323***               | 0.411                         | -0.825***                | 0.274            | -2.148***                        | 0.684            |
| Time <sup>2</sup> (t <sub>pyo</sub> <sup>2</sup> )  | 0.114***                | 0.039                         | 0.071***                 | 0.026            | 0.184***                         | 0.064            |
| Income (\$10,000)   | -0.107                  | 0.097                         | -0.027                   | 0.072            | -0.134                           | 0.164            |
| West  | 4.180***                | 0.800                         | 2.750***                 | 0.774            | 6.930***                         | 1.454            |
| East  | 0.648*                  | 0.396                         | -1.691***                | 0.413            | -1.044*                          | 0.711            |
| Number of males in the shopping party   | -0.226                  | 0.250                         | -0.387*                  | 0.254            | -0.614*                          | 0.453            |
| Number of females in the shopping party   | -0.470***               | 0.143                         | -0.027                   | 0.180            | -0.497**                         | 0.286            |
| Number of children in the shopping party  | -0.135                  | 0.336                         | 0.003                    | 0.237            | -0.132                           | 0.479            |
| Urban   | -0.288*                 | 0.177                         | -0.602***                | 0.214            | -0.889***                        | 0.342            |
| Weekday visit   | -0.410                  | 0.401                         | -0.577**                 | 0.327            | -0.986*                          | 0.687            |
| Miles   | -0.001                  | 0.003                         | -0.001                   | 0.003            | -0.002                           | 0.005            |
| Number of males in the household  | 0.007                   | 0.147                         | 0.053                    | 0.153            | 0.060                            | 0.259            |
| Number of females in the household  | -0.277*                 | 0.206                         | -0.254*                  | 0.168            | -0.531*                          | 0.330            |
| Number of children in household   | -0.291**                | 0.145                         | -0.034                   | 0.138            | -0.325*                          | 0.249            |
| Age   | 0.013**                 | 0.007                         | 0.000                    | 0.008            | 0.014                            | 0.013            |

<sup>a</sup>Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

<sup>b</sup>Standard errors and statistical tests were calculated using the asymptotic covariance obtained using bootstrapping.



**Table 3.6. Elasticities Estimates**

| Variable   | Pick-your-own strawberries<br>(PYOS ) |                     |              | Pre-picked strawberries<br>(PPS) |                     |              |
|------------|---------------------------------------|---------------------|--------------|----------------------------------|---------------------|--------------|
|            | Disc.<br>Choice                       | Conditional<br>Mean | Total Effect | Disc.<br>Choice                  | Conditional<br>Mean | Total Effect |
| Price PYOS | -1.12                                 | -0.42               | -1.30        | 1.10                             | 0.69                | 1.79         |
| Price PPS  | 1.79                                  | 0.16                | 1.90         | -1.76                            | -1.21               | -2.98        |
| Time PYOS  | 0.09                                  | 0.01                | 0.09         | 0.09                             | -0.05               | -0.12        |

## Appendices

### Appendix 3.1. Derivation of Solutions to Maximization Problem

Consider the conditional maximization problem:

$$\text{Max } \bar{u}_j(x_j, k + (\psi_j + \xi_j)x_j) \quad \text{st. } x_j\pi_j + k = I$$

Making  $y = k + (\psi_j + \xi_j)x_j$  substituting back into the utility function and adding and subtracting  $(\psi_j + \xi_j)x_j$  in the budget constraint we obtain:

$$\text{Max } \bar{u}_j(x_j, y) \quad \text{st. } x_j\pi_j + k + (\psi_j + \xi_j)x_j - (\psi_j + \xi_j)x_j = I \quad \text{or}$$

$$\text{Max } \bar{u}_j(x_j, y) \quad \text{st. } x_j[\pi_j - (\psi_j + \xi_j)] + y = I$$

The solutions to this maximization problem have the form:

$$x_j^* = x_j(\pi_j - \psi_j - \xi_j, I) \quad \text{and} \quad y^* = (\pi_j - \psi_j - \xi_j, I) \quad \text{and therefore (9) and (10) follow.}$$

### Appendix 3.2. Parameters of Reduced Form Discrete Choice Probit Model and Auxiliary Time Equations

| Variable  | Discrete Choice Effects |            | Time PYOS |            | Time PPS  |            |
|---|-------------------------|------------|-----------|------------|-----------|------------|
|   | Parameter               | Std. Error | Parameter | Std. Error | Parameter | Std. Error |
| Intercept   | -2.757*** <sup>a</sup>  | 0.404      | 2.787     | 4.282      | 0.739     | 1.790      |
| Price ( $P_{pvo}P_{pre}$ )                                  | -7.025***               | 0.639      | -5.471    | 6.735      | -10.061** | 5.621      |
| West  | -2.773***               | 0.280      | -1.084    | 2.345      | -5.502**  | 2.576      |
| Income (\$10,000)   | -0.012                  | 0.017      | -0.110*   | 0.070      | -0.091*** | 0.039      |
| First visit   | 0.153*                  | 0.106      | 0.805*    | 0.512      | -0.046    | 0.366      |
| Miles Traveled  | 0.000                   | 0.001      | -0.001    | 0.002      | -0.002*   | 0.001      |
| Number of males in the shopping party                       | 0.101                   | 0.086      | -0.692*   | 0.464      | -0.146    | 0.285      |
| Number of females in the shopping party                     | 0.287***                | 0.089      | -0.208**  | 0.091      | 0.041     | 0.286      |
| Number of children in the shopping party                    | 0.005                   | 0.015      | 0.164     | 0.187      | -0.007    | 0.010      |
| Number of males in the household                            | 0.002                   | 0.030      | 0.030     | 0.246      | -0.019*   | 0.012      |
| Number of females in the household                          | -0.075                  | 0.099      | -1.133*   | 0.757      | 0.047     | 0.228      |
| Number of children in the household                         | 0.136***                | 0.051      | -0.651**  | 0.361      | -0.269*   | 0.209      |
| Number of members in household working > than 40 hours/week | -0.091                  | 0.075      | 0.576*    | 0.428      | 0.145     | 0.202      |
| Number of members in household working < than 40 hours/week | 0.170**                 | 0.102      | 0.618*    | 0.481      | -0.270    | 0.371      |
| Number of retired members in household                      | 0.039                   | 0.072      | -0.115    | 0.370      | 0.013     | 0.142      |
| Age   | -0.008**                | 0.004      | 0.014     | 0.026      | -0.009    | 0.023      |
| Current residence city                                      | 0.187                   | 0.213      | -0.684    | 0.910      | -0.749*   | 0.468      |
| Current residence rural/town                                | -0.202**                | 0.112      | -0.366    | 0.409      | -0.323    | 0.330      |
| Parents residence city                                      | 0.077                   | 0.133      | -0.907    | 0.751      | -0.397    | 0.394      |
| Parents residence rural/town                                | 0.216**                 | 0.125      | -0.819*   | 0.628      | -0.557*   | 0.391      |
| Weekday visit   | 0.231**                 | 0.121      | 1.460**   | 0.487      | 0.163     | 0.369      |
| Mills ratio   |                         |            | -0.161    | 1.775      | -0.506    | 1.353      |
| R <sup>2</sup>  |                         |            | 0.09      |            | 0.09      |            |
| Adj. R <sup>2</sup>   |                         |            | 0.04      |            | 0.04      |            |
| Loglikelihood value   | -458.19                 |            |           |            |           |            |
| Ben/Lerman R <sup>2</sup>                                   | 0.63                    |            |           |            |           |            |
| Cramer R <sup>2</sup>                                       | 0.26                    |            |           |            |           |            |
| % of Correctly Predicted                                    | 71%                     |            |           |            |           |            |

<sup>a</sup> Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively

### Appendix 3.3. Log-Income Equation Estimation Results

| Variables  | Coefficient | Std. error             |
|--|-------------|------------------------|
| Constant   | 9.478       | 0.203**** <sup>a</sup> |
| No. of persons in household working more than 40 hours | 0.090       | 0.022***               |
| No. of persons in household working less than 40 hours | -0.059      | 0.021***               |
| No. of persons in household retired                    | 0.006       | 0.035                  |
| Age  | 0.569       | 0.081***               |
| Age <sup>2</sup>                                       | -0.062      | 0.008***               |
| East   | -0.077      | 0.053*                 |
| West   | 0.088       | 0.053**                |
| Urban residence  | 0.120       | 0.041***               |
| $\sigma$   | 0.622       | 0.018***               |
| Log-likelihood value                                   | -1816.7     |                        |

<sup>a</sup> Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively

### Appendix 3.4. Derivation of Elasticities for the Aggregate Goods

To derive the equations for the elasticities of the aggregate good we follow Deaton and Muellbauer (1980, p. 121) and consider a three good model in which two prices move in proportion. Consider the three prices  $p_1$ ,  $p_2$  and  $p_3$  and assume that  $p_1$  and  $p_2$  bear some fixed ratio  $\rho$  to some base period prices  $p_1^0$  and  $p_2^0$ . Therefore,  $p_1 = p_1^0 \rho$ ;  $p_2 = p_2^0 \rho$ .

If the composite commodity is defined as  $Q = p_1^0 q_1 + p_2^0 q_2$  which uses the fixed base-period prices as the weights, then  $\rho$  can be seen as the “price” for the combined group. This is because only  $\rho$  is allowed to change whereas the ratio  $p_1/p_2$  remains fixed at  $p_1^0/p_2^0$ . Hence a change in the price of the aggregate commodity equals:

$$\frac{\partial Q}{\partial \rho} = p_1^0 \frac{\partial q_1}{\partial \rho} + p_2^0 \frac{\partial q_2}{\partial \rho}. \text{ Expressions for } \frac{\partial q_1}{\partial \rho} \text{ and } \frac{\partial q_2}{\partial \rho} \text{ can be obtained from the}$$

estimated demand equations  $q_1 = D_1(p_1, p_2, p_3, I)$  and  $q_2 = D_2(p_1, p_2, p_3, I)$  where  $I$  is total income or expenditures. Therefore it can be shown that the elasticity for the aggregate commodity  $Q$  equals:

$$\eta = \frac{\partial Q}{\partial \rho} \frac{\rho}{Q} = \frac{p_1^0 q_1}{Q} \left( \frac{\partial q_1}{\partial p_1} \frac{p_1}{q_1} + \frac{\partial q_1}{\partial p_2} \frac{p_2}{q_1} \right) + \frac{p_2^0 q_2}{Q} \left( \frac{\partial q_2}{\partial p_1} \frac{p_1}{q_2} + \frac{\partial q_2}{\partial p_2} \frac{p_2}{q_2} \right) \text{ or}$$

$$\eta = w_1 (\varepsilon_{11} + \varepsilon_{12}) + w_2 (\varepsilon_{21} + \varepsilon_{22})$$

Without loss of generality, for the calculations we assume a value of  $\rho=1$ .

