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Logistics Analysis of the Pathogen Control Provisions of the Almond Marketing Order

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Abstract

The Marketing Order for California almonds was amended in 2007 to enhance food safety. Around 400-500 million pounds of almonds undergo an added step in processing to reduce risk of salmonella contamination. This paper reports on the logistics necessary for implementing the program. We use a linear programming model and assess the uncertain costs of transportation and the risks related to regulatory approval of certain pasteurization technologies. The total cost of treatment and the associated logistics is approximately $28 million per year. Capacity for treatment is adequate. The pricing of out-sourced treatment services is the main driver in the cost estimates.

Keywords: Production; cost; capital, total factor, and multifactor productivity; capacity

Introduction

Production and exports of almonds increased over the last decade, aided in part by the successful positioning of almonds as healthful and nutritious alternatives for snacking and in recipes. The industry's promotion efforts were threatened by two incidents, in 2003 and 2005, when salmonella contamination was discovered. In response to the contamination and the associated outbreaks of illness, the Almond Board of California sought an amendment to its Marketing Order, which required handlers to assure treatment for pathogen control.[1] The salmonella control Action Plan, referred to as "pasteurization," went into effect in September 2007.[2]

While the almond industry's Action Plan is unique in many respects, this industry is not alone in facing questions about the costs of the measures intended to prevent food contamination. Since the almond recalls, peanut products and pistachios have experienced product recalls (Martin and Moss; Funk; Wittenberger and Dohlman). And like the almond industry, pistachio producers used the Marketing Order mechanism as the legal structure for a common safety practice (Sumner, et al.) Thus this analysis of the logistics of compliance has wider relevance in the economics of food protection, particularly where technology and the nature of the product permits a treatment protocol for pathogen reduction.

Pathogen control for almonds involves the introduction of a new processing step into the value chain at the handler level. The numerous farms that produce almonds in California are not directly affected by the pathogen control program. The processing firms (handlers) are subject to the Marketing Order. Almonds are hulled in the field, and then the in-shell nuts are transported to handlers for shelling and intermediate processing.

There are several alternative ways in which pathogen control activities are integrated into the logistics of handling. Some handlers conduct the pathogen-reduction treatment in-house, then establish separate inventories of treated and untreated products. Other handlers use off-site treatment, which requires that inventory be separated in addition to the loading and transportation of untreated product to the treatment facility. The treatment can be undertaken on bulk bins of product or on pallets of case-packed product, depending on the technology of the treatment operation. Fumigation, for example, is typically on bulk bins. Steam application is either applied to loose product on conveyors or to plastic-wrapped pallets, depending on the technology. After treatment at an off-site facility, the almonds may be shipped directly to customers or returned to the handler for storage until an order is received.

Some value-added processing steps that are standard practice for almonds effectively pasteurize, therefore little change in the logistics is required for those items. Blanching and oil roasting are examples of processes that can achieve pathogen control standards with modest modifications to

[1] *Federal Register*. Vol. 72, No. 61 / Friday, March 30, 2007. 7 *CFR* Part 981, p. 15021.[Docket No. FV06–981–1 FR]. Almonds Grown in California; Outgoing Quality Control Requirements, Final Rule.

[2] Pasteurization has a specific definition to food scientists and FDA regulators in terms of percentage pathogen reduction. In this paper, the term pasteurization is used more generally as a synonym for the terms treatment and pathogen control.

the time or temperatures used. For these product forms, relatively modest changes in the system are needed.

Exported goods experienced the least change in the value chain after the Action Plan. The Marketing Order does not cover almonds exported outside North America. Several handlers export their entire production and need no treatment process.

In the almond industry, where the demand for pathogen control is established by the Action Plan, the decision to "make or buy" treatment services is a key influencer of strategic positioning over the long term. The industry committee responsible for developing the Action Plan expected that the availability of treatment services for hire would enable smaller handlers to comply without making substantial capital investments. Thus the analysis of capacity for treatment is important to understand implementation of the almond industry program.

Pathogen Control and the Market for Treatment Services

The Almond Board of California (ABC) implemented its pathogen control program in collaboration with FDA and various private sector experts so that treatments provide the necessary reduction in salmonella (4-log reduction). Moreover, ABC's rules and procedures provide oversight that the companies in the industry are in compliance. These rules effectively establish a demand for food safety expertise that did not exist prior to the change in the Marketing Order. The different roles of agents in establishing a credible system can be understood with the following brief description of the pathogen control program.

Process Approval

A treatment process needs to be validated in terms of its technology to accomplish a 4-log reduction in salmonella. The validation of technology requires an investment in time, expertise, testing, and the management of the approval process with FDA. Approved technologies include oil roasting, dry roasting, blanching, steam processing and propylene oxide (PPO) fumigation. The Almond Board of California assists in obtaining approvals and assembles an expert review panel to aid in the development of additional acceptable treatment technologies. Apart from salmonella control, a series of quality issues relating to hardness, flavor, effects on brown skins or color of blanched product, and more have been studied in an effort to broaden the choices of pasteurization processes that are acceptable from the point of view of safety and food quality.

Technology Validation

For either a new treatment facility or an existing process, operators must demonstrate scientifically that the equipment in operation satisfies requirements of the Action Plan. Third party experts are usually hired to do this and the documentation of the validated technology is provided to ABC.

Auditing the Pathogen Control Plan

Handling companies develop a plan annually for treatment of the crop and are subject to audits to verify that the activities are taking place. The auditing services are procured from the certification agency DFA of California.[3]

Supply, Demand, and Pricing of Almonds

Since the adoption of the salmonella control Action Plan in 2007, almond production rose by 14%, to 1.6 billion pounds in the 2008/2009 crop year (ending July 2009) (Almond Board of California). North American shipments subject to the Action Plan regulation increased by 4%, to 451 million pounds in the 2008/2009, crop year. The remaining amount, approximately one billion pounds, is exported outside North America and is exempt from the treatment requirement. More than half of California almond production is exported each year; the leading destinations by volume are Spain, Germany, and China.

Farm prices of almonds fell consistently since 2005 along with the rapid increase in production. The grower price was less than $1.50 per pound in crop year 2008/2009, down by 50% from the peak in 2005/06.

The downturn in prices affects the economic impact of the pasteurization rules, according to some business metrics. As an example, assume that the total cost of treatment and the associated handling/management is approximately 10 cents per pound. In a year in which prices of almonds are high, say $2.50 per pound as they were in 2005/2006, the impact of the program in terms of share of farm price is 4%. When market prices are down to $1.50, the burden of the pathogen treatment in terms of per-pound value is significantly higher, 6.7%.

Almond exports rose consistently during the last several years (Figure 1). In some years, exports grew significantly faster than domestic shipments. The growth trend in exports has served as a relief valve on the total costs of the Action Plan because most exports are exempt.

Almonds are prepared in a variety of ways to meet differentiated demands among final consumers worldwide. The bakery and confectionary industries purchase almonds in whole or blanched forms and further process them into sweet baked goods, candies, breakfast cereals and snack bars and mixes. Some handlers, typically the larger operations, conduct a full range of processing within their businesses and deliver consumer-packaged-goods to retailers or distributors. Some consumers demand organic or raw foods and several handlers are specialized in serving organic product niches. Other handlers provide both organically-grown and conventionally-grown nuts.

Given the various preferences and requirements of the highly differentiated consumer markets, handlers must establish specifications for production and, now, standards for pathogen reduction treatments, to meet a wide range of dimensions in terms of quality. For example, quality to certain customers means timely fulfillment of a large order of consistent size product, to be used for further processing. To another customer, quality is intact brown skins for goods that are

[3] DFA of California is also known as the American Council for Food Safety and Quality.

meant to be sold whole, in a natural or organic product line. Treatment of almonds with heating processes has been perceived as an impediment to meeting certain quality specifications. There is a risk that flaking of almond brown skins might result from heat or steam. Further, for a very small niche of consumers who select almonds as a raw food item, any form of heat treatment is not acceptable.

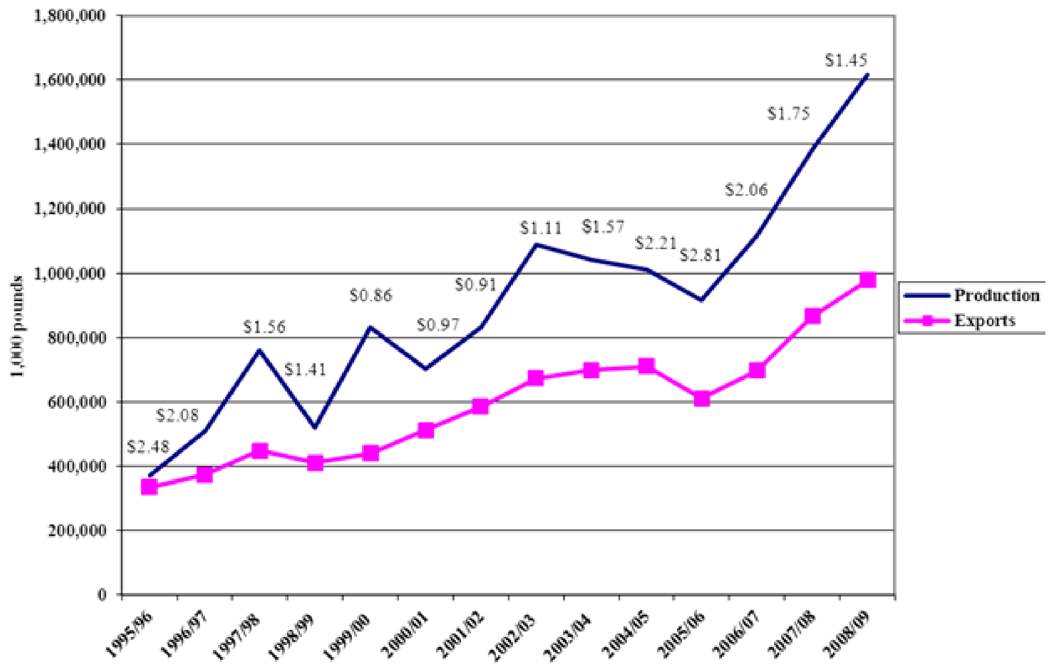

Figure 1. Growth in almond production, exports and grower prices, 1995-2008.

Source: NASS. 2008/09 is forecast
Note: Dollar values in the figure are the season average grower price received in the year

A further dimension of quality is accuracy in terms of records regarding the processes that the goods have undergone. Subsequent to the Action Plan, domestically shipped almonds must be certified as treated. Or, if they have not been treated, they must be labeled "unpasteurized" and shipped outside North America or to a customer that has been approved to conduct pasteurization in its processes.

The availability of approved, validated treatment facilities was disrupted when a particular equipment vendor's technology that seemed promising in 2006 failed to achieve the 4-log pathogen reduction required by FDA. The inability of the Ventilex technology to be approved was a major blow to investors and to the nearby handlers that had planned to use Ventilex as their out-source treatment facility.

Least–Cost Treatment Transportation Plan

An economic model of logistics costs, including shipping, handling, and treatment, is used to develop the least-cost plan from an industry-wide perspective (Bazaraa, Jarvis, and Sherali). The main goals of the model are to identify capacity constraints, if any, and to analyze the effects of possible changes in energy costs on the future implementation of the almond industry Action Plan.

The availability of treatment capacity is a critical issue that affects the costs of implementing the almond industry's food safety Action Plan. To avoid the possibility of bottlenecks in accessing treatment services, some of the largest handlers invested in on-site treatment facilities. A large number of handlers, many of them smaller businesses, depend on outsourcing arrangements for the required pathogen-reduction treatment. Scenarios that may affect the total cost of the program are examined, including changes in fuel prices, potential production growth in the industry, and the failure of a technology to provide adequate pathogen control.