## **Chapter 4**

# **The Theory of the Economics of Time Revisited**

### **4.1. Introduction**

This chapter presents a deterministic theoretical model of consumer behavior for economic problems where the time dimension is important. This model is appropriate for choice situations that involve decisions about how much money and time to devote to obtain/consume several goods.

The model presented in this section is similar to the model presented in DeSerpa (1971) in that: (1) utility is a function of the commodities and the time allocated to them, and (2) the consumer is subject to two budget constraints. DeSerpa's work is extended by deriving the complete comparative statics of the problem using duality theory. Implications for the specification of demand systems consistent with this theory are provided. Similarly to the previous chapter, the theoretical results are used to empirically analyze the economic behavior of customers visiting pick-your-own (PYO) fruit operations.

The two linear consumer constrained problem without considering the effect of time in the utility function has received some attention in the economics literature (e.g. Larson and Shaikh, 2001; Hanemann, 2004). However, the time spent obtaining (consuming) the goods is not assumed to provide utility. Time is only seen as a scarce resource constraining the problem.

## 4.2. Consumer Problem

The general decision framework is one in which an individual needs to decide how much of  $n$  goods  $x_1, x_2, \dots, x_n$  to obtain (consume). The objective of the individual is to maximize the utility from the goods obtained (consumed) and the time devoted to obtain (consume) the goods. The price of the  $n$  goods can be represented by  $p_1, p_2, \dots, p_n$  and the time prices by  $a_1, a_2, \dots, a_n$ . Vectors containing the quantities, total time spent on each good, and time and money prices for the  $n$  goods, can be represented by  $\mathbf{x}$ ,  $\mathbf{t}$  ( $t_i = a_i x_i$ ) and  $\mathbf{p}$ ,  $\mathbf{a}$ , respectively. The consumer maximum time and money available for consumption are  $T$  and  $M$ , respectively. In this case, the consumer problem is:

$$\text{Max}_{\mathbf{x}} U(\mathbf{x}, \mathbf{t}) \text{ st. } \mathbf{p}'\mathbf{x} \leq M, \mathbf{a}'\mathbf{x} \leq T \quad \text{P(1)}$$

The corresponding Lagrangian function of problem P(1) can be written as:

$$L(\mathbf{x}, \lambda, \mu) = U(\mathbf{x}, \mathbf{t}) - \lambda(\mathbf{p}'\mathbf{x} - M) - \mu(\mathbf{a}'\mathbf{x} - T). \quad (2)$$

The first order conditions are then:

$$\begin{aligned} L_{\mathbf{x}}(\mathbf{x}, \lambda, \mu) &= U_{\mathbf{x}}(\mathbf{x}, \mathbf{t}) + U_{\mathbf{t}}(\mathbf{x}, \mathbf{t}) \cdot \mathbf{a} - \lambda \mathbf{p} - \mu \mathbf{a} = \mathbf{0} \\ L_{\lambda}(\mathbf{x}, \lambda, \mu) &= \mathbf{p}'\mathbf{x} - M = 0 \\ L_{\mu}(\mathbf{x}, \lambda, \mu) &= \mathbf{a}'\mathbf{x} - T = 0 \end{aligned} \quad (3)$$

where  $(.)$  indicates element by element multiplication. The first order condition defines a system of  $n+2$  equations and  $n+2$  unknowns which can be solved to obtain the critical point  $(\mathbf{x}^*, \lambda^*, \mu^*)$  that satisfies these conditions.

For comparison purposes, and before we present the comparative statics of the solution to problem P(1), we summarize the results of the comparative statics of the solution to the two linear constraint problem when time is not included in the utility function. The problem being consider is then

$$\text{Max}_x U(\mathbf{x}) \text{ st. } \mathbf{p}'\mathbf{x} \leq M, \mathbf{a}'\mathbf{x} \leq T \quad \text{P(4)}$$

Let  $x_i = h_i(p, a, T, M)$ ,  $i=1, \dots, N$ , be the ordinary demand functions associated with this problem and  $V(p, a, T, M) = \max_x U(x) - \lambda(p'x - M) - \mu(a'x - T)$  the corresponding indirect utility function. The differential properties of the ordinary demand functions are (Hanemann, 2004):

$$(a) \quad \frac{\partial h_i}{\partial p_j} = \frac{\partial x_i}{\partial p_j} \Big|_{M \text{ compensated}} - x_j \frac{\partial h_i}{\partial M} \quad i, j = 1, \dots, N$$

$$(b) \quad \frac{\partial h_i}{\partial a_j} = \frac{\partial x_i}{\partial a_j} \Big|_{T \text{ compensated}} - x_j \frac{\partial h_i}{\partial T} \quad i, j = 1, \dots, N$$

Define the  $(N \times N)$  matrices  $S^p$  and  $S^w$  with elements:

$$S_{ij}^p = \frac{\partial h_i}{\partial p_j} + x_j \frac{\partial h_i}{\partial M} \text{ and } S_{ij}^w = \frac{\partial h_i}{\partial a_j} + x_j \frac{\partial h_i}{\partial T}.$$

(c)  $S^p$  and  $S^w$  are each symmetric, so that  $S_{ij}^p = S_{ji}^p$  and  $S_{ij}^w = S_{ji}^w$ .

(d)  $S^p$  and  $S^w$  are each negative semi-definite.

$$(e) \quad \frac{\partial V}{\partial T} S_{ij}^p = \frac{\partial V}{\partial M} S_{ji}^w \quad i, j = 1, \dots, N. \quad \left( \frac{\partial V}{\partial Y} \Big/ \frac{\partial V}{\partial M} = \frac{\lambda}{\mu} = \theta \right)$$



Part (a) defines the Slutsky decomposition of the effect of a money price change. Similarly, part (b) is the Slutsky decomposition of a time price change. In Part (a) the compensation is made by adjusting M so as to maintain the utility constant. In part (b) the compensation is performed by adjusting T. Part (d) implies negative own money price and time price compensated effects. Finally, parts (d) and (e) imply restrictions on functional forms to serve as demand functions which can be imposed and/or tested.

Hanemann (2004) also suggests an algorithm for the construction of solutions to the two linear constraints consumer problem. The solutions are based on the solutions to the one linear constraint problem. The algorithm is:

- (1) Take a demand system  $g_i(p, M)$  which is known to solve the traditional one linear constraint problem, and the corresponding indirect utility function  $W(p, M)$ .
- (2) The demand functions  $x_i = h_i(p, a, T, M)$  for the two linear constraint problem can be constructed by replacing  $p$  by  $p + \theta a$  and  $M$  by  $M + \theta T$  in  $g_i(p, M)$ . In equation form:
 
$$x_i = h_i(p, a, T, M) = g_i(p + \theta a, M + \theta T) = (p_1 + \theta a_1, p_2 + \theta a_2, \dots, p_n + \theta a_n, M + \theta T) \quad (5)$$
- (3) Using the same logic, the indirect utility functions for the two constraint problem can be constructed from the indirect utility functions for the one linear constraint consumer problem.
- (4) To obtain an expression for  $\theta(p, t, M, T)$ , the time constraint  $T = a'g(p + \theta a, M + \theta T)$  can be solved for  $\theta(p, t, M, T)$ . However, since in practice it will be

difficult to obtain a closed form solution for  $\theta$ , Hanemann (2004) suggests using numerical methods to solve the problem.

#### 4.2.1. Comparative Statics of Solutions

In this section the gain duality method proposed by Hatta (1980) is used to derive the comparative statics of the solution to problem P(1). The gain method is applicable to problems of the form:

$$\Phi(\boldsymbol{\alpha}, \boldsymbol{\beta}) = \max_{\mathbf{x}} \{f(\mathbf{x}; \boldsymbol{\alpha}) \text{ s.t. } \mathbf{k}(\mathbf{x}; \boldsymbol{\alpha}) = \boldsymbol{\beta}\} \quad \text{P(6)}$$

where  $\Phi$  is the indirect objective function and,

$$\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) = \arg \max_{\mathbf{x}} \{f(\mathbf{x}; \boldsymbol{\alpha}) \text{ s.t. } \mathbf{k}(\mathbf{x}; \boldsymbol{\alpha}) = \boldsymbol{\beta}\} \quad (7)$$

is the optimal value of the decision vector,  $\boldsymbol{\alpha}$  is a vector of parameters common to both the objective function  $f$  and the vector constraint function  $\mathbf{k}$ , and  $\boldsymbol{\beta}$  is a vector of constrained parameters. The gain optimization problem corresponding to problem P(6) is:

$$G(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}^0, \boldsymbol{\beta}^0)) = \Phi(\boldsymbol{\alpha}, \mathbf{k}(\mathbf{x}^*(\boldsymbol{\alpha}^0, \boldsymbol{\beta}^0); \boldsymbol{\alpha})) - f(\mathbf{x}^*(\boldsymbol{\alpha}^0, \boldsymbol{\beta}^0); \boldsymbol{\alpha}), \quad (8)$$

where  $G$  is the gain function and  $\mathbf{x}^*(\boldsymbol{\alpha}^0, \boldsymbol{\beta}^0)$  is the optimal value of the choice vector for problem P(6) when  $\boldsymbol{\alpha} = \boldsymbol{\alpha}^0$  and  $\boldsymbol{\beta} = \boldsymbol{\beta}^0$ . It is important to point out that the gain problem transforms a constrained problem to a non-constrained problem by substituting  $\boldsymbol{\beta} = \mathbf{k}(\mathbf{x}^*(\boldsymbol{\alpha}^0, \boldsymbol{\beta}^0); \boldsymbol{\alpha})$  into the indirect utility function (Caputo, 1998). By construction  $G \geq 0$  and reaches a minimum value of zero at  $\boldsymbol{\alpha} = \boldsymbol{\alpha}^0$ . The first order necessary condition  $G_{\boldsymbol{\alpha}} = 0$  and the second order necessary condition (symmetry and positive semidefiniteness of  $G_{\boldsymbol{\alpha}\boldsymbol{\alpha}}$ ) yield the complete comparative statics of the problem.

Since problem P(1) belongs to the class of problems indicated by P(6), the derivation of the comparative statics of the problem can be done by applying the method proposed by Hatta (1980).

Let  $\mathbf{x}^* = \mathbf{x}^*(\mathbf{p}, \mathbf{a}, T, M)$  be the  $n \times 1$  vector of ordinary demand functions associated with problem P(1). Define the  $2n \times 1$  parameter vector  $\boldsymbol{\alpha} = [\mathbf{p}; \mathbf{a}]$  containing money and time prices, with the semicolon (;) denoting vertical concatenation. Define  $\boldsymbol{\beta} = [T; M]$  as the  $2 \times 1$  parameter vector containing the money and time constraint parameters and  $\mathbf{k}(\mathbf{x}; \boldsymbol{\alpha}) = [\mathbf{x}' \mathbf{p}; \mathbf{x}' \mathbf{a}]$  as the  $2 \times 1$  vector containing the constraint functions. The maximization problem P(1) can be then rewritten as:

$$\text{Max } U(\mathbf{x}, \boldsymbol{\alpha}) \text{ s.t. } \mathbf{k}(\mathbf{x}; \boldsymbol{\alpha}) = \boldsymbol{\beta} \quad \text{P(9)}$$

and the ordinary demand functions can then be rewritten as  $\mathbf{x}^*(\mathbf{p}, \mathbf{a}, T, M) = \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})$ .

Notice that for this case since utility is only a function of the time prices

$U_{\boldsymbol{\alpha}}(\mathbf{x}, \boldsymbol{\alpha}) = [\mathbf{0}; U_{\mathbf{a}}(\mathbf{x}, \boldsymbol{\alpha})]$ . Since the vector  $\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})$  satisfies the constraint  $\mathbf{k}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}), \boldsymbol{\alpha}) = \boldsymbol{\beta}$  the following equation can be defined:

$$\mathbf{s}(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = \mathbf{x}^*(\boldsymbol{\alpha}, \mathbf{k}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}), \boldsymbol{\alpha})) \quad (10)$$

which can be interpreted as the demand function when the initial endowment is given by  $\mathbf{k}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}), \boldsymbol{\alpha})$ .

#### 4.2.2. Slutsky-Hicks Equation

Using equation (10), the Slutsky-Hicks Equation for problem P(9) is

$$\mathbf{s}_{\boldsymbol{\alpha}}(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = \mathbf{x}_{\boldsymbol{\alpha}}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) + \mathbf{x}_{\boldsymbol{\beta}}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) \mathbf{k}_{\boldsymbol{\alpha}}(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \quad (11)$$

where  $\mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  is a  $n \times 2n$  matrix which can be written as the following partitioned matrix

$$\mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = [\mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \quad \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))]. \quad (12)$$

The submatrix  $\mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  defines the Slutskian substitution matrix for money price changes. Along the Slutskian demand curve, the price change is accompanied by an income compensation that keeps the original consumption bundle on the new budget plane (Hatta, 1980)<sup>5</sup>. Moreover,

$$\mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = \mathbf{x}_p^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) + \mathbf{x}_M^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) \mathbf{x}'(\boldsymbol{\alpha}, \boldsymbol{\beta}). \quad (13)$$

The submatrix  $\mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  defines the Slutskian substitution matrix for time price changes. The compensation of the time price change in this case is performed by adjusting T. This submatrix takes the form:

$$\mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = \mathbf{x}_a^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) + \mathbf{x}_T^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) \mathbf{x}'(\boldsymbol{\alpha}, \boldsymbol{\beta}) \quad (14)$$

Equations (13) and (14) look similar to the substitution matrix for the two linear constrained maximization problem without time in the utility function (Larson and Shaikh, 2001; Hanemman, 2004). In order to explore the implication of the inclusion of time consider the following companion problem to P(9)

$$\text{Max } U(\mathbf{x}, \boldsymbol{\alpha}_1) \text{ s.t. } \mathbf{k}(\mathbf{x}, \boldsymbol{\alpha}_2) = \boldsymbol{\beta} \quad \text{P(15)}$$

where  $\boldsymbol{\alpha}_1 = [\mathbf{p}_1; \mathbf{a}_1]$  and  $\boldsymbol{\alpha}_2 = [\mathbf{p}_2; \mathbf{a}_2]$ . Let  $\bar{\mathbf{x}}^* = \bar{\mathbf{x}}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta})$  be the solution to problem P(15) and define the function  $\bar{s}$  by

$$\bar{s}(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \bar{\mathbf{x}}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta})) = \bar{\mathbf{x}}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, k(\bar{\mathbf{x}}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}), \boldsymbol{\alpha}_2)) \quad (16)$$

<sup>5</sup> It can be shown that in the limit the Hicks and Slutsky compensation are identical (Silberberg, 1990).

Since problems P(9) and P(15) are equivalent when  $\alpha_1 = \alpha_2 = \alpha$  then

$\bar{x}^*(\alpha, \alpha, \beta) = x^*(\alpha, \beta)$  and  $\bar{s}(\alpha, \alpha, \bar{x}^*(\alpha, \alpha, \beta)) = s(\alpha, x^*(\alpha, \beta))$ . Hence

$$s_\alpha(\alpha, x^*(\alpha, \beta)) = \bar{s}_{\alpha_1}(\alpha, \alpha, x^*(\alpha, \beta)) + \bar{s}_{\alpha_2}(\alpha, \alpha, x^*(\alpha, \beta))$$

This result and (11) imply

$$x_\alpha^*(\alpha, \beta) = \bar{s}_{\alpha_1}(\alpha, \alpha, x^*(\alpha, \beta)) + \bar{s}_{\alpha_2}(\alpha, \alpha, x^*(\alpha, \beta)) - x_\beta^*(\alpha, \beta)k_\alpha(\alpha, x^*(\alpha, \beta)), \quad (17)$$

where

$$\bar{s}_{\alpha_1}(\alpha, \alpha, x^*(\alpha, \beta)) = \bar{x}_{\alpha_1}^*(\alpha, \alpha, \beta),$$

$$\bar{s}_{\alpha_2}(\alpha, \alpha, x^*(\alpha, \beta)) = \bar{x}_{\alpha_2}^*(\alpha, \alpha, \beta) + \bar{x}_\beta^*(\alpha, \alpha, \beta)k_{\alpha_2}(\alpha, \bar{x}^*(\alpha, \alpha, \beta)),$$

$\bar{x}_\beta^*(\alpha, \alpha, \beta)k_{\alpha_2}(\alpha, \bar{x}^*(\alpha, \alpha, \beta)) = x_\beta^*(\alpha, \beta)k_\alpha(\alpha, x^*(\alpha, \beta))$ . Therefore:

$$x_\alpha^*(\alpha, \beta) = \bar{x}_{\alpha_1}^*(\alpha, \alpha, \beta) + \bar{x}_{\alpha_2}^*(\alpha, \alpha, \beta) \quad (18)$$

where  $\bar{x}_{\alpha_1}^*$  captures the effect of the parameters in the utility function and  $\bar{x}_{\alpha_2}^*$  represents the regular price effects. It is easily seen that since the money price parameters do not enter the utility function  $\bar{s}_{\alpha_1}(\alpha, \alpha, x^*(\alpha, \beta)) = 0$ . It is also interesting to point out that the effect of the time price change in the Marshallian demand equation equals the substitution effect. In this case, an income effect is not necessary since the change in the price does not cause any change in the budget constraint and therefore there is not need for compensation.

### 4.2.3. Roy's Identity

The indirect utility function for problem P(9) is

$$V(\boldsymbol{\alpha}, \boldsymbol{\beta}) = \max_{\mathbf{x}} \{U(\mathbf{x}, \boldsymbol{\alpha}) \text{ s.t. } \mathbf{k}(\mathbf{x}; \boldsymbol{\alpha}) = \boldsymbol{\beta}\}, \quad (19)$$

and the corresponding gain function is then:

$$G(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = V(\boldsymbol{\alpha}, \mathbf{k}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha})) - U(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}). \quad (20)$$

By applying the envelope theorem to (20) and using the fact that  $G_{\alpha} = 0$  it can be shown that

$$V_p(\boldsymbol{\alpha}, \boldsymbol{\beta}) + V_M(\boldsymbol{\alpha}, \boldsymbol{\beta})\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}) = 0 \quad (21)$$

$$V_a(\boldsymbol{\alpha}, \boldsymbol{\beta}) + V_T(\boldsymbol{\alpha}, \boldsymbol{\beta})\mathbf{x}^* - U_a(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) = 0 \quad (22)$$

Notice that equation (21) is the traditional Roy's identity, whereas that equation (22) is a new form of Roy's identity that incorporates the effect of time in the utility function. Since for problem P(1),  $U_a(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) = U_t(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) \cdot \mathbf{x}^*$

$$\frac{V_{a_i}(\boldsymbol{\alpha}, \boldsymbol{\beta})}{V_{p_i}(\boldsymbol{\alpha}, \boldsymbol{\beta})} = \frac{V_T(\boldsymbol{\alpha}, \boldsymbol{\beta}) - U_{t_i}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha})}{V_M(\boldsymbol{\alpha}, \boldsymbol{\beta})} = \frac{\mu}{\lambda} - \frac{U_{t_i}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha})}{\lambda} = \frac{\kappa_i}{\lambda}$$

The term  $\kappa_i / \lambda$  is composed of the value of time as a resource ( $\mu/\lambda$ ) and  $U_{t_i}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) / \lambda$ , the value of time spent on the  $i$ th commodity. This is in DeSerpas' terms the value of saving time in the  $i$ th activity, or more succinctly the value of time in the  $i$ th activity. If the effect of time in the utility function were not considered, the value of time in any activity would be the same across all activities and would equal  $\mu/\lambda$ , the value of time as a resource. However, if time is included in the utility function, the value

of time is activity dependent. It can also be shown (DeSerpa, 1971) that  $\kappa_i / \lambda \geq 0$  which implies that  $\mu / \lambda \geq U_i(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) / \lambda$ .