A linear programming (LP) model is used to represent the geographic patterns of production and treatment and identify the routes that minimize total transportation costs from handlers to treatment facilities and then from treatment facilities to shipping points. The constraints reflect product flows as of the 2006/2007 crop year. The 100 handling companies were aggregated into supply points of origin according to ZIP codes. The largest handlers (those shipping more than 5 million pounds per year) were the starting point for creating supply regions. Some of those large handlers share a ZIP code with another handler and were combined into the same supply location (leaving 20 source points in the model). The distances combined within a source region are typically 20-35 miles.

The location of 16 treatment facilities is based on data provided by the Almond Board of California (ABC); capacity is estimated from discussions with industry sources, including vendors of technologies. Final destination points are represented as East Coast USA, two California locations, Canada, and Mexico.

The objective function is:

$$\text{(1)} \quad \text{Minimize Cost} = \sum_i \sum_j C_{ij} X_{ij} + \sum_j \sum_k C_{jk} X_{jk} + \sum_i V_j X_{ij}$$

where $i = 1, 2, \ldots, 20$ handlers
$j = 1, 2, \ldots, 16$ treatment facilities
$k = 1, 2, \ldots, 5$ shipment destinations, shipping to New York (for East Coast USA & Europe), San Francisco (for West Coast USA & Asia), Long Beach (for West Coast USA & Asia), Mexico, and Canada

Variables are:

- X_{ij} quantity of almonds transported from handler *i* to treatment facility *j*
- X_{jk} quantity of almonds transported from treatment facility *j* to shipment destination *k*
- C_{ij} transportation cost from handler *i* to treatment facility *j*
- C_{jk} transportation cost from treatment facility *j* to shipment destination *k*
- V_j variable costs of treatment facility *j*

The constraints are the standard set for supply at handler locations, capacity at 16 treatment locations, and demand at 5 demand centers. Solutions were obtained using GAMS (General Algebraic Modeling System) MINOS solver.

The linear program modeling framework has several embedded assumptions and limitations. One important limitation is that logistics choices are assumed to be made with the goal of cost-minimization alone. To that extent, other non-monetary factors that affect the decision to select a treatment location are overlooked. For example, with this model, one cannot analyze the possibility that customers choose a treatment location for reasons related to the type of technology, service levels, or proprietary decisions.

The assurance processes that lead to high quality products generate transactions costs that are difficult to price in a market exchange. Unobserved costs include the "hassle factor," the time and energy of staff in arranging for the approvals or audits, or the unwillingness of customers to make a transaction because of concerns about reputation or quality. These are not included in the model.

Another important assumption is the absence of economies of scale. That is, costs are assumed to be accurately modeled on the basis of a charge per-mile or per-pound and there are not significant overheads or sunk costs. This assumption is standard in transportation analysis and is supported by industry sources as applicable for this study.

The cost of shipment from treatment providers to destination points is excluded from the total costs reported in this study, because even in the absence of the Action Plan, almonds would have been shipped to those destinations. Transportation from the handler to the treatment location and the variable charges of treatment services are included in the total cost estimate.

Treatment facilities included in this model use fumigation technology (poly-propylene oxide), blanching, oil roasting, steam, and moist heat treatments. The cost of treatment used is an average of the expected charges; there is no differentiation in pricing for different types of technology or for individual businesses' policies.

Data and Baseline Parameters

The baseline volume of 502.5 million pounds was determined from the 2006/2007 crop year shipment records and includes the almonds that were destined for North American customers in that year (Table 1). Almonds exported outside of North America (821 million pounds) are not subject to the treatment requirement, hence are not included in the estimate of logistics costs.

A portion of the almond crop is shipped domestically without treatment because the almonds are delivered to a user under the Direct Verifiable (DV) program. Under the DV program food processing companies (40 different premises and 24 firms) were approved to receive untreated almonds on the basis that their production processes provide pathogen control. The actual levels of DV shipments are proprietary information. We assume in the baseline model that a relatively small share of the crop is shipped under the DV program (110,000 pounds). This assumption, if incorrect, will tend to overestimate the costs of the Action Plan. The rationale for a conservative size of the DV program is that there are no published sources on the volume shipped under the program and industry sources were not available to provide defensible estimates.

Table 1. Shipments of California almonds, by final destination, 2007 / 08 crop year.

	Pounds
Total	1,323,850,551
Shipments to USA customers	454,474,255[a]
Exports	869,376,296
Of which:	
To Mexico	9,103,173[a]
To Canada	39,038,456[a]
Direct Verifiable program (estimate)	110,000[b]

Note: [a] Treatment required under the Action Plan.
[b] Authors' estimate of a limited Direct Verifiable program. This assumption is re-examined in further analysis.
Source: Sue Olson, ABC, via email Oct. 2008 for shipment destination.

Baseline cost parameters are $2.70 per gallon of diesel fuel, $13.50 for truckers' hourly wages, and maintenance expenses of 9 cents per mile. The fuel economy is fixed at 7 miles per gallon. Treatment charges are set at 5.5 cents per pound of almonds for all technology types and locations.

Results of Logistics Analysis

The total logistics cost associated with the food safety Action Plan is an estimated $28 million per year. Cost efficiencies are obtained because the largest handlers have access to treatment facilities on their own premises, or nearby. Low-cost transportation is a competitive advantage to those almond handling firms that have invested in on-site treatment. Investments in treatment facilities that several handlers have made contribute to system-wide efficiency in terms of transportation costs. Other handler firms that have not invested in on-site treatment, but are located near a service provider, also benefit from low-cost transportation.

The findings indicate that:

- Capacity of treatment is not a limiting factor.
- Charges for outsourced treatment are the largest contributor to total cost of the Action Plan.
- Diesel fuel costs rising to historically high levels adds less than 1% to the total cost ($290,000).

Capacity for pathogen-reducing treatment of almonds is more than adequate for the industry's needs. Even excluding the Ventilex systems from total capacity due to the failure to attain regulatory approval, there is sufficient treatment access in terms of industry-wide needs. More than 320 million pounds of treatment capacity goes un-used. Four of the fourteen different treatment locations have excess capacity. These results are strong indications that treatment is adequately distributed in the California almond industry.

The North (Chico area) and Central regions (Modesto area) are not capacity constrained, even under the assumption that Ventilex is shut down and not replaced. However, in the Sacramento region, total capacity is insufficient to meet the demand. The optimized logistics model indicates that treatment facilities in the regions north and south of Sacramento are used when Sacramento hits full capacity. Those alternative routes each exceed 100 miles.

The marginal benefits of additional capacity at two treatment locations (Wasco and Lost Hills) are among the highest. That is to say, there is an incremental benefit from locating capacity in these regions. Part of the reason is the large volume of almonds that are supplied by handlers in these locations. If there were more capacity, modest savings in transportation costs would be expected. At the margin, a one-pound increase in capacity in these locations leads to transportation cost savings of 60 cents.

Impact of Regulatory Approvals on Capacity Constraints

When the Action Plan went into effect, several treatment facilities were operating under temporary approvals, as appropriate for the implementation phase of the regulation. During 2008, three of the treatment facilities using Ventilex steam technology failed to meet final approval for satisfactory pathogen-reduction performance.

The baseline results reported in this study do not include the Ventilex facilities. As a test of the impact of removing that capacity from the system, a model was developed in which Ventilex facilities are included, which was actually the case in the 2007 crop year. Treatment capacity increases by 162 million tons with the inclusion of these facilities, and the impact on total cost is minimal. Total cost falls by $40,000, or by less than one percent (0.14%). The cost per pound treated was held constant in both versions of the model; therefore, changes in location alone explain the estimated modest change. With Ventilex facilities in place, a route of more than 150 miles from region 4 to region 3 is no longer necessary and the shadow price of capacity limits at the two facilities in region 4 is reduced.

It should be noted that the logistics model does not represent the firm-level impact of the lack of access to Ventilex technology. There are adjustment costs in finding an alternative arrangement for treatment, particularly if a handler's customer requirements did not allow the use of another form of treatment technology nearby.

Charges for Treatment Services

The total cost of the Action Plan logistics is highly sensitive to the charges for treatment that are assumed. Lacking detailed data on charges for treatment, we use a constant cost per pound treated for each treatment facility, regardless of technology and location. This assumption is consistent with a competitive market for treatment services. Each additional penny in the average per-pound charge for treatment generates $5 million more in total logistics costs (Table 2).

Table 2. Effect on total cost of increasing charge for treatment.

Charges for treatment	**Total logistics cost**
in cents per pound	*in million dollars*
3.5	17.98
4.5	23.00
5.5	28.03
6.5	33.06
7.5	38.08
8.5	43.11
9.5	48.13
10.5	53.16

Source: Author's estimates from simulation

Fuel Prices

As a starting point, the baseline model has diesel fuel price at $2.70 per gallon. This was the average price in California during 2003-2009, according to the U.S. Department of Energy. Diesel prices ranged from $1.10 per gallon in February 1999 to $4.97 per gallon in July 2008, then fell to $2.30 per gallon in early 2009 (Table 3). The sensitivity of the logistics costs to diesel fuel prices is relatively low. If diesel fuel is included at $4.97 per gallon (the July 2008 peak), total costs rise by $290,000.

Table 3. Statistics on diesel prices, in dollars per gallon.

	2003-2009	**1995-2009**
Average	2.71 [a]	2.00
Standard deviation	0.82	0.85
Minimum	1.54	1.10
Maximum	4.97	4.97
Median	2.68	1.61

aPrice used in baseline model.
Note: Prices for diesel on highway, ultra-low sulfur, California.
Source: Energy Information Administration, U.S. Department of Energy.

Conclusions and Discussion

An economic model of an efficient logistics system for treatment of almonds indicates that total capacity is adequate to treat all the almonds shipped to North American customers. Costs of the treatment and related logistics are estimated at approximately $28 million per year.

Energy costs have a relatively small effect on the total cost. If diesel prices return to the high levels of the summer of 2008, the increase in the total cost of transportation is expected to be less than $300,000. Given the modest impact of diesel fuel, attention should be focused on the charges for pathogen-reduction treatment as the driver in total cost of the Action Plan. The majority of handlers depend on outsourcing to custom providers to treat their products. The most efficient locations for treatment are the largest handlers' operations, and it is important to know whether services are offered on a for-hire basis in ways that meet the needs of the smaller handlers. Clearly, an economically efficient treatment industry is an important goal. Treatment services are not "one size fits all," and as in most differentiated markets, pricing issues are complex. Is monitoring the competitiveness of the market for treatment services a role for industry, for USDA, or for FDA?

Food contamination incidents since the adoption of the Action Plan have reinforced the value of a proactive system to reduce contamination risks industry-wide. Peanuts, and now pistachios, have been implicated in salmonella incidents. According to the Almond Board of California,

> "Product recontamination was a contributing factor in a number of product recalls of other nuts in 2009. ABC acted quickly to develop the Plant Environmental Monitoring Program (PEM), which is an important tool that hullers/shellers, handlers, DV users, and manufacturers can use to help control product recontamination. A well-thought-out PEM will help to significantly reduce the risk of product recontamination in a processing operation." (ABC, Almanac 2009: 18).