#### 4.2.4. Negative Semidefiniteness and Symmetry Conditions

To facilitate the study of the implications of the second order conditions of the gain function, the following function  $\mathbf{c}$  needs to be introduced. Function  $\mathbf{c}$  is related to the second order necessary conditions for problem P(9) as follows

$$G_{aa}(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = -\mathbf{c}(\boldsymbol{\alpha}, \boldsymbol{\beta})\mathbf{s}_a(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) \quad (23)$$

with

$$\mathbf{c}(\boldsymbol{\alpha}, \boldsymbol{\beta}) = V_M(\boldsymbol{\alpha}, \boldsymbol{\beta})\mathbf{k}_{ax}^M(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) + V_T(\boldsymbol{\alpha}, \boldsymbol{\beta})\mathbf{k}_{ax}^T(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) - U_{ax}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}), \boldsymbol{\alpha})$$

which for problem P(9) can be shown to equal:

$$\mathbf{c}(\boldsymbol{\alpha}, \boldsymbol{\beta}) = \begin{bmatrix} \lambda \mathbf{I} \\ \mu \mathbf{I} - U_{ax}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}), \boldsymbol{\alpha}) \end{bmatrix}$$

If it is further assumed that  $v_{ij} = \frac{\partial^2 U}{\partial a_i \partial x_j} = \frac{\partial^2 U}{\partial x_i \partial a_j} = 0, \forall i \neq j$ , which implies that

the marginal utility of the consumption of any good is only a function of the own time price, the matrix  $\Gamma = \mu \mathbf{I} - U_{ax}(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}), \boldsymbol{\alpha})$  is a diagonal matrix with elements

$\varphi_i = \mu - \frac{\partial^2 U}{\partial a_i \partial x_i} = \mu - v_{ii}$ . It follows then that:

$$\mathbf{c}(\boldsymbol{\alpha}, \boldsymbol{\beta})\mathbf{s}_a(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) = \begin{bmatrix} \lambda \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) & \lambda \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \\ \Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) & \Gamma \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \end{bmatrix} \quad (24)$$

Using problem P(15) which differentiates the parameters entering into the utility function from the parameters entering the constraints the following expression can be obtained:

$$\mathbf{c}(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}) \bar{s}_a^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \bar{x}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta})) = \begin{bmatrix} \lambda \bar{s}_p & \lambda \bar{s}_{a_1} & \lambda \bar{s}_{a_2} \\ -U_{ax} \bar{s}_p & -U_{ax} \bar{s}_{a_1} & -U_{ax} \bar{s}_{a_2} \\ \mu \bar{s}_p & \mu \bar{s}_{a_1} & \mu \bar{s}_{a_2} \end{bmatrix} \quad (25)$$

where  $\bar{s}_p = \bar{s}_p(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \bar{x}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}))$ ,  $\bar{s}_{a_1} = \bar{s}_{a_1}(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \bar{x}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}))$  and

$\bar{s}_{a_2} = \bar{s}_{a_2}(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \bar{x}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}))$ . Notice that (25) reduces to (24) when  $\boldsymbol{\alpha}_1 = \boldsymbol{\alpha}_2 = \boldsymbol{\alpha}$ ;

however (25) allows us to obtain a richer set of comparative static results.

Given the symmetry and positive semidefiniteness of the matrix  $G_{aa}$  it follows that  $\mathbf{c}(\boldsymbol{\alpha}, \boldsymbol{\beta}) \mathbf{s}_a(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha})$  and  $\mathbf{c}(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}) \bar{s}_a(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \bar{x}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}))$  are symmetric and negative semidefinite which imply:

$$\mathbf{c}(\boldsymbol{\alpha}, \boldsymbol{\beta}) \mathbf{s}_a(\mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}); \boldsymbol{\alpha}) = \begin{bmatrix} \lambda \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) & \Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \\ \Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) & \lambda^{-1} \Gamma \Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \end{bmatrix} \quad (26)$$

$$\mathbf{c}(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta}) \bar{s}_a(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \bar{x}^*(\boldsymbol{\alpha}_1, \boldsymbol{\alpha}_2, \boldsymbol{\beta})) = \begin{bmatrix} \lambda \bar{s}_p & -U_{ax} \bar{s}_p & \mu \bar{s}_p \\ -U_{ax} \bar{s}_p & \lambda^{-1} U_{ax} U_{ax} \bar{s}_p & -\mu \lambda^{-1} U_{ax} \bar{s}_p \\ \mu \bar{s}_p & -\mu \lambda^{-1} U_{ax} \bar{s}_p & \mu^2 \lambda^{-1} \bar{s}_p \end{bmatrix} \quad (27)$$

From (24) and (26) the following results are obtained:

(i)  $\lambda \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  is symmetric and negative semidefinite

$$(a) \frac{\partial s_i}{\partial p_j} = \frac{\partial s_j}{\partial p_i} \Rightarrow \frac{\partial x_i}{\partial p_j} + x_j \frac{\partial x_i}{\partial M} = \frac{\partial x_j}{\partial p_i} + x_i \frac{\partial x_j}{\partial M}$$

$$(b) \frac{\partial x_i}{\partial p_i} + x_i \frac{\partial x_i}{\partial M} \leq 0$$



(ii)  $\Gamma \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  is symmetric and negative semidefinite

$$(a) \quad \varphi_i \frac{\partial s_i}{\partial a_j} = \varphi_j \frac{\partial s_j}{\partial a_i} \Rightarrow \varphi_i \left( \frac{\partial x_i}{\partial a_j} + x_j \frac{\partial x_i}{\partial T} \right) = \varphi_j \left( \frac{\partial x_j}{\partial a_i} + x_i \frac{\partial x_j}{\partial T} \right)$$

$$(b) \quad \varphi_i \left( \frac{\partial x_i}{\partial a_i} + x_i \frac{\partial x_i}{\partial T} \right) \leq 0$$

(iii)  $\Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = \lambda \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$

$$(a) \quad \varphi_i \frac{\partial s_i}{\partial p_j} = \lambda \frac{\partial s_i}{\partial a_j} \Rightarrow \varphi_i \left( \frac{\partial x_i}{\partial p_j} + x_j \frac{\partial x_i}{\partial M} \right) = \lambda \left( \frac{\partial x_i}{\partial a_j} + x_i \frac{\partial x_i}{\partial T} \right)$$

Part (i) implies that the money price and income effects for the two constraint problem with time entering into the utility function are similar to those of the traditional one constraint consumer demand problem. Part (i) also implies the negativity of the own money price effect.

Part (ii) indicates that for  $\varphi_i > 0$  and for goods that are time normal (i.e.

$\frac{\partial x_i}{\partial T} > 0$ ) the Marshallian demand functions should also display the negativity of the own

time price effect. On the other hand, if  $\varphi_i < 0$  and the goods are time normal, the

Marshallian demand functions can have a positive own time price effect.

Using the symmetry characteristic of  $\Gamma \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  from part (ii) and the fact

$\Gamma \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = \lambda^{-1} \Gamma \Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  (from 24 and 26) some additional conditions for the

terms in the matrix  $\Gamma$  can be inferred. Specifically, it can be shown that the symmetry of

$\lambda^{-1} \Gamma \Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  and  $\mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$  matrices imply that

$\left(\mu - \frac{\partial^2 U}{\partial a_i \partial x_i}\right)^2 = \left(\mu - \frac{\partial^2 U}{\partial a_j \partial x_j}\right)^2 \forall i, j$  which is only satisfied if the absolute values of

$\left(\mu - \frac{\partial^2 U}{\partial a_i \partial x_i}\right)$  and  $\left(\mu - \frac{\partial^2 U}{\partial a_j \partial x_j}\right)$  are equal. In words, this optimality condition would

mean that at the optimum the absolute value of the marginal effect of the time price in the marginal utility of the goods has to be equal across all goods.

This condition is fulfilled if for example all of the second partial derivatives

$\frac{\partial^2 U}{\partial a_i \partial x_i} \forall i$  are equal in which case the marginal effect of time prices in the marginal utility

of the goods is equal across all goods.

It is important to remember that the derivative of the marginal utility of the  $i$ th

good with respect to its own time is  $\frac{\partial^2 U}{\partial a_i \partial x_i} = \frac{\partial^2 U}{\partial x_i \partial t_i} x_i + \frac{\partial^2 U}{\partial t_i^2} t_i + \frac{\partial U}{\partial t_i}$ . Hence, even

though the cross partial derivatives  $\frac{\partial^2 U}{\partial a_i \partial x_i} \forall i$  are restricted to be equal across all goods,

the individual partial derivatives  $\frac{\partial^2 U}{\partial x_i \partial t_i} x_i$ ,  $\frac{\partial^2 U}{\partial t_i^2} t_i$  and  $\frac{\partial U}{\partial t_i}$  can be different across the  $n$

goods.

In the literature it is customary to express the result in part (iii) as

$\lambda^{-1} \Gamma \mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) = \mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta}))$ . Therefore, the diagonal elements in the matrix  $\lambda^{-1} \Gamma$

have the form  $\varphi_i / \lambda = \mu / \lambda - v_{ii} / \lambda$ . The term  $\varphi_i / \lambda$  does not equal the term  $\kappa_i / \lambda$ ,

interpreted previously as the value of time in activity  $i$ th, but they are related since

$\frac{\varphi_i}{\lambda} = \frac{\kappa_i}{\lambda} - \frac{1}{\lambda} \left[ \frac{\partial^2 U}{\partial x_i \partial t_i} x_i + \frac{\partial^2 U}{\partial t_i^2} t_i \right]$ . It is interesting to point out that even though  $\kappa_i / \lambda$  is

guaranteed to be larger than zero, there is nothing that restricts the value of  $\varphi_i / \lambda$ . With negligible second order effects, these two quantities will also equal each other and  $\varphi_i / \lambda$  could be interpreted as the value of time in the  $i$ th activity.

Using the companion problem P(15) a richer set of comparative statics can be obtained. From (25) and (27) the following results are obtained:

(iv)  $\lambda \bar{s}_p$  is symmetric and negative semidefinite

$$(a) \frac{\partial \bar{s}_i}{\partial p_j} = \frac{\partial \bar{s}_j}{\partial p_i} \Rightarrow \frac{\partial \bar{x}_i}{\partial p_j} + \bar{x}_j \frac{\partial \bar{x}_i}{\partial M} = \frac{\partial \bar{x}_j}{\partial p_i} + \bar{x}_i \frac{\partial \bar{x}_j}{\partial M}$$

$$(b) \frac{\partial \bar{x}_i}{\partial p_i} + \bar{x}_i \frac{\partial \bar{x}_i}{\partial M} \leq 0$$

(v)  $U_{ax} \bar{s}_{a_1}$  is symmetric and positive semidefinite

$$(a) v_{ii} \frac{\partial \bar{s}_i}{\partial a_{1j}} = v_{jj} \frac{\partial \bar{s}_j}{\partial a_{1i}} \Rightarrow v_{ii} \frac{\partial \bar{x}_i}{\partial a_{1j}} = v_{jj} \frac{\partial \bar{x}_j}{\partial a_{1i}}$$

$$(b) v_{ii} \frac{\partial \bar{x}_i}{\partial a_{1i}} \geq 0$$

(vi)  $\mu \bar{s}_{a_2}$  is symmetric and negative semidefinite

$$(a) \frac{\partial \bar{s}_i}{\partial a_{2j}} = \frac{\partial \bar{s}_j}{\partial a_{2i}} \Rightarrow \frac{\partial \bar{x}_i}{\partial a_{2j}} + \bar{x}_j \frac{\partial \bar{x}_i}{\partial T} = \frac{\partial \bar{x}_j}{\partial a_{2i}} + \bar{x}_i \frac{\partial \bar{x}_j}{\partial T}$$

$$(b) \frac{\partial \bar{x}_i}{\partial a_{2i}} + \bar{x}_i \frac{\partial \bar{x}_i}{\partial T} \leq 0$$

(vii)  $\mu \bar{s}_p = \lambda \bar{s}_{a_2}$

$$(a) \quad \mu \frac{\partial \bar{s}_i}{\partial p_j} = \lambda \frac{\partial \bar{s}_j}{\partial a_{2i}} \Rightarrow \mu \left( \frac{\partial \bar{x}_i}{\partial p_j} + \bar{x}_j \frac{\partial \bar{x}_i}{\partial M} \right) = \lambda \left( \frac{\partial \bar{x}_j}{\partial a_{2i}} + \bar{x}_i \frac{\partial \bar{x}_j}{\partial T} \right)$$

$$(viii) \quad -U_{ax} \bar{s}_p = \lambda \bar{s}_{a_1}$$

$$(a) \quad v_{ii} \frac{\partial \bar{s}_i}{\partial p_j} = \lambda \frac{\partial \bar{s}_j}{\partial a_{1i}} \Rightarrow v_{ii} \left( \frac{\partial \bar{x}_i}{\partial p_j} + \bar{x}_j \frac{\partial \bar{x}_i}{\partial M} \right) = \lambda \left( \frac{\partial \bar{x}_j}{\partial a_{1i}} \right)$$

Part (iv) is basically the same result obtained in part (i). Notice also that when  $\mathbf{a}_1 = \mathbf{a}_2 = \mathbf{a}$ ,  $\bar{\mathbf{s}}_p = \mathbf{s}_p$ . Parts (v), (vi) and (viii) indicate the separate comparative static results of the parameters entering the utility function and the budget constraint. Part (v) shows that if the marginal utility of the good is an increasing function of the time price, an increase in the time price causes an upward shift in the demand curve for the good.

Part (vi) shows the effect of the money price in the budget constraint. For time normal goods, the own time price has a negative effect on the demand of the good. Part (vii) shows that the demand restrictions implied by the effect of the time in the budget constraint are similar to the demand restrictions implied by the two linear constraints consumer problem (see Larson and Shaikh, 2001).

Parts (vii) and (viii) indicate expressions that can be used to calculate the different time price effects as a function of the price effects. In other words, if it is possible to estimate the parameters  $\mu$ ,  $\lambda$  and  $v_{ii}$ , then the separate effects of time in the utility function and as a scarce resource can be calculated.

From these results, only part (i) was derived previously by DeSerpa (1971). The remaining results are new. Some of these results are not possible to derive in DeSerpas

model since his comparative statics method rules out the possibility of time compensation.

#### 4.2.5. Homogeneity

In order to explore the homogeneity properties of the demand functions  $\mathbf{x}^*(p, a, T, M)$  with respect to  $\mathbf{p}$  and  $M$  and  $\mathbf{a}$  and  $T$  we can make use of Theorems 1 and 4 from Hatta (1980). For problem (7) these Theorems imply the following result:

$$\begin{bmatrix} M\mathbf{p}'\mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) & M\mathbf{p}'\mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \\ T\mathbf{a}'\mathbf{s}_p(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) & T\mathbf{a}'\mathbf{s}_a(\boldsymbol{\alpha}, \mathbf{x}^*(\boldsymbol{\alpha}, \boldsymbol{\beta})) \end{bmatrix} = 0 \quad (28)$$

Notice that because  $\mathbf{s}_p$  is symmetric  $\mathbf{p}'\mathbf{s}_p = \mathbf{s}_p\mathbf{p}$  and therefore the functions  $\mathbf{x}^*(\mathbf{p}, \mathbf{a}, T, M)$  are homogenous of degree zero with respect to  $\mathbf{p}$  and  $M$ . However, since  $\mathbf{s}_a$  is not symmetric  $\mathbf{a}'\mathbf{s}_a = 0$  does not directly imply  $\mathbf{s}_a\mathbf{a} = 0$ . Using the result in part (iii) it follows that  $\mathbf{s}_a\mathbf{a} = \lambda^{-1}\Gamma\mathbf{s}_p\mathbf{a}$ . From (28) and the fact  $\mathbf{s}_p$  is symmetric then it follows that  $\mathbf{a}'\mathbf{s}_p = \mathbf{s}_p\mathbf{a} = 0$  which implies that  $\mathbf{s}_a\mathbf{a} = \lambda^{-1}\Gamma\mathbf{s}_p\mathbf{a} = 0$ . Therefore, the demand functions  $\mathbf{x}^*(\mathbf{p}, \mathbf{a}, T, M)$  are also homogenous of degree zero with respect to  $\mathbf{a}$  and  $T$ .

#### 4.1.6. Comparison of Properties of Demands Functions

To close this section, Table 4.1 presents a comparison of the properties that theoretically consistent demand functions should satisfy under the standard consumer utility maximization problem (only constraint), under two constraints (money and time constraints), and under the problem considered in this study with time entering into the

utility function and considering two linear constraints. The properties of the two constraint problems encompass the properties of the one constraint problem. Since this Table only includes the properties of demand that are usually the focus of attention in the demand analysis, there is no difference in the properties between the standard two-constraint consumer problem and the more general two-constraint problem incorporating time in the utility function. The differences in the properties between the demands of the standard two-constraint problems and the two-constraint problem with time in the utility function lie in the interpretation and properties of the proportionally factor between the Slutskian money prices substitution effects and the Slutskian time prices substitution effects as we will see in the next section.

### 4.3. Implications for Empirical Analysis

To explore the possible implications of the comparative statics results for the solution to the two-constraint consumer problem with time in the utility function, two scenarios are considered. The first is the case where the all the

terms  $\varphi_i = \mu - \frac{\partial^2 U}{\partial a_i \partial x_i} = \mu - v_{ii}$  are equal in magnitude and sign, and the second case is

when they are equal in magnitude but have different signs. To abbreviate notation, the following definitions will be used in this section  $\theta(\mathbf{p}, \mathbf{t}, M, T) = \mu / \lambda$ ,

$\phi_i(\mathbf{p}, \mathbf{t}, M, T) = \varphi_i / \lambda$  and  $\omega_{ii}(\mathbf{p}, \mathbf{t}, M, T) = v_{ii} / \lambda$ .

**First case:** All the terms  $\phi_i = \theta - \omega_{ii} \forall_i$  are equal in sign in magnitude.

In this case the implications for empirical analysis are similar to those derived by Larson in Shaik (2001). For example, for the single equation case and under the assumption that the resource value of time equals the wage rate ( $\theta = w$ ), an equation taking the form

$$x_i = \alpha + \gamma(p_i + wa_i + \omega_{ii}a_i) + \beta(M + wT + \omega_{ii}T) + u_i \quad (29)$$

satisfies the proportionality property of the Slutskian money and time own-prices substitution effects. This is the case because the zero homogeneity property of equation (29) (which can be obtained for example by normalization of time prices and total time by some other time price) ensures that the effects of money prices, time prices, income and total time through  $w_{ii}(\mathbf{p}, \mathbf{a}, M, T)$  vanish. Therefore, in this case a complete specification of the single demand equation requires the inclusion of interaction terms between time price and the wage, the interaction term between total time and the wage, and the own time price and total time alone. The empirical implementation of equation (29) is another matter because of multicollinearity problems. However, this is an empirical issue that should be analyzed in a case by case basis. If an equation like (29) is estimated it is not possible to know *a priori* the sign of the parameter  $w_{ii}$ .

Equation (29) might be seen as providing some justification for the use of a proportion of the wage for the calculation of a full price and full income if in fact  $0 < v_{ii} < w$ . However, there is no restriction with regard to the sign or size of  $v_{ii}$ .

If the assumption that the resource value of time equals the wage rate is thought not to be adequate, equation (29) could be substituted by

$$x_i = \alpha + \gamma(p_i + \phi_i a_i) + \beta(M + \phi_i T) + u_i \quad (30)$$

Estimation of a reduced form model for (30) would allow to recover the value  $\phi_i$ . However, as mentioned previously, this is not the marginal value of time as interpreted by Larson and Shaik (2001). This example underlines the difficulty involved in recovering the value of time from the demand equations, a point that was also made in the DeSerpas' (1971) paper.

For systems of demand equations, a system with the following structure will satisfy the requirements of the theory

$$x_i = h_i(\mathbf{p} + \phi \mathbf{a})g(M + \phi T) \text{ for } i=1, \dots, n. \quad (31)$$

This system of demand equations was proposed by Larson and Shaik (2004) for the two-constraint consumer problem, but it can be shown to satisfy also the requirements of the theory when time is included in the utility function. Notice that since we are assuming that the values  $\phi_i$  are equal in sign and magnitude across all of the equations we have substituted the  $\phi_i$ 's for  $\phi$ . Equation (31) can then be estimated specifying a function for  $\phi = \phi(\mathbf{p}, \mathbf{a}, M, T)$ . The properties (e.g., degree of homogeneity) of this



function though cannot be determined without knowing or assuming properties for

$$\frac{\partial^2 U}{\partial a_i \partial x_i} \quad 6.$$

**Second case:** The terms  $\phi_i = \theta - \omega_{ii}$  are equal in magnitude but not in sign.

In a system of two demand equations, the possibility of the terms  $\phi_i$  having different signs could be assessed estimating the following system of equations:

$$\begin{aligned} x_1 &= h_1(\mathbf{p} + \phi \mathbf{a})g(M + \phi T) \\ x_2 &= h_2(\mathbf{p} - \phi \mathbf{a})g(M - \phi T) \end{aligned} \quad (32)$$

The evaluation of the appropriateness of this system versus a system where all the  $\phi$  terms have equal sign can be done by means of some goodness of fit test such as the  $R^2$  or Akaike Information Criteria. This type of analysis becomes impractical in large demand systems of equations.