The experience of the almond industry demonstrates that regulatory risk is a factor in the efficient deployment of safety-enhancing technology and services. Industry is investing in technologies under the expectation that the systems will satisfy technical standards, and there are real possibilities that the systems in place may not perform as expected. While the impact of the approval problems in this industry-wide model was modest in terms of capacity constraints, the particular firms involved had to make adjustments to find alternative treatment providers.

Another issue related to technology results from the differentiation of consumer demands in the market. Some processes are not acceptable to certain customers, even if they accomplish pathogen control. As a result, the market for treatment services must be differentiated as well. For example, a custom provider that can offer pathogen reduction services without fumigation can meet the requirements of organic food producers and consumers. There will be some potential for differentiation and possibly profit-making as treatment service providers find ways to attract specialized customers who will pay for premium-priced services in association with the premium-priced final goods.

In assessing the developing market for safety-enhancing services, economists have much to offer. It can easily be established that some mark-ups in the pricing of treatment services are simply cost recovery; justified by the complexity of bringing in small lots from many different handlers. Another valid reason for differentials in charges across types of treatment is that some markets with high willingness to pay for quality will be able to sustain higher charges for the form of treatment that is acceptable to those customers, leading to a premium price at the treatment facility.

As the market for pathogen control services matures, one could expect that competitive forces would affect the supply and demand for treatment services. Handlers requiring custom treatment would be able to choose between alternative providers on the basis of location, service provided, and timeliness. And, if the competition were vigorous, one would expect an equilibrium at which treatment suppliers price their custom services to cover their cost, not to be a profit center.

Such a competitive market will develop more quickly if there are few constraints on the scientific expertise needed to assure the qualifications of service providers.

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Environmental Regulation and Regional Economy: Economic Impacts of the Elimination of Azinphos-methyl on the Apple Industry and Washington State

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Abstract

The Environmental Protection Agency declared the pesticide azinphos-methyl must not be used in apple production after September 2012. We use this ban to contribute to the debate on environmental regulation versus industrial output. We use a computable general equilibrium model to estimate the change to sales, price, and employment in the Washington apple industry and the statewide economy had this ban existed in 2007. We estimate the ban decreases profit per acre by $101; changes sales by -0.8%, prices by 0.2%, and employment by 0.1% in the apple industry; but has negligible impacts on the Washington economy.

Keywords: apples, azinphos-methyl, CGE, economic impact, environmental regulation

There is an ongoing debate in academia, government, and industry on determining the extent to which environmental and health regulation is costly to the production output of the economy. This debate is flaring once again because the U.S Environmental Protection Agency (EPA) has mandated the nationwide elimination of the pesticide azinphos-methyl, also known as AZM or Guthion, by September 30, 2012 (2009; EPA 2009). We use this case to contribute to the debate on the economic impacts of environmental regulation. And it is a very heated debate. For example, Williams and Hinman (1999) write "…it is rather obvious that producers will suffer significant economic losses…." whereas a commenter writes that small economic impacts are "a sufficiently obvious outcome that it doesn't merit highlighting…"[1] These opposing quotes, both professing their views are "obvious," show how unsettled this debate is, and the need for our research.

We estimate the statewide impact of eliminating AZM in favor of a new pest management alternative in apple production in Washington. In particular, the economic effects we study are changes to sales (value of activity produced), prices, and employment for the apple industry, industries that supply inputs to the apple industry, industries using apples as an input, household income, and profit per acre.

We study Washington because it accounts for 58% of U.S. apple production in 2007 (USDA NASS 2009) and 65–75% of the fresh market (Pollack and Perez 2005). Furthermore, Washington is particularly vulnerable to the AZM ban for two reasons. First, since the late 1960s, AZM has been the most used pesticide by apple growers in Washington, primarily as a control for codling moth, the leading pest in Western apple orchards (Brunner et al. 2007). In 2007, AZM was used by 80% of Washington apple growers (Granatstein et al. 2010) and applied to 66% of Washington's apple bearing acres (USDA NASS 2008). Second, apples are the leading agricultural commodity, with sales accounting for more than 70% of the market value of Washington's $2+ billion fruit industry and 22% of all Washington farm receipts (USDA NASS 2009).

AZM belongs to the organophosphate (OP) class of pesticides, and the EPA's mandate is the result of concerns about the risks of OPs to the health of farm workers and the quality of local water and aquatic ecosystems. Details about the toxicity of AZM and other supporting data that guided the agency's decision are provided in the EPA's Ecological Risk Assessment (EPA OPPT 2005) and Organophosphorus Cumulative Risk Assessment (EPA OPP 2006).

The EPA regulation challenges the apple industry to control the codling moth while transitioning to a combination of safer, AZM-alternative pesticides. Though an AZM-alternative Integrated Pest Management (IPM) program is more worker- and environmentally-friendly, it requires different timing and more precise spray applications than AZM.[2] Furthermore, an

[1] This anonymous comment was forwarded to the author in a personal communication from Gary Brester. (Brester, G. W. 2010. Montana State University, Bozeman, MT, August 17.)

[2] Integrated Pest Management is an encompassing phrase describing a combination of mating disruption, field monitoring for targeted pesticide use, and new pesticides to protect against pests. It is endorsed by the Washington State University Tree Fruit Research & Extension Center (n.d.). Many growers already use an OP-based IPM program and need to switch to an OP-alternative IPM scheme (Brunner 2009). Details of various alternatives to AZM can be found in Brunner et al. (2007), but the most likely alternative includes the OP-alternative pesticides Altacor

additional spray of new pesticides is required to maintain yield and quality since the alternative pesticides do not have as long-lasting residues (Brunner 2009). Therefore, for the same output, the alternative codling moth treatment is more costly per acre than using AZM because both the unit price and the quantity needed increases.

We use a computable general equilibrium (CGE) model to estimate the impacts of the AZM ban because we are interested in both quantity and price changes for Washington's apple industry as well as other upstream and downstream economic sectors. Furthermore, we like the CGE model's discipline and data requirements. Unlike a partial equilibrium approach or other methods, CGE analysis accounts for inter-sector relationships and price changes.

We estimate the increase in the per acre expenditure of switching to a non-AZM pesticide scheme that ensures the same volume and quality of apples. We then consider the apple industry's response to this cost increase by allowing growers to change the quantity of output by altering the amount of the various inputs (such as labor or pesticides) used in production. Our model accounts for the two biggest fears of apple growers: the increased cost of non-AZM pesticides and that more of the non-AZM pesticide is required for the same protection as AZM (Granatstein et al. 2010).

We find a decrease of $16 million in profit for the Washington apple industry, or $101 per acre. This is a sizable impact, but given the size of Washington's $1.5 billion apple industry, the relative impact is small. We find a change in apple sales of -0.8%, price of 0.2%, and employment of 0.1%. The change in employment is due to growers substituting labor for pesticides. Other impacted industries experience changes to sales, price, and employment that are small relative to the size of the industry as well. Taken as a whole, if the AZM ban had been in place in 2007, the Washington economy would have had 0.003% fewer sales and 0.001% more employment leading to an overall $2.3 million decrease in Gross State Product.[3] Thus, for the particular case of the banning of AZM in Washington apple production, our estimates indicate that this new environmental regulation is not particularly damaging to the regional economy, but that the fears of apple growers are plausible.

As part of the discussion to eliminate AZM in agricultural production, the EPA conducted an economic assessment of the AZM ban on apple growers (EPA BEAD 2005). The study estimates the impacts on growers by comparing the net revenues of the current practice of using AZM to three alternative pest management scenarios. For the Western U.S. region, the EPA estimates the net revenues of growers currently using AZM will decline between $8.7 and $50.1 million, a 4–23% reduction in profit. While these estimates put into perspective the potential economic consequences of eliminating AZM, the range of impacts is too large to be useful. Brunner (2006) criticizes these results for not using realistic costs to implement AZM-alternative pesticides. Furthermore, these results do not capture the economic significance of the net effects of the ban as it ripples through the larger Washington economy.

(chlorantraniliprole) and Delegate (spinetoram). Growers are not expected to quit production entirely or switch to organic or other non-chemical pest control systems in large numbers (Brunner 2009).

[3] Washington GDP was $325.5 billion in 2007 and the crop and animal production sector accounted for 1.25% of that (BEA 2010). Although the value of the apple industry is only about .46% of state GDP, the industry is an important part of the agricultural economy since its value is 36.76% of the crop and animal production sector.

Williams and Hinman (1999) use an enterprise budget to estimate the profitability of producing Red Delicious apples in Washington under conventional practices and when OPs are eliminated from the insect control program. The study estimates a 320% decline in the grower's profit (from positive profit to a loss) if either all OPs are eliminated or all but one OP is eliminated. The large decline in estimated profits is due to a higher cost of orchard maintenance, increased insect damage, and losses in yield and quality. However, the Williams and Hinman (1999) study does not consider that growers could switch to other non-OP pesticides. Also, it does not consider the wider economic impacts.

Modeling Approach

CGE modeling is a general strategy to estimate economy-wide impacts. It is widely used to study impacts from topics as diverse as implementing or removing agricultural subsidies and production incentives (e.g., Doroodian and Boyd 1999; Razack et al. 2009), trade restrictions and liberalizations (e.g., Philippidis and Hubbard 2005; Mai 2008), and environmental standards (e.g., Rendleman et al. 1995; Cassells and Meister 2001). Kehoe and Kehoe (1994) give a relatively simple introduction to the theory of CGE analysis as well as testing—and passing—the reliability of this method.

Zilberman et al. (1991) establish the precedence of using CGE modeling in the context of a pesticide ban. They use general equilibrium techniques to examine the ban of certain pesticides such as ethyl on selected fruits, vegetables, and field crops in California.[4] The study indicates that the availability of effective substitutes is important to mitigate the effects of a ban. Their findings support our choice to explicitly consider other pesticides in the alternative scenario instead of pesticide-free management.

Strengths of the CGE Method Over Alternative Methods

Perhaps the best evidence of the soundness of the CGE modeling method is that this approach has been used in applied work for more than 30 years in a wide-range of contexts, including pesticide bans. The reason CGE is so popular is that there are many benefits from using it for estimating the economic impacts of a regulation compared to input-output or partial equilibrium methods. First, using a conventional apple enterprise budget allows us to construct an apple production function with data agreed upon by apple-growers themselves. We convert this enterprise budget into an input-output accounting production function and scale it up to state- level production using AZM for the benchmark year. We then insert the scaled budget into the statewide Social Accounting Matrix (SAM). The SAM is data on regional industry sales to, and purchases from, other industries and income and expenditures of regional households and government. The SAM can be used to capture the extent to which the state's total industry sales and jobs are dependent on the fruit industry. We make the necessary adjustments to the rest of the fruit industry to get back a balanced SAM. The fact that the benchmark and counterfactual SAM must balance is a key strength of CGE modeling—absent in other methods—because it enforces the discipline that total commodity

[4] Ethyl parathion is an example. All registered uses of products containing ethyl parathion were cancelled on October 31, 2003 (Federal Register 2005).

supply equals total commodity demand for every commodity in the regional economy The model's results are net changes to the variables of interest rather than gross changes.

Compared to an input-output approach, CGE is preferred for this context because it endogenizes the growers' response to the ban by allowing the growers to make profit- maximizing quantity adjustments. The input-output method forces all adjustment to occur through industry-wide quantities whereas adjustment in our CGE method occurs through both quantity and price in all commodity markets. The assumptions needed for an input-output model are more restrictive than a CGE model and thus our results are more appropriate for short-run predictions and analysis (Cassey et al. 2011).