#### 4.4. An Incomplete Demand System Consistent with the Theory

A system of demand equations that is consistent with economically rational consumers choices based on the two-constraints can be devised by using the results from the previous section and also LaFrance's (1985, 1990, 2004) work on incomplete demand systems of equations. Incomplete demand systems of equations are relevant in this study because of our focus on a small group of goods.

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<sup>6</sup> Homogeneity properties of  $\lambda(\mathbf{p}, \mathbf{a}, M, T)$ ,  $\mu(\mathbf{p}, \mathbf{a}, M, T)$  and  $\theta(\mathbf{p}, \mathbf{a}, M, T)$  are stated in Larson and Shaikh (2001). Larson and Shaikh (2004) show that  $\theta_{p_i} / \theta_M = x_i(\mathbf{p}, \mathbf{a}, M, T)$  and  $\theta_{t_i} / \theta_M = x_i(\mathbf{p}, \mathbf{a}, M, T)$  and use this properties to specify a function for  $\theta$ .

Even though the work on incomplete demand systems has been done for the one constraint case, with some additional assumptions, its results can be extrapolated to the case of two constraints problems with and without time in the utility function. The properties of incomplete demand systems of equations corresponding to the one constraint consumer problem are: (1) demand functions that are homogenous of degree zero in prices and income, (2) positive value demand functions, (3) income greater than total expenditures on the demands for the goods on the incomplete system, and (4) the submatrix of Slutsky substitution terms for the demands is symmetric and negative definite (LaFrance and Hanemann, 1989).

If we assume that the  $\phi_i$ 's functions are parameters that can be estimated<sup>7</sup>, intuitively, an incomplete demand systems of equations consistent with the two-constraint consumer problem with time included in the utility function should have the following properties: (1) demand functions that are homogenous of degree zero in money prices and income, (2) demand functions that are homogenous of degree zero in time prices and total time, (3) positive value demand functions, (4) income and total time greater than total expenditures and total time spent on the set of goods comprising the incomplete system, (5) symmetry and negative semi-definiteness of the Slutskian money prices substitution sub-matrix, (6) symmetry and negative semi-definiteness of the Slutskian time prices substitution sub-matrix and (7) proportionality of the Slutskian money prices and the Slutskian time prices substitution sub-matrices.

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<sup>7</sup> Formally, the  $\phi_i$ 's are functions of all money and time prices and also income and total time. However, the use of an incomplete demand system is most of the time motivated by the fact that there is not data on the prices for other commodities. Therefore, the estimation of such a function appears to be impractical.

Previous studies implementing the two-constraint demand model have used the Almost Ideal Demand System or its linear approximation (Shaikh and Larson, 2003; Larson and Shaikh, 2004). However, this system corresponds to a complete demand system of equations. In this study, a modified version of the linear quadratic incomplete demand model (LQ-IDS) of LaFrance (1990) will be used for the empirical application. The one linear constraint LQ-IDS model is as follows (LaFrance, 2004):

$$\mathbf{x} = \boldsymbol{\alpha} + \mathbf{A}\mathbf{z} + \mathbf{B}\mathbf{p} + \gamma[\mathbf{M} - \boldsymbol{\alpha}'\mathbf{p} - \mathbf{p}'\mathbf{A}\mathbf{z} - (0.5)\mathbf{p}'\mathbf{B}\mathbf{p}], \quad (33)$$

where  $\mathbf{x}$  is a  $m \times 1$  vector of quantities of goods of interest ( $m < n$ ),  $\mathbf{z}$  is a  $k \times 1$  vector of socio-demographic characteristics of the consumers,  $\mathbf{p}$  is a  $m \times 1$  vector of money prices,  $M$  is money income,  $\boldsymbol{\alpha}$  and  $\boldsymbol{\gamma}$  are  $m \times 1$  vector of parameters,  $\mathbf{B}$  is a  $m \times m$  vector of parameters with elements  $\beta_{ij}$ ,  $\mathbf{A}$  is a  $m \times k$  vector of parameters with elements  $a_{ik}$ . The restrictions of homogenous of degree zero of demands in prices and income can be obtained by deflating all prices and income by a price index. Adding up conditions is not necessary for incomplete demand systems since the expenditure in a small group is small than the total income. Finally, the symmetry of the Slutsky substitution matrix implies that  $\mathbf{B}$  is symmetric.

The LQ-IDS demand model can be modified to comply with the restriction of an incomplete demand system of equation consistent with the two-constraint consumer problem with time included in the utility function:

$$\mathbf{x} = \boldsymbol{\alpha} + \mathbf{A}\mathbf{z} + \mathbf{B}(\mathbf{p} + \varphi\mathbf{a}) + \gamma[(\mathbf{M} + \varphi\mathbf{T}) - \boldsymbol{\alpha}'(\mathbf{p} + \varphi\mathbf{a}) - (\mathbf{p} + \varphi\mathbf{a})'\mathbf{A}\mathbf{z} - (0.5)(\mathbf{p} + \varphi\mathbf{a})'\mathbf{B}(\mathbf{p} + \varphi\mathbf{a})] \quad (34)$$

where  $\mathbf{a}$  is a  $m \times 1$  vector of time prices,  $T$  is the total time available. Homogeneity of degree zero with respect to money prices and income can be imposed by dividing money

prices and income by a price index and homogeneity of degree zero with respect to time prices and total time can be obtained by dividing time prices and total time by a time price index<sup>8</sup>.

The Slutskian money prices substitution sub-matrix and the Slutskian time prices substitution sub-matrix for this model have the form:

$$S_p = \mathbf{B} + \gamma \gamma' [(M + \varphi T) - \boldsymbol{\alpha}'(\mathbf{p} + \varphi \mathbf{a}) - (\mathbf{p} + \varphi \mathbf{a})' \mathbf{A} \mathbf{z} - (\mathbf{p} + \varphi \mathbf{a})' \mathbf{B} (\mathbf{p} + \varphi \mathbf{a})] \quad (35)$$

$$S_a = \varphi (\mathbf{B} + \gamma \gamma' [(M + \varphi T) - \boldsymbol{\alpha}'(\mathbf{p} + \varphi \mathbf{a}) - (\mathbf{p} + \varphi \mathbf{a})' \mathbf{A} \mathbf{z} - (\mathbf{p} + \varphi \mathbf{a})' \mathbf{B} (\mathbf{p} + \varphi \mathbf{a})]) \quad (36)$$

Symmetry of the two Slutsky substitution sub-matrices is satisfied if  $\mathbf{B}$  is symmetric. Finally the proportionality of the time and money Slutsky matrices is satisfied if the parameter  $\varphi$  is a constant for all the goods.

## 4.5. Empirical Implementation

### 4.5.1. Data

The data set used for the empirical implementation of model (34) is the same dataset used for the estimation of the discrete/continuous choice model in the previous chapter. This data is from a consumer survey conducted at direct market strawberry operations throughout the state of North Carolina during the spring of 1999. Each operation offered customers two options for buying strawberries: they could either pick their own strawberries (PYOS) for the growers' field or they could buy pre-picked strawberries (PPS) at the grower's fruit stand. The survey was divided into two segments.

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<sup>8</sup> In the case of incomplete demand systems corresponding to the one constraint problem, LaFrance and Hanemman (1989) argue that the deflator function is defined over any nonempty subset of the elements of the price vector of goods not considered on the incomplete demand system. For example, the individual price of any of the goods left out of the incomplete demand system can be used as a deflator.

The first segment was administered when the consumer arrived to the direct market operation and the second, when the consumer left the operation. A total of 1,701 customers were interviewed.

The theoretical framework derived in the previous section is suitable to analyze the demand for these two types of fruit since the purchase of pick-your-own fruit requires spending time harvesting the fruit in addition to the monetary price. For pre-harvested fruit, it is assumed that there is only a monetary price involved in the purchase of the product.

The same approaches used in the previous chapter for the transformation of the income variable from discrete to continuous form (Appendix 3.3) and the estimation of missing time prices were utilized in this study. However, there are other elements of the model that were treated differently.

**The Total Time Variable (T).** Since the income used for estimation is the total annual household income, total time was calculated as the total number of hours available in a year (8760 hours).

**The Time Parameter ( $\phi$ ).** As explained previously, in this study  $\phi$  is considered as a parameter to be estimated. However, to make it to vary across households, this parameter is specified as a linear function of the working status of the households, the wage (annual income divided by 1800 hours) and a dummy variable indicating if the visit was during the weekday. This specification is consistent with a specification in which hours of work enter into the utility function, in which case the term  $\theta = \mu / \lambda$  is related to marginal income.

### 4.5.2. Estimation Procedures

An obstacle for the estimation of model (34) is the presence of zero purchases. This is because customers either bought pick-your-own fruit or pre-harvested fruit. Therefore, the empirical model is a two equation censored system of demand equations. The first equation is the quantity demanded of pre-picked fruit and the second equation is PYO fruit. Several methods have been proposed for the estimation of censored system of equations. In this study, we use the two-step procedure suggested by Shonkwiler and Yen (1999). This procedure is an extension of the two step Heckman procedure for the estimation of the univariate Tobit model. In a first step, probit models are used to obtain estimates of the parameters of an equation determining the sample selection of each individual equation. In the second step, an augmented model is created by using the parameter estimates of the first step and then a pooled non-linear least squares procedure is used to estimate the parameters of the model.