We do not use a partial equilibrium approach for two reasons. The first reason is we want to model the net impacts of the ban on the Washington economy and not just in the direct and indirect industries that would be modeled in partial equilibrium. That means we consider changes in the secondary price effects that are held fixed in partial equilibrium. The second reason is practical. We do not have sufficiently long time-series data for the partial equilibrium model's parameters to be econometrically estimated with meaningful precision. Instead we have a Washington SAM and have estimates for the free parameters in the CGE model that are specifically for Washington.

Model Development and Calibration

Our model is a modification of the Washington State CGE developed by Holland et al. (n.d.), which is an enhancement of Löfgren et al. (2002). The model's assumptions are that given prices, endowments, and technology, producers maximize profit and consumers maximize utility. We use Walrasian competitive equilibrium, with the government and a foreign sector, as our solution concept. The model closures are that 1) capital and land are activity specific and fixed, 2) labor is supplied perfectly elastically, is mobile, and unemployment or out-of-region migration are possible, 3) foreign and rest of the United States savings are variable, and 4) price level (CPI) varies to achieve the savings-investment closure. Closure 2 means the labor market is slack. There is an unspecified level of unemployment that cannot be separated from the possibility of migration into or out-of the region. The implications are that the sum of labor demand across all sectors leads to equilibrium quantity adjustment, but no change to wage. Numerically, the model is constructed using GAMS software and calibrated with the PATH solver.[5]

Our CGE model uses 2007 data because AZM was the predominant pesticide used in Washington that year and it was the last year when AZM could be used without restriction. Data on the interactions between the sectors of the Washington economy are obtained from the IMPLAN database (MIG 2004; see Data Sources in the appendix). We focus on the upstream and downstream sectors of the apple industry in order to study them in detail. Thus our sectors include (but are not limited to) Fruit, Pest Management, Nursery, Electricity, Utilities, Wholesale, Frozen, Can Dry, Other Food, and Transportation. Figure 1 illustrates the supply chain of the apple industry. We highlight the chemicals or agricultural pesticides in the figure since these are the inputs

[5] GAMS code for the model is available in the online appendix at http://faculty.ses.wsu.edu/Cassey/Webpage/Appendix/Apples_OP/FinalModel.txt. Select equations available in the technical appendix.

exogenously modified in our counterfactual. We aggregate the remaining industries into 23 total sectors for computational reasons.

IMPLAN data come at the sector level, so in order to model the apple industry specifically, we split the fruit sector with 71.5% to apples and the remaining to a separate other fruit industry as that is the split reported by the Washington Fact Sheets (USDA NASS 2009). We use the Washington conventional apple enterprise budget from Mon and Holland (2006) for production cost information. We assume the AZM ban affects only the growers using AZM, so we scale the industry production costs to account for the fact that only two-thirds of apple producing acres were sprayed with AZM in 2007 (Lehrer 2010).[6]

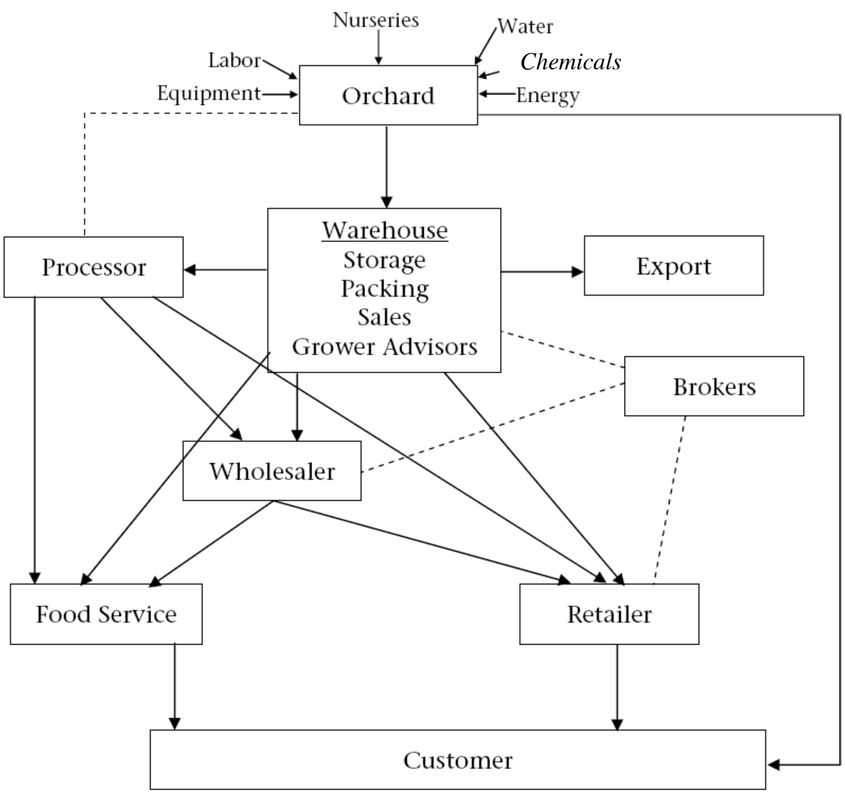

Figure 1. Supply Chain of the Washington Apple Industry
Source: Reprinted from Schotzko and Granatstein (2004, 27).

We model the reactions of the economy in two alternative scenarios. The 2007 benchmark is where AZM is the predominant insecticide to control codling moth in Washington apple production. The second scenario is the counterfactual in which there is a complete AZM ban in 2007. We first calibrate the model to find the parameters needed for the model data to replicate the actual 2007 data (including employment). Then we apply these calibrated parameters to the counterfactual to estimate what would have happened if AZM were banned in 2007. Our model does have free

[6] In 2007, 66% of Washington apple bearing acres were sprayed with AZM at least once. Ten percent of acres were in organic production. The remaining acres were managed with non-AZM pest control. According to Lehrer (2010), these non-AZM pest management programs are very similar to what we model in our counterfactual with the exception that not all of the non-AZM pesticides that we consider were actually available for commercial use in 2007.

parameters, mostly elasticities, whose value cannot be calibrated and so must be entered manually. We use parameter values specified for use in the Washington State CGE model (Holland et al. n.d.). (A list of free parameters, the values we use, and our source, is in Table A1 in the appendix.) Details of our calibration are available in the technical Appendix.

Assumptions Particular to the AZM Ban

We look at the economic impact of the AZM ban in apple production in comparison to the next best alternative insecticides and management systems. Based on Brunner et al. (2007), we assume that the next best alternative is an IPM program using an assortment of new AZM- alternative insecticides. Though not all of the new pesticides expected to replace AZM were available in 2007, the counterfactual assumes that these alternatives were available. We estimate what per acre cost of using these alternative pesticides would have been if they were available in 2007 in order to maintain the same volume and quality. Then we enter the increase in cost (as the percent difference from actual 2007 costs) into the model by decreasing the technical coefficient of pesticides for apple production.[7] This forces the apple industry to react to a situation where the effectiveness of per unit pesticide is less than before by choosing different levels of production inputs such as labor or pesticides, resulting in changes to apple output. The essence is that we counterfactually tell growers the increase in cost to achieve the benchmark output, but then let them decide to produce something other than the benchmark given the change in cost. Because our model adjusts the equilibrium price and quantity of other agricultural products as well, we account for reallocation of production to other crops.

Because the increase in the per acre pesticide expenditure to maintain previous yield and quality is not the same as the technical coefficient (which is independent of price), we make an assumption on how pesticide expenditure relates to pesticide productivity (apple yield per unit of pesticide). We decrease the technical coefficient on pesticides in the apple activity by the same amount we calculate to be the increase in pesticide expenditures needed to maintain yield and quality. This assumption errs on the high side—in reality the decrease to the technical coefficient will be less than the increase in expenditure—because both the price and quantity of the AZM-alternative pesticides increases compared to AZM in the expenditure calculation. But the change to the technical coefficient is, by definition, the change in yield from using the same amount of the alternative management scheme. Thus the change to the technical coefficient must be a quantity change only and so can be no greater than the expenditure change (%ΔExpenditure = %ΔPrice + %ΔQuantity+ %ΔPrice*%ΔQuantity). We do not have enough information to identify this quantity change separately from expenditure. Therefore we use our expenditure estimate for our technical coefficient knowing the resulting economic impact estimate will be an upper bound. We have done a sensitivity analysis of these assumptions (not reported) and found that our results are the same qualitatively.

Our pesticide expenditure estimate is based on the cost needed to maintain the yield and quality of the apple crop at the benchmark level. All impacts come from how the apple industry responds to the increased prices and quantities for the new OP-alternative pesticides. Our costs for the counter-

[7] Technical coefficients refer to the portion of the total inputs of a sector that are required from another sector. These parameters represent direct backward linkages of an industry to other industries and constitute the recipe for production of that industry (Krumme 2010).

factual include an additional spray application and its associated use of extra chemicals, labor hours, and tractor use. This models the two biggest fears of apple growers (Granatstein et al. 2010). Though non-AZM IPM programs require precise timing of applications that can take time for the grower to learn, our counterfactual assumes that growers have already learned the best application methods.

We assume that there are no differences in the costs of monitoring between the AZM- based IPM and the AZM-alternative IPM. AZM-alternative IPM requires more precise spraying and timing of applications than the conventional scheme. Most growers, however, use a pesticide consultant to organize their pesticide use. In most cases of switching away from AZM, the service of the pesticide consultant is provided by the pesticide distributor, without additional charge, conditional on the grower using pesticides from the manufacturer (Brunner 2009). Thus we assume any additional costs due to more precise monitoring and application procedures using the new pesticides are either explicitly given in the quoted price of the pesticide or are captured in the number of spray applications.

Finally, it is not apparent now whether the use of new pesticides will result in more or less labor costs on net. The more rigorous application that the new pesticides require to be effective increases labor costs. But workers can return to the crop one day after spraying compared to 14 days for AZM. This enhanced worker flexibility decreases labor costs. We settle on no change to labor efficiency, though we do a robustness check in the Appendix.

Rather than project the accumulated costs of switching from AZM to the next best alternative from the phase-out period (2007 to 2012) and onwards, we estimate the economic impacts if AZM could not be used in 2007. Though other OPs such as Lorsban (chlorpyrifos), Dianizon, and Imidan (phosmet) are legal as of this writing, increased EPA scrutiny leads us to predict all OP usage will be curtailed in the future. Therefore we do not consider switching from AZM to another OP to be a realistic option.[8] We assume that the Washington apple growing industry reacts to the AZM ban by choosing the amount of AZM-free alternative pesticide and other inputs to production given the decrease in the technical coefficient. Finally, we assume that no foreign countries prevent the importation of Washington apples due to the alternative pesticide.

Though AZM is a pesticide used to control codling moth, the ban will affect apple growers' control of other pests, such as the leafroller, to some degree. Therefore, there will be changes to the percent of acres sprayed with other pesticides. We account for changes to the use of other pesticides as a result of the AZM ban.

Costs of Pest Management

In the 2007 benchmark, 66% of apple producing acres used AZM along with pheromones for mating disruption and the pesticides Intrepid and Rimon to make up an IPM program. There is no one-for-one replacement for AZM, so in the 2007 counterfactual, three pesticides—Delegate, Altacor, and Assail—substitute for AZM. The use of pheromones and chemicals for other pests—like mites, leafrollers, and aphids are the same across the two cases, though the acres sprayed change.

[8] As of this writing, Lorsban is restricted to use before bloom in the spring, when codling moth are not active. Diazinon is not effective against codling moth. Imidan is therefore the only OP- based alternative that could be used for codling moth control .

Table 1 gives the projected costs of an insect control program in 2007 for the two scenarios. *Input cost per acre* is the quoted purchaser price of the pesticide times the number of sprays times the percent of acres sprayed.