This procedure works as follows. Consider the two equation system:

$$q_{1n}^* = f(\mathbf{p}, \mathbf{a}, M, T, \mathbf{z}_n; \boldsymbol{\theta}_1) + \varepsilon_{1n}, \quad d_{1n}^* = \mathbf{w}_n' \boldsymbol{\eta}_1 + v_{1n} \quad (37)$$

$$q_{2n}^* = f(\mathbf{p}, \mathbf{a}, M, T, \mathbf{z}_n; \boldsymbol{\theta}_2) + \varepsilon_{2n}, \quad d_{2n}^* = \mathbf{w}_n' \boldsymbol{\eta}_2 + v_{2n} \quad (38)$$

$$d_{in} = \begin{cases} 1 & \text{if } d_{in}^* > 0 \\ 0 & \text{if } d_{in}^* \leq 0 \end{cases}$$

$$q_{in} = d_{in} * q_{in}^*$$

$$n = 1, \dots, M; i = 1 = \text{PYO}, i = 2 = \text{pre-harvested fruit}$$

$q_{1n}^*$  and  $q_{2n}^*$  are the latent quantity demanded,  $d_{1n}^*$  and  $d_{2n}^*$  are the latent variables defining the sample selection in (37) and (38);  $q_{1n}, q_{2n}, d_{1n}, d_{2n}$  are the observed dependent variables;  $f(\mathbf{p}, \mathbf{a}, M, T, \mathbf{z}_n; \boldsymbol{\theta}_i)$  represents the  $i$ th equation in model (34), where

$\theta_i$  is the parameter vector,  $z_n$  is the vector of socioeconomic characteristics of the nth household;  $\mathbf{p}$ ,  $\mathbf{a}$ ,  $M$  and  $T$  are the same as defined previously;  $\varepsilon_{in}$  and  $v_{in}$  are errors;  $\mathbf{w}_n$  is a vector of household characteristics explaining the sample selection and  $\eta_i$  is the corresponding parameter vector for the  $i$ th sample selection equation. The procedure is then:

(1) Estimate in the first step a probit model which explains the sample selection.

Since the system is composed by only two equations only one probit model is required (i.e.,  $\eta_1 = -\eta_2$ ).

(2) Use the estimates of  $\eta_i$  from the probit models to calculate  $\hat{\Phi}_{in}$  and  $\hat{\phi}_{in}$  which represent estimates of the cdf and pdf of  $v_{in}$ .

(3) To obtain estimates of the  $\theta_i$  parameters, use the following equations:

$$q_{in} = \hat{\Phi}_{in} f(\mathbf{p}, \mathbf{t}, M, T, \mathbf{z}_n; \theta_i) + \delta_i \hat{\phi}_{in} + \xi_{in} \quad (39)$$

$i = 1 = \text{PYO}, i = 2 = \text{pre - harvested fruit}$

Consistent estimates of the parameters in each equation were obtained by using equation by equation non-linear least squares procedures. Using these parameter estimates as starting values and to impose the restrictions derived from theory, pooled non-linear least-squares was utilized in a second step of the estimation of the system (10). According to Shonkwiler and Yen (1999), the errors  $\xi_{in}$  in the system of equations (39)

are heteroskedastic with variance:

$$\begin{aligned} \text{var}(\xi_{in}) = & \sigma_i^2 \Phi_{in} + [1 - \Phi_{in}] \left\{ f(\mathbf{p}, \mathbf{t}, M, T, \mathbf{z}_n; \boldsymbol{\theta}_i)^2 \Phi_{in} + 2f(\mathbf{p}, \mathbf{t}, M, T, \mathbf{z}_n; \boldsymbol{\theta}_i) \delta_i \phi_{in} \right\} \\ & - \delta_i^2 \left\{ \mathbf{w}_n' \boldsymbol{\eta}_1 \phi_{in} + \phi_{in}^2 \right\}. \end{aligned} \quad (40)$$

Therefore, a weighted system estimator used in the SUR procedure would need to take this specific form of heteroskedasticity into account. However, since additional variability is induced by the use of imputed regressors, the asymptotic covariance matrix of the parameters was approximated using a non-parametric bootstrapping procedure as outlined by Wooldridge (2002, p.379).

The bootstrapping procedure is as follows. Let  $S = \{w_1, w_2, \dots, w_N\}$  denote the sample used for estimation purposes and  $\hat{\theta}$  the estimated parameter. At each bootstrap iteration,  $b$ , a random sample of size  $N$  is drawn with replacement from the original sample. Denote the sample at iteration  $b$  as  $S^{(b)} = \{w_1^{(b)}, w_2^{(b)}, \dots, w_N^{(b)}\}$ . This bootstrap sample is used to obtain the  $\hat{\theta}^{(b)}$  pooled non-linear least squares estimates of the system of equations (imputed time prices and income are also re-estimated using each bootstrap sample). The procedure has to be iterated  $B$  times, to obtain  $\hat{\theta}^{(b)}$ ,  $b=1, 2, \dots, B$ . The sample variance of the  $\hat{\theta}^{(b)}$ 's was used to obtain standard errors for  $\hat{\theta}$ , the parameter estimates of the original sample. A total of  $B=1000$  replications were used in the procedure.

The estimation approach taken here for estimation purposes has been criticized because it is not theoretically consistent since it is said not to satisfy the budget constraint (Pudney, 1990). However, given the fact that we are using an incomplete demand



systems of equations framework, the system of equations is not required to satisfy the budget constraint.

#### **4.6. Empirical Results**

Since the proposed incomplete demand system of equations nests the incomplete demand system generated from the one-constraint consumer demand problem, statistical tests can be performed to evaluate the performance of the two-constraint incomplete demand system versus the one-constraint incomplete demand system. In order to compare the models, we tested the null hypothesis that the parameter  $\phi$ , which is the parameter corresponding to time price, is different from zero. The Lagrange multiplier test rejected this null hypothesis (Table 4.2). This shows some evidence that the two constraints consumer problem is superior to the one constraint consumer problem.

Symmetry of both Slutskian matrices was also evaluated by testing the null hypothesis that  $B_{12}=B_{21}$ . The Lagrangean test failed to reject this null hypothesis, therefore the symmetry restrictions are satisfied. The curvature of the Slutskian matrices was analyzed by calculating its characteristics roots. At the mean values of the explanatory variables, the characteristic roots of both substitution matrices were negative. Proportionality of the Slutskian matrices is imposed by the structure of the system. Homogeneity could not be tested or imposed given the lack of data on money and time prices for other commodities. Table 4.2 summarizes the results of the tests of the theory.

The estimation results for the parameters of the demand equations with symmetry imposed are presented in Table 4.3. This Table also shows the values of the parameters

corresponding to the time parameter function. The number of households working less than 40 hours per week and the number of retired persons in the household decreases the value of the time parameter. The wage received by the household and the dummy variable indicating that the visit was done during the weekday increases the value of the time parameter. As explained previously, when time enters into the utility function the time parameter is not necessarily the opportunity cost of time. However, since the time parameter  $\varphi$  is a positive function of the value of time as a resource parameter ( $\theta = \mu / \lambda$ ), the effects of the working status and the wage in the value of the time parameter are expected to have the same sign that the effects of these variables in the value of time as a resource parameter.

Since the demand equations are non-linear in the explanatory variables, and also because the selection mechanism and the demand equations share several of the explanatory variables, the parameters are not the marginal effects. Marginal effects and elasticities were calculated by differentiating equation (39) and are presented in Table 4.4.

Prices, location of residence of the customers and number of females in the shopping party and visiting during the weekdays are the more important determinants of the quantity demanded of PYOS. The marginal effects of the dummy variables are the effects in relation to an individual with characteristics of the dummy variables not included in the model (Central region, currently living in the rural area, and visiting during the weekend). Relative to this type of customer, customers living in urban areas demand 1.5 fewer pounds of PYOS relative to the baseline customer and customers

visiting during the weekdays demand 0.75 more pounds of fruit. Even though the location of the operations variable is not statistically significant, the magnitude of the parameter indicates that customers living in the Western part of the state demand 2.3 fewer pounds of PYOS. Each additional female in the shopping party increases the quantity demanded of PYOS by 0.7 pounds. The effect of prices can be analyzed using the elasticity estimates. The own money price elasticity of PYOS is estimated in -1.4. The cross price elasticity is 1.5. The own time price elasticity for PYOS is -0.16.

Prices, location of the operations, and weekday visits are the important determinants of the quantity demanded of PPS. Relative to the baseline customer, customers in the Western region demand 4 more pounds of PPS, customers living in the Eastern region demand 3 fewer pounds of PPS, and customers visiting during the weekday demand 0.5 fewer pounds. The own money price elasticity of PPS is estimated to be -2.8. The cross money price elasticity is 2.2. The cross time price elasticity of PPS with respect to the time price of PYOS is 0.247.

The elasticity of the aggregate commodity composed by PYOS and PPS was also calculated (see equations in Appendix 3.4). This elasticity measures the effect of a proportional change in the price of the two types of fruit on the aggregate quantity demanded. The elasticity for the aggregate good is estimated to be -0.25.

The estimated elasticities indicate that both PYOS and PPS are money price elastic, with PPS being more price elastic than PYOS. The income elasticities indicate that both types of fruit are income inelastic. PYOS is found to be a normal good whereas PPS is an inferior good.

#### **4.6. Summary and Conclusions**

This study analyzes a deterministic model of consumer behavior where consumers obtain utility from the consumption of goods and from the time spent obtaining/consuming the goods. Moreover, consumers are subject to two budget constraints. The solutions to this problem involve the quantities of the goods demanded as a function of money and time prices and total money and time available. Duality theory is used to derive the comparative statics of the solutions and characterize the demand equations.

The theoretical results are used to propose an incomplete demand system of equations which is consistent with the theory. The system is used to empirically analyze the demand for pick-your-own fruit versus pre-harvested fruit at North Carolina pick-your-own operations. The framework proposed in this paper is suitable to analyze the demand for these two types of fruit since the purchase of pick-your-own fruit requires spending time harvesting the fruit in addition to the monetary price. Moreover, the time spent picking the fruit is seen by most of the customers as a recreational activity.

Statistical tests show that the two-constraints model performs better than the one-constraint model. The estimated model was also found to satisfy the symmetry and curvature properties of the Slutskian substitution sub-matrices. However, more work is necessary to test all of the restrictions implied by the theoretical model with a richer dataset. Specifically, the homogeneity property and the equality of the effect of time price on the marginal utility of goods consumption across all goods need to be explored further.

Elasticity estimates show that strawberries sold at pick-your-own operations are price elastic, with PYOS being less price elastic than PPS. This information and the effect of the socio-demographic characteristics of the individuals can be used by farmers for the design of marketing strategies.