Table 1. Insect Control Program Costs, Benchmark (with AZM) and Counterfactual, $/Acre

Compound	Trade Name	Benchmark			Counterfactual		
		Input	*Application*	*Total*	*Input*	*Application*	*Total*
Oil	Oil	20.40	25.50	45.90	20.40	25.50	45.90
Miticides	Miticides	12.00	6.0	18.00	12.00	6.00	18.00
	AZM-Guthion		0				
azinphosmethyl		**42.07**		**89.59**	**-**	**-**	**0.00**
phosmet	**Imidan**	**3.12**	**3.12**	**6.24**	**-**	**-**	**0.00**
methoxyfenozide	**Intrepid**	**7.78**	**5.61**	**13.39**	**18.30**	**13.20**	**31.50**
spinosad	**Success**	**31.23**	**16.38**	**47.61**	**-**	**-**	**0.00**
imidacloprid	**Provado**	**3.40**	**-**	**3.40**	**0.84**	**-**	**0.84**
novaluron	**Rimon**	**12.17**	**5.85**	**18.02**	**4.06**	**1.95**	**6.01**
chlorpyrifos	**Lorsban**	**12.29**	**-**	**12.29**	**7.68**	**-**	**7.68**
thiacloprid	Calypso	1.49	0.99	2.48	1.49	0.99	2.48
Pheromones	Pheromones	78.40	21.00	99.40	78.40	21.00	99.40
diazinon	Diazinon	2.10	2.97	5.07	2.10	2.97	5.07
AZM alternatives:							
rynaxypyr	Altacor	-	-	-	53.78	30.00	83.78
spinetoram	Delegate	-	-	-	67.12	36.00	103.12
acetampirid	**Assail**	**39.75**	**23.46**	**63.21**	**30.50**	**18.00**	**48.50**
	Total	*266.19*	*158.40*	*424.59*	*296.65*	*155.61*	*452.26*

Sources: USDA NASS (2008); Brunner (2009).
Notes: See online appendix tables 2–3 for more details and sources. Changes from the benchmark to the counterfactual appear in bold. Numbers are rounded to nearest hundredth. Total cost per acre is the sum of input cost per acre based on the price of the pesticide times the number of sprays times the percent of acres sprayed and the application cost per acre which is the cost of the labor, fuel, and depreciation to spray an acre once (assumed to be $30) times the number of sprays times the percent of acres sprayed.

We account for that fact that only 66% of Washington's acres were sprayed with AZM at least one time (Lehrer 2010). Thus the other 33% of acres are not directly affected by the pesticide ban. *Application cost per acre* is the cost of the labor, fuel, and depreciation to spray an acre once (assumed to be $30) times the number of sprays times the percent of acres sprayed. *Total cost per* *acre* is the sum of the input cost and application cost per acre. Brunner (2009) provides the costs for the pesticides and their use.

The total cost of the insecticide program is $425 per acre when AZM is used to control codling moth compared to $452/acre when AZM alternatives are used. Thus we estimate a 6.5% increase in the cost of pesticides—and therefore a 6.5% decrease in the technical coefficient of pesticides in the apple activity—in the counterfactual.[9] The per acre cost in the counterfactual is greater because the non-AZM pesticides are more expensive per acre and an additional spray is required to match the protection of AZM (from 1.58 applications of AZM per acre to 2.80 applications of AZM alternatives per acre).[10] Provado and Lorsban do not have application costs because we assume these pesticides are always mixed with other pesticides. Note that these budgets include the cost of controlling other insects. The cost of codling moth control alone is $211/acre (AZM + phosmet + pheromones + half sprays of Intrepid and Rimon) in the benchmark and $354/acre (Delegate + Altacor + Assail + pheromones + half sprays of Intrepid and Rimon) in the counterfactual. The cost differences between the two scenarios are attributed not only to the cost of AZM and AZM alternatives but also to the resulting change in chemicals that control other pests.[11]

Results and Discussion

The results for sales, prices, and employment are listed in Table 2. The benchmark is the 2007 data with AZM. The counterfactual is the model's estimates for what would have occurred in 2007 if AZM had been banned. The percent change = ((counterfactual – benchmark) / benchmark)*100.

As seen in the first row, the model estimates that the change in apple sales would have been -0.8% or -$11.6 million. The corresponding price change to Washington consumers would have been an increase of 0.2%. This price change occurs because we assume the Washington apple market is perfectly competitive and is imperfectly substitutable with outside apples. We treat the AZM ban as a negative supply shock, shifting the supply curve in. The decrease in production is 0.8%. We estimate employment in the apple industry to be 22 workers larger in the counterfactual. This is because the model is compensating for the decrease in pesticide efficiency by substituting more labor.

[9] By comparison, the loss in productivity from organic techniques is about 10% of which most of the loss is due to fertilization and thinning techniques rather than pest control (Granatstein et al. 2010).

[10] We cannot calculate the decrease in the technical coefficient from per acre application counts because of the interaction of other pesticides in control.

[11] Chlorpyrifos: use of this product decreases due to other chemicals that control both leafrollers and codling moth (Altacor, Intrepid and Delegate). Methoxyfenozide: use increases for leafroller control because of the reduced use of Lorsban (chlorpyrifos); Spinosad: the product is replaced by Delegate (spinetoram) in the counterfactual; Imidacloprid: use decreases because Assail (acetampirid) provides control of aphids, which is the primary use of Provado (imidacloprid); and Novaluron: use declines due to concerns with disrupting pest mites. Thiaclorpid and acetamiprid are used for codling moth and aphids control.

Table 2. Results for Sales, Employment, and Domestic Consumer Price

	SALES (VALUE OF ACTIVITY PRODUCED)			EMPLOYMENT		CONSUMER PRICE	
	Benchmark	Counterfactual	Percent Change	Benchmark	Counterfactual	Percent Change	Percent Change
	(Million $)	(Million $)	(%)	(Workers)	(Workers)	(%)	(%)
Apples	1545.96	1534.36	-0.751	15857	15879	0.139	0.203
Other Fruit	614.11	614.34	0.038	7811	7822	0.141	0.203
Other Crops	3599.81	3599.90	0.002	34523	24527	0.010	-0.006
Upstream Ind.							
Pest Mgmt	100.69	100.35	-0.335	61	60	-0.764	-0.394
Nursery	401.18	401.19	0.002	3819	3819	0.004	-0.001
Electric	5916.96	5916.96	-0.004	21851	21850	-0.005	-0.002
Utilities	1644.18	1644.18	-0.004	2316	2316	-0.008	-0.001
Downstream Ind.							
Wholesale	25174.77			136000	136000	-0.002	-0.001
Frozen	990.43	989.73	-0.002	7277	7272	-0.077	0.015
Can Dry	2205.53	2204.91	-0.071	3447	3446	-0.055	0.006
Other Food	12088.83	12087.42	-0.028	28174	28169	-0.016	0.004
Transportation	16891.14	16890.92	-0.012	111000	111000	-0.001	-0.001
Other Sectors	476831.34	476829.16	-0.001	3511530	3511529	-0.000	—

Notes: Percent Change = ((Counterfactual – Benchmark) / Benchmark) * 100. Values are rounded. Sales = quantity of activity x price of activity and are the revenue received by the producer. Employment is the quantity demanded of labor by activity. Washington consumer price is the market demand price for the commodity produced and sold within Washington to consumers or intermediate producers and includes indirect taxes and transaction costs

Though the absolute magnitude of the AZM ban's impact is in the millions, the economic impact is relatively small given the size of Washington's apple industry. Our findings are much less severe than those estimated by Williams and Hinman (1999) because they do not allow apple growers to switch to an alternative pesticide when AZM is banned, an important distinction as shown by Zilberman et al. (1991).

Our industry profit estimate, however, is within the lower range of the EPA (EPA BEAD 2005). We estimate that the aggregate Washington apple industry would have had $16 million less profit in 2007 if AZM had been banned, about $101 per acre, due to the increase in pesticide cost and decrease in sales. This is calculated by using the parameters of the CGE model to get counterfactual cost estimates that we then insert into the enterprise budget (and not from the CGE model itself where profit in terms of opportunity cost must be zero).

The rows immediately following apples are the horizontal industries: other fruit and other crops. Because the AZM ban will affect all crops and not just apples, we decrease the technical coefficient of pesticides in the other fruit industry. Otherwise the model responds to the AZM ban by increasing the production of other fruit to offset the decrease in apple sales. That is not a realistic scenario since AZM will not be allowed on other fruit or crops. In order to maintain the benchmark levels for other fruit, we decrease the technical coefficient by 0.55%. This is admittedly ad hoc and is a limitation if the AZM use on other crops differs from apples. However, our results are robust to our choice and thus we do not consider the necessity of this assumption to be a major limitation.

The results show a slight increase in the consumer price of other fruit (0.203%), though unlike apples, there is also a slight increase in overall sales (0.038%). The other crops sector shows a slight increase in price, but with a very small increase in sales.

The next group is the upstream industries. Besides apples and other fruit, pest management is, not surprisingly, the sector most affected by the AZM ban. The increase in the cost of pesticides results in a decrease in total sales. Here too, the economic impact of the ban is relatively mild as a percent of the industry. Both the electric and utility sectors decrease slightly in sales because of the decrease in apple production.

The downstream industries are also modestly affected by the AZM ban in percentage. The downstream industry most impacted by the AZM ban is the frozen sector. But even here, sales are estimated to have been only $704,000 less in the counterfactual and resulting in five fewer employees. The remaining sectors were aggregated because of their weak economic connections with the apple industry. The ban has negligible impact on them.

Though perhaps a surprise to industry representatives, the overall Washington economy is not strongly affected by the AZM ban relative to its overall size. This is because though the apple industry is one of the largest industries in Washington, it is still small compared to the statewide economy. We estimate that Washington would have had 21 more workers in employment if the AZM ban had been in effect in 2007 and overall state sales would have been 0.003% smaller. The fact that there are not large impacts to the statewide economy is consistent with theoretical results on tax increases to specific inputs and sector-specific factor taxes (Wing 2004). We estimate the change to indirect taxes and state government revenue to be negligible.

Other estimates from our simulation of the AZM ban include that household income does not change appreciably. But we estimate a change in household consumption of apples by -0.122%. This is due to the slight, but nonetheless positive change in the price of Washington apples. This reduction in apple consumption means there could be a very minor negative health consequence for consumers offsetting the health benefits to orchard workers and their families. This conjecture is, however outside of our formal model.

Our economic impact estimate does not include economic changes from a healthier work force and healthier communities or changes to income or employment from the end of sales of AZM (produced by Bayer CropScience, Gowan Co., and Makhteshim Agan) and their replacement by alternatives. Also we do not consider the additional costs facing the American consumer from potential increased Washington apple prices. Finally we do not consider any impact from either the State or Federal government-provided education programs to inform apple growers about the ban and how to effectively manage it. However, our model does calculate equivalent variation by household and welfare. These may be found in Table A2 in the Appendix.

Conclusion

Because of the size of the apple industry in Washington's economy, the EPA's ban on AZM could have resulted in large economic impacts to the apple industry, causing ripples through the upstream and downstream industries, and the overall economy. We use realistic prices for the likely AZM-alternative IPM system to estimate the percent increase in expenditure for spraying an acre of apple orchard if the AZM ban had been in effect in Washington in 2007. We enter this cost estimate into a CGE model of the Washington economy by decreasing the technical coefficient of pesticides in the apple activity by 6.5%. Then we simulate the Washington economy in 2007 with the ban in effect. We estimate that though the apple industry would have had multimillion-dollar decreases in sales and profit, the direct impact of the ban is not large relative to the more than $1.5 billion size of the industry. Because the direct impact is small, we estimate a negligible change to the sales and employment of Washington due to the AZM ban.