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**Table 4.1. Comparison of the properties of the demand functions for alternative consumer optimization problems**

| <b>Properties of demand functions</b>  | <b>Standard one-constraint consumer problem</b> | <b>Two-constraint consumer problem</b> | <b>Two-constraint consumer problem with time in the utility function</b> |
|--|---|--|--|
| Adding up in money expenditures  | X   | X                                      | X  |
| Adding up in time expenditures   |   | X                                      | X  |
| Marshallian demands with homogeneity of degree zero in total expenditures and money prices | X   | X                                      | X  |
| Marshallian demands with homogeneity of degree zero in total time and time prices          |   | X                                      | X  |
| Symmetry and negative semi-definiteness of the Slutskian money prices substitution matrix  | X   | X                                      | X  |
| Symmetry and negative semi-definiteness of the Slutskian time prices substitution matrix   | X   | X                                      | ?  |
| Proportionality of Slutskian money prices and Slutskian time prices substitution matrices  |   | X                                      | X  |

**Table 4.2. Tests of the Demand Restrictions**

| <b>Restriction Tested</b>     | <b>Test type</b>     | <b>Value of the statistic</b> | <b>Probability of rejecting the null hypothesis</b> |
|-------------------------------|----------------------|-------------------------------|---|
| $\phi=0$<br>(Time parameter)  | LM                   | 22.07                         | 0.0025  |
| $B_{12}=B_{21}$<br>(Symmetry) | LM                   | 2.23                          | 0.1351  |
| Negative<br>Semi-definiteness | Characteristic roots | -1.94, -59.93                 | -   |



**Table 4.3. Parameter Estimates of the Demand Equations**

| Variable/Parameter                                   | Pick-your-own Strawberries<br>(PYOS) (i=1) |                     |                                    | Pre-harvested Strawberries<br>(PPS) (i=2) |                     |                       |
|--|--|---------------------|------------------------------------|---|---------------------|-----------------------|
|  | Parameter                                  | OLS<br>Std<br>Error | Boot.<br>Std<br>Error <sup>b</sup> | Parameter                                 | OLS<br>Std<br>Error | Boot.<br>Std<br>Error |
| Intercept ( $\alpha_i$ )                             | 13.732*                                    | 11.343              | 10.585                             | 14.672**                                  | 4.121               | 6.737                 |
| West ( $a_{i1}$ )                                    | 1.421                                      | 6.821               | 18.565                             | 2.817                                     | 1.802               | 3.702                 |
| East ( $a_{i2}$ )                                    | 1.771                                      | 4.792               | 12.334                             | -6.384*                                   | 2.652               | 4.229                 |
| Age ( $a_{i3}$ )                                     | -0.009                                     | 0.061               | 0.119                              | 0.005                                     | 0.026               | 0.032                 |
| Miles ( $a_{i4}$ )                                   | 0.053                                      | 0.064               | 0.314                              | -0.020                                    | 0.021               | 0.028                 |
| Number of males in the shopping party ( $a_{i5}$ )   | -1.032                                     | 1.383               | 3.994                              | 0.346                                     | 0.497               | 1.110                 |
| Number of females in the shopping party ( $a_{i6}$ ) | 1.017                                      | 0.831               | 4.131                              | 0.888                                     | 0.666               | 1.728                 |
| Number of children in the household ( $a_{i7}$ )     | 0.956                                      | 0.641               | 3.785                              | 0.142                                     | 0.383               | 1.572                 |
| Number of males in the household ( $a_{i8}$ )        | -0.298                                     | 0.999               | 2.900                              | 0.089                                     | 0.292               | 0.581                 |
| Number of females in the household ( $a_{i9}$ )      | -0.975                                     | 1.053               | 3.725                              | 0.271                                     | 0.408               | 0.958                 |
| Number of children in household ( $a_{i10}$ )        | 0.125                                      | 0.774               | 4.607                              | 0.425                                     | 0.481               | 0.901                 |
| Urban ( $a_{i11}$ )                                  | -4.085                                     | 2.540               | 7.484                              | 1.230                                     | 0.673               | 1.397                 |
| $b_{i1}$   | -23.985**                                  | 8.730               | 11.815                             | 24.141**                                  | 8.253               | 5.858                 |
| $b_{i2}$   | 24.141***                                  | 8.253               | 5.858                              | -28.578***                                | 5.577               | 6.941                 |
| Income (\$10,000) ( $\gamma_i$ )                     | 0.462                                      | 0.259               | 0.724                              | -0.553**                                  | 0.140               | 0.323                 |
| Inverse Mills' Ratio                                 | -3.641                                     | 3.110               | 5.729                              | -3.333                                    | 3.230               | 5.165                 |
| <b>Time equation</b>                                 |  |                     |                                    |   |                     |                       |
| Intercept  | -0.775                                     | 1.621               | 3.268                              |   |                     |                       |
| Number of members in household working > 40 h/week   | -0.073                                     | 0.090               | 0.466                              |   |                     |                       |
| Number of members in household working < 40 h/week   | -0.618                                     | 0.658               | 2.808                              |   |                     |                       |
| Number of retired people in household                | -0.194                                     | 0.266               | 0.677                              |   |                     |                       |
| Wage   | 0.071*                                     | 0.019               | 0.053                              |   |                     |                       |
| Weekday visit ( $a_{i11}$ )                          | 0.464                                      | 0.533               | 2.138                              |   |                     |                       |

<sup>a</sup>Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

<sup>b</sup>Standard errors and statistical tests were calculated using the asymptotic covariance obtained using bootstrapping.

Table 4.4. Marginal Effects and Elasticities

| Variable/Parameter                      | Pick-your-own Strawberries (PYOS) (i=1) |                              | Pre-harvested Strawberries (PPS) (i=2) |                 |
|---|---|------------------------------|--|-----------------|
|   | Parameter                               | Boot. Std Error <sup>b</sup> | Parameter                              | Boot. Std Error |
| Marginal Effects                        |   |                              |  |                 |
| West                                    | -2.265                                  | 2.189                        | 4.029***                               | 1.367           |
| East                                    | -0.512                                  | 2.579                        | -3.084*                                | 2.253           |
| Age                                     | -0.015                                  | 0.026                        | 0.009                                  | 0.016           |
| Miles                                   | 0.020                                   | 0.032                        | -0.003                                 | 0.005           |
| Number of males in the shopping party   | -0.372                                  | 0.673                        | 0.008                                  | 0.500           |
| Number of females in the shopping party | 0.660*                                  | 0.523                        | 0.596                                  | 0.806           |
| Number of children in the household     | 0.222                                   | 0.518                        | 0.374                                  | 0.782           |
| Number of males in the household        | -0.152                                  | 0.480                        | 0.025                                  | 0.272           |
| Number of females in the household      | -0.198                                  | 0.689                        | -0.124                                 | 0.453           |
| Number of children in household         | 0.182                                   | 0.526                        | 0.211                                  | 0.372           |
| Urban                                   | -1.520*** <sup>a</sup>                  | 0.619                        | -0.017                                 | 0.438           |
| Weekday visit                           | 0.746***                                | 0.345                        | 0.247*                                 | 0.165           |
| <b>Elasticities</b>                     |   |                              |  |                 |
| Price PYOS                              | -1.392***                               | 0.507                        | 2.192***                               | 0.523           |
| Price PPS                               | 1.527***                                | 0.588                        | -2.805***                              | 0.649           |
| Time PYOS                               | -0.162                                  | 2.130                        | 0.247*                                 | 0.165           |
| Time PPS                                | -                                       | -                            | -                                      | -               |
| Income                                  | 0.118                                   | 0.280                        | -0.212                                 | 0.258           |
| Total Time                              | 0.025                                   | 0.103                        | -0.047                                 | 0.077           |
| Time parameter                          | -0.925***                               | 0.506                        | 0.894***                               | 0.352           |

<sup>a</sup>Significance levels of 0.01, 0.05 and 0.10 are indicated by \*\*\*, \*\*, and \*, respectively.

<sup>b</sup>Standard errors and statistical tests were calculated using the asymptotic covariance obtained using bootstrapping.

## **Chapter 5**

# **Dissertation Summary and Conclusions**

This dissertation comprises three essays analyzing the economic behavior of customers visiting farms with recreational purposes in the United States. The first essay uses the Travel Cost method with data from the 2000 National Survey on Recreation and the Environment to determine and quantify the effect of the different factors affecting customers' decisions to visit United States farms for recreational purposes. Estimation results indicate that farm recreational trips are price and income inelastic. Location of residence, race and gender were found to be important determinants of the number of farm recreational trips. Given data limitations, the cost of the last trip was assumed to represent the average cost of a trip to a farm. Further work is required to obtain a better estimate of the costs of visiting farms. This task is probably not an easy one since recreational farms are very heterogeneous commodities.

The first essay also presents an estimate of the total consumer surplus generated from the agricultural landscape. This consumer surplus was estimated to be 24.6 billion

dollars, which is about one half of the last 10 years average of the US total net farm (50 billion dollars). More precise estimates of the benefits generated by the agricultural landscape will require more detailed information on the current status of the agricultural landscape surrounding the location of residence of the visitors and also the recreational farms.

The second and third essays develop two different methods to analyze consumer behavior of individuals when time is an important component of the decision process. The inclusion of the time dimension into the consumer problem is necessary to analyze the consumer behavior of one specific type of agritourism: pick-your-own (PYO) activities. The purchase of PYO fruit involves both time and money costs. Moreover, the time spent harvesting the fruit is perceived by most of the customers as a recreational activity. This is in contrast to traditional economic models of consumer behavior which assume that the demand for goods originates from an optimization problem where consumers are maximizing utility (which is derived only from the consumption of goods) subject to a budget (money) constraint.

The second essay uses a structural econometric model of consumer behavior. This modeling approach is in line with previous work on discrete/continuous choice modeling (e.g., Hanemann, 1984). Therefore, this model explains the decision to choose the type of fruit and how much fruit to buy separately but under the same framework.

The third essay considers the problem from a different perspective and assumes a deterministic decision framework. The solutions to the consumer problem are characterized based in their comparative statics.

The two proposed approaches have advantages and disadvantages. The structural econometric model explains the decision to choose the type of fruit and how much fruit to buy separately but under the same framework. The econometric model under this framework is derived directly from the consumer optimization problem and therefore the problem of zero expenditures is handled in a theoretical consistent manner.

In contrast, the deterministic approach employed in the third essay explains only the quantity (positive quantity) demanded of each type of fruit. The deterministic model produces non-stochastic demand equations and therefore error assumptions are considered later on for estimation purposes and to take into account the problem of zero expenditures.

A comparison of the estimation results obtained using the two frameworks indicates that both approaches identified the same set of variables as the main determinants of the demand behavior. Even though the magnitudes of the marginal effects of the socio-demographic characteristics were not very close, the signs of the effects were the same. On the other hand, the values of the money price elasticities were very similar in both models. These results provide evidence on the robustness of the elasticity estimates to the choice of the modeling framework.