We use a CGE modeling method to assess the economic impacts of the AZM ban because we are interested in quantity and price changes and inter-sector spillovers for all industries in the state economy that cannot be achieved with other methods. Though the benefits of this method include modeling discipline and easily satisfied data requirements with actual apple budgets, there are some limitations as well. First, we do not assess the economic impact on any particular apple grower, demographic of grower, or geographic region of the state, only the industry overall. Second, though we allow apple growers to shift production to other crops, we do not estimate the change in acres used in apple or other crops production as VanSickle and NaLampang (2002) do for the phase out of methylbromide. Third, we follow Brunner (2009) in assuming that the new AZM-alternative IPM systems can be thought of as maintaining apple crop volume and quality at increased cost and decreased efficiency. Therefore we do not consider any economic impacts from a reduction in quality or yield beyond those embedded in our cost estimate. Fourth, we choose a middle ground on how we model the AZM ban's effect on other U.S. apple producing states. We do not put a negative shock to the apple industry in other U.S. states besides Washington because of the difficulty in estimating what that shock should be for the representative "other" state. If we were to do this, the impact on Washington would be smaller than we estimated since doing so would increase the price of apples from the rest of the United States (but not the rest of the world) and thereby decrease consumers desire to substitute Washington apples for these other apples. On the other hand, we also do not allow for the AZM ban to cause apple production to increase in other regions, because the ban is nationwide. Fifth, we are not able to estimate the long-term health consequences from workers being exposed to fewer OPs and Washington consumers eating fewer apples. Finally, we estimate the economic impact from the AZM ban for 2007 only and we do not consider costs from transitioning from AZM to AZM-free states. These transition costs may be severe for some individual growers. Therefore the economic impact to the apple industry and the Washington economy will be larger if considered over a period of years.

The upcoming AZM ban is another salvo in the ongoing battle over the extent to which health and environmental regulation negatively impacts industry. Our paper informs academics, government agents, and industry representatives of the economic impact from this particular environmental regulation. We find that the Washington apple industry faces a profit loss that averages $101 per acre. But given the size of this industry and the regional economy, the relative overall industrial and statewide impacts are small. This is consistent with Benson and Shumway (2009) who ex post show that, though some experts predicted the death of the Washington bluegrass seed industry after the implementation of a burn ban, the industry actually grew by two-thirds. In the AZM case, the environmental remedy is not expected to have dramatic negative consequences for regional output, though the growers' fears of higher pesticide prices and an inability to pass costs on to the consumer are justified.

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Appendix 1

Data Sources

Washington Fruit and Apple Data

We use USDA NASS (2009) Agri-Facts for Washington (http://www.nass.usda.gov/ Statistics_by_State/Washington/Publications/Agrifacts/agri1jul.pdf) to calculate the ratio of the value of apple production to the total value of fruit production. We then apply this ratio to the value of production in the Washington fruit industry given by 2007 IMPLAN data (see next subsection). We use USDA NASS (2008) Agricultural Chemical Usage 2007 Field Crops Summary (http://usda.mannlib.cornell.edu/usda/nass/AgriChemUsFruits//2000s/2008/AgriChemUsFruits-05-21-2008.pdf) for apple bearing acres and pesticide and AZM use in Washington.

Input-Output Data

We use a 2007 IMPLAN (IMpact analysis for PLANning) input-output table for the Washington State economy. IMPLAN data files are sold by the Minnesota IMPLAN Group, Inc (MIG). MIG compiles input-output data from a variety of sources, but mainly the U.S. Bureau of Economic Analysis, Bureau of Labor Statistics, Census Bureau, Department of Agriculture and Geological Survey.[12]

Insect Control Costs

The cost estimates of an insect control program with and without AZM are obtained from Brunner (2009) and available at the online appendix at http://faculty.ses.wsu.edu/Cassey/Web page/. Costs include the prices of some new products registered and sold in 2008. The cost of the labor, fuel, and equipment depreciation associated with a one acre- application is thought to be $30 (though we increase this in a robustness check below). Other management costs such as pruning, fertilization, weed and disease control, and harvest are treated in the model as a constant between the benchmark and counterfactual.

Robustness of Results

Because some of our assumptions have a degree of conjecture, we consider two ad hoc changes to the model to determine the extent to which these assumptions affect the results.

Changes to the cost of applying one spray on one acre.

We assume that the cost of the labor, fuel, and depreciation to spray an acre once is $30 for both the benchmark and the counterfactual. This is based on anecdote. Therefore we check the difference in total pesticide cost in the two scenarios when this increases by 10% (to $33), 25% (to $37.50), and 50% (to $45). Note that this cost, whatever its value, is assumed to be the same in both the benchmark and counterfactual. By increasing this labor, fuel, and depreciation cost, the

[12] See http://implan.com/index.php?option=com_content&task=view&id=86&Itemid=57.

percent increase in the total cost of using AZM to AZM alternative decreases from 6.5% to 6.2%, 5.8%, and 5.2%. Because the increase in total cost decreases, the estimates in the main text become even smaller and thus we do not separately report them.

Changes to the production share of labor.

There is currently no consensus about how switching from AZM to non-AZM alternatives will affect labor productivity. It is possible that labor efficiency in the apple industry decreases because of the greater need for monitoring and precisely timed applications of the AZM alternatives. But this is offset by the possibility that workers can return to the orchard much quicker after spraying the AZM alternatives compared to AZM. The main results assumed that these conflicting forces result in no change to labor efficiency.

We experiment by increasing the production function share parameter of labor in the apple activity. This means the apple industry needs to use more labor than before. We find the economic impact estimates for both the apple industry and the overall economy are very sensitive to this parameter. Changing this labor production share parameter by values smaller than 1% results in large consequences. We conclude that any large economic consequences from the AZM ban will be due to the as yet unknown changes to labor in the apple industry and not to the expenditure changes from alternative pesticides.[13]

[13] The details of this experimentation may befound in the online appendix at http://faculty.ses.wsu.edu/Cassey/Webpage/

Appendix 2

Technical Appendix

Free Parameters

GAMS and the PATH solver calibrate our CGE model's parameters except for thirteen free parameters that cannot be calibrated with the SAM. The values we use for the free parameters are commonly used in the literature. In particular, we use the default values provided by Holland et al. (n.d.) without modification. Interested readers may request from the authors the calibrations done in GAMS and the PATH solver.

Table A1. Free Parameters in CGE Model

Parameter	Description	Value	Notes
xed(C,T)	Elasticity of demand for world export function	-5.00	
esubp(A)	Elasticity of substitution for production	0.99	
esubd(C)	Elasticity of substitution (Armington) between regional output and imports	2.00	
esubs(C)	Elasticity of substitution (transformation) regional output and imports	2.00	
esube(C)	Elasticity of substitution (transformation) between RoW and RUS exports	2.00	
esubm(C)	Elasticity of substitution (Armington) between RoW and RUS imports	2.00	
ine(C,H)	Income elasticity	1.00	
income_ine(C)	Investment on commodities elasticity	1.00	
frisch(C)	Consumption flexibility: min subsistence level	-1.00	Zero minimum
ifrisch(C)	Investment demand flexibility: min investment level	-1.00	No minimum
efac(LAB)	Demand elasticity for labor	4.00	
efac(CAP)	Demand elasticity for capital	0.50	

Source: Holland, Stodick, and Devadoss (n.d.)

Equivalent Variation by Household and Welfare

Table A2 displays the household income and welfare impacts due to the AZM ban. There are nine categories of households based on the household's income range and they are: less than 10K, 10-15K, 15-25K, 25-35K, 35-50K, 50-75K, 75-100K, 100-150K, and 150K+. These ranges are denoted in the table by their last number.

Table A2. Average Net Income and Equivalent Variation by Household

	Average Net Household Income			Equivalent Variation
	Benchmark ($)	Counterfactual ($)	Percent Change (%)	(dollars / household)
10K	5397.55	5397.55	-0.000117	-0.001985
15K	4297.40	4297.39	-0.000170	-0.004282
25K	8952.98	8952.95	-0.000349	-0.025789
35K	11486.49	11483.95	-0.000371	-0.034301
50K	31045.46	31045.33	-0.000424	-0.100178
75K	56306.06	56305.77	-0.000520	-0.212274
100K	43073.57	43073.40	-0.000406	-0.094268
150K	37323.44	37323.32	-0.000323	-0.050530

Notes: Net income included taxes, savings, inter-household transfers, and overseas transfers. Households are ordered by their income range and are denoted by the last value in their range.

Selected Equations and Code from the Model

Below we include the equations from the model directly affected by our counterfactual change to the technical coefficient of the pesticide commodity for the apple activity.[14] Note that the model is a system of simultaneous equations and therefore the equations below do not relate to each other sequentially.

For the counterfactual, we decrease the technical coefficient for the pesticide commodity in apple activity. The technical coefficient is the parameter ica(C,A) and is the quantity of commodity C as intermediate input per unit of activity A.

It is defined by $ica(c,A) = QINTO(C, A) \text{ x } QAO(A)$ where QINTO(C,A) is the initial quantity of intermediate use of commodity C by activity A and QAO(A) is the initial activity level. We code

```
ica("PESTMAN-C","APPLE-A")= .935*ica("PESTMAN-C","APPLE-A");
ica("PESTMAN-C","FRUIT-A")= .9945*ica("PESTMAN-C","FRUIT-A");
```

into GAMS.

The technical coefficient enters the model as a term in the production shift parameter of the apple activity. Given QFO(F,A), the initial quantity demanded of factor F by activity A, the indirect business tax rate, tb(A), and the Constant Elasticity of Substitution production function share parameter, δ(F,A), and exponent, ρ(A),

[14] The full GAMS code is available as part of the online appendix, http://faculty.ses.wsu.edu/Cassey/Webpage/Appendix/ Apples_OP/FinalModel.txt.

$$ad(A) = \frac{QAO(A)(1 - tb(A) - \sum_C ica(C,A))}{\left(\sum_F \delta(F,A) * QFO(F,A)^{-\rho(A)}\right)^{-1/\rho(A)}}$$

The technical coefficient is also a term in the intermediate input demand equation for commodity C in the production of activity A, QINT(C, A) = ica(C, A) *
QA(A), where QA(A) is the activity level of A and is calculated by

$$QA(A) = \frac{ad(A)}{1 - tb(A) - \sum_C ica(C,A)} * \left(\sum_F QF(F,A)^{-\rho(A)}\right)^{-1/\rho(A)}$$

Thus, changing the technical coefficient parameter directly impacts the intermediate input demand equation, which in turn changes the quantity supplied to domestic commodity demands (including intermediate producers), thus changing QF(F,A), the quantity demanded of factor F by activity A, and finally changing the quantity of activity A price (of commodity C and θ(A,C) is the yield of output C per unit of activity A.

The activity price is $PA(A) = \sum_C PX(C) * \theta(A,C)$ where *PX(C)* is the producer (supply) price (of commodity *C* and *θ(A,C)* is the yield of output C per unit of activity A. For Table 2, we calculate *Sales(A) = PA(A) * QA(A)*.

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Factors Affecting Producer Awareness of State Programs Promoting Locally Grown Foods: The Case of Fruit and Vegetable Growers in Tennessee

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Abstract

Interest in locally grown foods has increased over the past few years. Tennessee currently has two state-funded programs promoting the consumption of Tennessee agricultural products by linking producers and consumers-Tennessee Farm Fresh and Pick Tennessee Products. Factors associated with fruit and vegetable producer awareness of each of these programs are analyzed using a bivariate probit model. Findings suggest that awareness was associated with education, percentage of income from farming, use of University/Extension publications, attendance at University/Extension education events, and operation location. These results should be of assistance to individuals attempting to increase producer awareness of programs promoting locally grown foods.

Keywords: state-sponsored marketing programs, fruit and vegetable marketing, Tennessee producer awareness, bivarita probit regression.

Introduction

Interest in locally grown foods (LGF) has dramatically increased over the past few years. In 2008, the U.S. market for LGF reached $5 billion (Tropp 2008). Big box retailers and grocery chains increasingly dedicate shelf space to differentiate "locally grown" from "conventional" produce as evidenced by Wal-mart, the top buyer of LGF at $400 million (Gambrell 2008). Interest in Community Supported Agriculture (CSA) programs is also growing (Brown and Miller 2008), and farmers markets are flourishing. Between 2000 and 2006, the number of farmers markets increased by 8.6% per year to 4,093 nationwide (Agricultural Marketing Service -USDA 2011). In Tennessee, the number of farmers participating in direct farm sales to consumers increased by 33% from 1997 to 2007. The number of farmers markets in Tennessee increased by 56% from 2006 to 2009.

There are several reasons for the increased interest in LGF (Onken, Bernard, and Pesek 2011). LGF may provide health and nutrition benefits because they may be fresher and their increased availability may encourage consumers to make healthier food choices (Martinez et al. 2010). LGF may also play a role in ameliorating a community's concerns over food security[1]. LGF provide a way for consumers to support local farmers and local economies (Gregoire and Strohbehn 2002; Peterson, Selfa, and Janke 2010; Starr et al. 2003). The sales retained within a region as consumers substitute LGF for imported products increases local farm revenue and regional income (Swenson 2009). Finally, consumption of LGF may have environmental benefits in reducing food miles to market, thereby moderating the use of fossil fuels in transportation (Anderson 2007; Gomez 2010)[2].

Because of these perceived benefits, federal and state governments have adopted a number of programs to support producers attempting to supply LGF (Martinez et al. 2010; Onken, Bernard, and Pesek 2011). Examples of federal programs include the Fresh Program, the Women and Infant Childcare (WIC) Farmers Market Nutrition Program (FMNP), and the Senior's Farmers Market Nutrition Program (SFMNP). The Fresh Program is a partnership of the U.S. Department of Defense and the U.S. Department of Agriculture (USDA) to promote the consumption of fresh, locally grown foods by schools and other institutions. The FMNP and SFMNP issue coupons to seniors and WIC participants that can be used at authorized farmers markets, roadside stands, and CSAs.

There are also a number of state-level programs designed to promote the consumption of LGF. For example, in Tennessee there are currently two state-funded programs to support and develop markets for Tennessee-grown products. Pick Tennessee Products (PTP) was created by the Tennessee Department of Agriculture in 1986. In 2008, the Tennessee Department of Agriculture - this time in cooperation with the Tennessee Farm Bureau - created Tennessee Farm Fresh (TFF). The purpose of both programs is to link producers with marketing channels for LGF and to in-

[1] Food security has been defined as all people at all times having access to enough food for an active, healthy life (Nord and Andrews 2002).
[2] The extent to which a shift toward LGF would actually engender environmental benefits is uncertain given that distance traveled is an imperfect measure of the environment impact of food transportation (Coley, Howard, and Winter 2009) and that the production of food typically has a larger impact on the environment than its transportation (Weber and Matthews 2008).

form consumers about opportunities to purchase LGF. The PTP program promotes all products available at Tennessee farms, farmers markets, and other retail outlets, while TFF focuses on the promotion of fresh products grown in Tennessee, including fruit and vegetables, nursery, dairy and some livestock products. The two programs offer an array of similar benefits, including: a listing on a web-site directory, the right to use the TFF and PTP logos, and advertising benefits. The two programs are differentiated by the following: the TFF program offers a banner with the TFF logo, TFF stickers, price cards, TFF reusable bags, and free access to workshops offered through the University of Tennessee Center for Profitable Agriculture to their members while the PTP program offers the right to participate in their on-line store but participation in this programs does not guarantee access to marketing tools (e.g., banner, price cards, stickers, workshops) (Howard 2012). Additionally, there are no fees required to participate in the PTP program, but the TFF program charges a $100 annual fee for participation.

A first step in gauging the effectiveness of these programs is to better understand awareness of the programs among those producers who would be most likely to benefit from the services offered by the two programs. Thus, the objectives of this study are to gauge awareness of the programs among Tennessee's fruit and vegetable producers and to identify and evaluate the factors associated with producer awareness. The study's focus is on fruit and vegetable producers because produce growers account for a large portion of direct agricultural sales (USDA 2007; Onken, Bernard, and Pesek 2011), which is one of the main marketing outlets for LGF (Martinez et al. 2010; Low and Vogel 2011). The information provided by this study should be of assistance to governmental agencies and other institutions that are interested in increasing producer awareness of programs or other efforts promoting LGF. Greater awareness of such programs or efforts to expand awareness may help producers increase profit margins through the adoption of new marketing strategies.

Description of Data

This study uses data from a 2011 survey of Tennessee's fruit and vegetable producers. The list frame for the survey was provided by USDA's National Agriculture Statistics Service (NASS) and included the entire population of fruit and vegetable producers in Tennessee. On February 2, 2011, the survey, a cover letter explaining the importance of the survey, and a postage paid return envelope were sent to Tennessee's 1,954 fruit and vegetable producers by first class mail. Approximately three weeks later, reminder postcards were sent. One month later, a second wave of surveys was mailed to those who had not returned the survey. Of the 1,954 questionnaires mailed, 587 were completed and returned, providing a response rate of approximately 30%. After eliminating observations with missing data, 316 responses were suitable for this analysis.

The survey included questions about: marketing outlets used to sell fruits and vegetables; barriers producers faced when participating in different markets; perceptions of the characteristics that define a "local" market; awareness of, and participation in, Tennessee's programs promoting LGF (i.e., TFF and PTP); and general farm business and operator characteristics. Secondary data concerning food marketing and other environmental factors or community characteristics (e.g., metro/non-metro county, number of farmers markets in a county) were collected from the Food Environmental Atlas (USDA, ERS 2011).

Empirical Model

Produce grower awareness of the TFF and PTP programs can be empirically specified as,

$$
(1) \qquad
\begin{aligned}
& y_{i1} = \beta_1^{'} x_{i1} + e_{i1} \\
& y_{i2} = \beta_1^{'} x_{i2} + e_{i2} \\
& Corr(e_{i1}, e_{i2}) = \rho
\end{aligned}
$$

where y_{i1}=1 if a producer is aware of TFF, and zero otherwise; y_{i2}=1 if a producer is aware of PTP, and zero otherwise; $\boldsymbol{\beta}_1$, and $\boldsymbol{\beta}_2$ are parameters associated with each awareness equation; e_{i1}, and e_{i2}, are random disturbances for each equation; and $\mathbf{x}_{i1}$, and $\mathbf{x}_{i2}$ are vectors of observed producer, farm, and county characteristics that may influence the likelihood that a producer is aware of either program. Given the similarities in the two programs, there are unobserved variables that are likely to similarly influence awareness of each of the programs and, thus, the error terms for the two equations are likely to be correlated ($Corr(e_{i1}, e_{i2}) = \rho$). A description of the variables used in this analysis is presented in Table 1 (see Appendix).

Producer characteristics hypothesized to influence awareness of PTP and TFF are: age (AGE); highest level of educational attainment, expressed in dichotomous variables for some high school (SOMEHS), high school graduate (HSGRAD), some college (SOMECOLL), associate's degree (ASSOCDEG), bachelor's degree (BACHDEG), and graduate degree (GRADDEG); the percentage of taxable household income coming from farming, expressed in a dichotomous variable for less than 25 percent (PF_INCOME); the number of University/Extension educational events or presentations related to produce marketing that the grower had attended in the past five years (EDUC_EVENTS); and whether the producer had used University/Extension publications to obtain information about how to better market produce in the last 5 years (PUBLICATIONS).

Age is expected to be negatively correlated with awareness as older producers tend to have shorter planning horizons and may be less likely to search for programs that offer alternatives to current marketing efforts. Education is expected to be positively correlated with awareness as marketing produce directly to consumers requires special skills and abilities, not all of which are likely to be directly related to agricultural operations (Uva 2002; Uematsu and Mishra 2011). Thus, given that direct marketing to consumers is one of the main marketing outlets for LGF (Martinez et al. 2010; Low and Vogel 2011), it is expected that more educated farmers may be more willing to experiment with LGF marketing strategies and more likely to be aware of programs promoting LGF. The percentage of household income from farming is hypothesized to be positively correlated with awareness of the programs, as producers with a high percentage of income from farming are more likely to be willing to invest the time and effort needed to improve their bottom line sales through novel marketing strategies and, therefore, more likely to be aware of programs designed to meet those needs. Attendance at University/Extension outreach events or presentations related to produce marketing strategies is expected to increase producer exposure to, and thus awareness of, the programs. Similarly, the use of University/Extension publications to obtain information about how to better market produce is also expected to increase producer awareness of these programs.

The characteristics of the producer's operation included in the analysis are: size of the producer's fruit and vegetable operation in acres (VEGSIZE); percentage of sales made directly to consumers (TDS), intermediaries (TIN), and retail outlets (TRE); percentage of direct sales to consumers in different geographic areas, expressed in dichotomous variables for in: the producer's county of operation (YOURCNTY); neighboring counties (NEXTCNTY); elsewhere in the state of Tennessee (INSTATE); elsewhere in the U.S. (INUS); and elsewhere in the world (OTHCNTRY).

It is hypothesized that the size of the producer's fruit and vegetable operation will be negatively correlated with awareness of the two programs. Producers managing larger operations may be more inclined to market products through wholesalers, whereas smaller operations might rely more on alternative marketing channels such as farmers markets and CSAs (Lockeretz 1986; Low and Vogue 2011; Watson and Gunderson 2010) where the services provided by the two programs would be of more use.

The percentage of sales made directly to consumers is likely to be positively correlated with producer awareness of the PTP and TFF programs as the services offered by these programs would seem to be more directly applicable to these types of sales. In addition, it could be that the concept of "local" is more important to the consumers who purchase produce directly from producers (Lockeretz 1986). Similarly, farmers who market produce directly to consumers through farmers markets and CSAs may have a greater chance of being exposed to programs promoting LGF as other producers also selling through these outlets may be already participating in programs promoting LGF (Low and Vogel 2011). Producers who market a greater share of their produce through intermediaries (e.g. wholesalers, grower cooperatives) or retailers (e.g. groceries) are less likely to be aware of programs promoting LGF, because the services offered by these programs may be less relevant to these types of sales and because consumers who purchase their produce through these outlets might be more interested in price than other characteristics (Lockeretz 1986). The percentage of a producer's direct sales to consumers in Tennessee is likely to be positively correlated with awareness of the programs promoting LGF given that the goal of these programs is to promote Tennessee-grown products. Therefore it is hypothesized that producers with a larger percentage of sales elsewhere in the U.S. and other countries are less likely to be aware of these programs.

The characteristics of the county in which the producer operates that are included in this analysis are: whether the county is located in east (EASTTENN), middle (MIDTENN), or west (WESTTENN) Tennessee; whether the county is a metropolitan county (METRO); and the number of farmers markets operating in the county (FMRKT10). Geographic location could influence producer awareness in a number of ways. Direct-to-consumer sales drivers are affected by regional characteristics such as proximity to farmers markets and to farmland (Low and Vogel 2011). Therefore, geographic location may explain producer exposure to programs promoting LGF. It is hypothesized that producers located in regions producing more fruit and vegetables and other specialty crops, and closer to farmers markets and farmer-to-grocer's marketing channels are more likely to be aware of programs promoting LGF (Low and Vogel 2011). Thus, it is also expected that the number of farmers markets located in the producer's county will positively influence the likelihood of program awareness. The greater the number of farmers markets in a county the more likely farmers would be to market fresh produce to this outlet.

Given that farmers markets are one of the most popular direct to consumer outlets for LGF it is expected that the greater the number of farmers markets in a county the more likely farmers are to be exposed to programs promoting LGF (Low and Vogel 2011).

Estimation Methods

The awareness equations presented in (1) may be correlated ($Corr(e_{i1}, e_{i2}) = \rho$) as explained above. Therefore, a bivariate probit regression was used to model awareness of TFF and PTP programs. Awareness of programs promoting LGF is hypothesized to be a function of observable exogenous variables.

Marginal effects are computed given the bivariate nature of the model (Greene 2003). The expected value of awareness of one of the programs (say, y_{i1}=1), conditional on the respondent being aware of the alternative program (y_{i2}=1) is defined as,

$$(2) \qquad E(y_{i1} | y_{i2} = 1, \mathbf{x}) = \text{Prob}(y_{i1} = 1 | y_{i2} = 1, \mathbf{x}) = \frac{\text{Prob}(y_{i1} = 1, y_{i2} = 1 | \mathbf{x})}{\text{Prob}(y_{i2} = 1 | \mathbf{x})}$$

$$= \frac{\Phi_2(\mathbf{x}'\boldsymbol{\gamma}_1, \mathbf{x}'\boldsymbol{\gamma}_2, \rho)}{\Phi(\mathbf{x}'\gamma_2)},$$

where $\mathbf{x} = \mathbf{x}_1 \cup \mathbf{x}_2$, $\mathbf{x}'\gamma_m = \mathbf{x}_1'\boldsymbol{\beta}_m$. Therefore γ_1 contains all the nonzero elements of $\boldsymbol{\beta}_1$ and possibly some zeros in the positions of variables in **x** that appear only in equation 2 in (1).

In order to simplify the marginal effects expression lets define $q_{i1} = 2y_{i1} - 1$ and $q_{i2} = 2y_{i2} - 1$. Thus

$$(3) \qquad q_{im} = \begin{cases} 1 & if \quad y_{im} = 1 \\ -1 & if \quad y_{im} = 0 \end{cases} \quad m = 1,2$$

Additionally, let $z_{im} = \mathbf{x}'_{im}\boldsymbol{\beta}_m$, $w_{im} = q_{im} z_{im}$, and $\rho_i^* = q_{i1} q_{i2} \rho$, and

$$(4) \qquad g_{i1} = \phi(w_{i1}) \Phi\left[\frac{w_{i2} - \rho_i^* w_{i1}}{\sqrt{1 - \rho_i^{*2}}}\right],$$

where ϕ represents the univariate standard normal density function and Φ represents the univariate standard normal cumulative distribution function. The subscripts 1 and 2 are reversed in (4) to obtain g_{i2}.

The derivative of (2) was taken with respect to the explanatory variables of interest to estimate the conditional marginal effects

$$(5) \qquad \frac{\partial E(y_{i1} | y_{i2} = 1, \mathbf{x})}{\partial \mathbf{x}} = \left(\frac{1}{\Phi(\mathbf{x}'\gamma_2)}\right)\left[g_1\gamma_1 + (g_2 - \Phi_2 \frac{\phi(\mathbf{x}'\gamma_2)}{\Phi(\mathbf{x}'\gamma_2)})\gamma_2\right],$$

where g_1 and g_2 are defined in (4).

Multicollinearity Tests

Multicollinearity may compromise inferences by inflating variance estimates (Greene 2003; Judge et al. 1988). A condition index was used to detect collinear relationships (Belsley, Kuh, and Welsch 1980). Condition indexes between 30 and 100 indicate that the explanatory variables have moderate to strong association with each other. A condition index accompanied by a proportion of variation above 0.5 indicates potential collinearity problems (Belsley, Kuh, and Welsch 1980).

Results and Discussion

Sample Overview and Descriptive Statistics

The average age of respondents included in this analysis (n=316) was 61 years, close to the average farmer age in Tennessee (58 years) according to the 2007 Census of Agriculture (USDA/NASS). For about 26% of the respondents the highest level of educational attainment was a bachelor's degree, followed by 22% who earned a graduate degree and 22% who graduated from high school but did not attend college. About 69% of respondents earned less than 25% of their household income from farming. Respondents had attended an average of 1.2 University/Extension educational events or presentations related to marketing strategies over the past five years. About 30% of the respondents had used University/Extension publications to obtain information about improving their produce marketing within the past five years.

The average size of the fruit and vegetable operations was 10.8 acres. The majority (about 84%) of sales made by the respondents were direct sales to consumers. Most (about 69% on average) of the direct sales made by the respondents in 2010 took place in their home county. The average percentage of direct sales made in neighboring counties and elsewhere in the state were 24% and 5%, respectively. About 42% of the respondents were located in Middle Tennessee, 40% in East Tennessee, and the reminder in West Tennessee. About 47% of the respondents lived in metropolitan counties.

About 42% of the respondents included in this analysis were aware of the TFF program and 54% were aware of the PTP program. Greater awareness of the PTP program is probably not too surprising given that it has been in existence for about 22 years longer than the TFF program. Comparisons of the mean values for producer, producer operation and county characteristics, on the basis of awareness of the TFF and PTP programs, are presented in Table 2 (See Appendix). Differences in mean values between those who were aware and those who were not aware of each program were compared using t-tests. Significant differences for the variables associated with producer characteristics were evaluated. The proportion of producers with 25% or less of their household income from farming who were unaware of the TFF and PTP programs was larger (80% and 83%, respectively) than the proportion of producers with 25% or less of their income from farming who were aware of these programs (55% and 58%, respectively). As expected, producers with a higher percentage of income from farming are more likely to be aware of programs design to increase sales through alternative marketing strategies, given that they have a higher dependence on the economic viability of the farming operation. On average, respondents who were aware of TFF and PTP had attended more University/Extension educational events or presentations related to produce marketing over the last five years (2.1 and 1.9 events, respectively) compared to respondents who were not aware of the programs (0.5 and 0.3, respectively); as hypothesized, producers who attend these educational events may be more interested in alternative produce marketing strategies and more likely to be exposed to information about programs promoting LGF. Finally, about 48% of the respondents aware of TFF and 42% of those aware of PTP have used University/Extension publications to obtain information about how to better market their produce within the last five years, which is significantly higher than the 17% and 15% of producers not aware of TFF and PTP, respectively who used University/Extension publications for this purpose. University/Extension publications related to produce marketing strategies may include information about programs promoting LGF and therefore producers using these publications are more likely to be aware of TFF and PTP.

Significant differences for the variables associated with characteristics of the producer's operation were also considered. The average size of the fruit and vegetable operations was larger for respondents aware of TFF and those aware of PTP (17.1 and 14.3 acres, respectively) than those who were unaware of the programs (6.6 and 7.0 acres, respectively). Contrary to the hypothesis that local food marketing is more likely to occur on smaller operations (Martinez et al. 2010), for this sample, it seems that larger operations are more likely to be aware of programs promoting LGF in Tennessee. The average percentage of fruit and vegetable sales made in the county in which a producer's operation was located was significantly higher for producers unaware of TFF and PTP (75% and 78%, respectively) compared to producers who were aware of the two programs (60% for both). However, the average percentage of sales made in neighboring counties and elsewhere in the State was significantly higher for producers who were aware of TFF and PTP (29% and 30%, respectively for sales in neighboring counties, and 8% and 7%, respectively for sales elsewhere in the State) than for those who were unaware of the programs (20% and 17%, respectively for sales in neighboring counties and 3% for sales elsewhere in the State). As expected, producers with relatively more sales in Tennessee are more likely to be aware of programs promoting LGF given that the goal of these programs is to promote products grown in Tennessee. Nonetheless, respondents selling a higher percentage of their produce within their county of operation were less likely to be aware of TFF and PTP.

Finally, significant differences associated with the characteristics of the county in which the grower operates were identified. About 54% of the producers who were aware of TFF live in metropolitan counties while only 42% of the producers not aware of the program live in metropolitan counties. This result is explained by the fact that marketing of LGF is more likely to take place in metropolitan counties (Martinez et al. 2010).

Bivariate Probit Marginal Effects

The marginal effects of the bivariate probit model used to examine the factors affecting awareness of the TFF and PTP programs are presented in Table 3. The correlation coefficient between the residuals (ρ) was positive and statistically significant at the 1% level, supporting the hypothesis that the error terms in the TFF and PTP awareness equations were correlated, and also suggesting that the bivariate probit approach appears appropriate.

Table 3. Conditional marginal effects from the Bivariate Probit Model for estimating factors affecting awareness of Tennessee Farm Fresh and Pick Tennessee Products.

	Marginal Effects of the Bivariate Probit Model	
	Prediction Conditions	
Independent Variables	AWARE_TFF=1 given AWARE_PTP=1	AWARE_PTP=1 given AWARE_TFF=1
AGE	0.0037 (0.0032)	-0.0044** (0.0018)
SOMEHS	0.2710*** (0.0858)	-0.3469** (0.1609)
HSGRAD	0.1280 (0.0925)	-0.0636 (0.0620)
SOMECOLL	0.0934 (0.1066)	-0.0505 (0.0713)
ASSOCDEG	-0.0812 (0.1514)	-0.0698 (0.0967)
GRADDEG	0.0396 (0.0999)	-0.0130 (0.0528)
PF_INCOME	-0.0452 (0.0834)	-0.0704* (0.0377)
EDUC_EVENTS	0.0172 (0.0219)	0.0246* (0.0130)
PUBLICATIONS	0.1920** (0.0742)	0.0059 (0.0407)
NEXTCNTY	0.0001 (0.0011)	0.0009 (0.0006)
INSTATE	0.0032 (0.0023)	0.0003 (0.0011)
INUS	0.0028 (0.0043)	-0.0024 (0.0020)
OTHCNTRY	-0.0039 (0.0072)	0.0043 (0.0042)
VEGSIZE	0.0062** (0.0031)	-0.0014 (0.0012)
TDS	0.0036* (0.0020)	-0.0006 (0.0009)
TIN	0.0003 (0.0024)	0.0011 (0.0011)
EASTTENN	-0.0322 (0.0776)	-0.0006 (0.0385)
WESTTENN	-0.0196 (0.1025)	-0.0273 (0.0551)
FMRKT10	-0.0126 (0.0323)	-0.0091 (0.0161)
METRO	0.1763** (0.0708)	-0.0417 (0.0361)

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Table 3 presents the conditional marginal effects for PTP and TFF, as described in (5). Five of the explanatory variables had statistically significant marginal effects on awareness of the TFF program, given that the producer was aware of the PTP program. These five variables were whether the producer had some high school education (SOMEHS), whether the producer had used University/Extension publications to obtain information about marketing produce within the past five years (PUBLICATIONS), the size of the producer's fruit and vegetable operation in acres (VEGSIZE), the percentage of the producer's total sales made directly to consumers (TDS), and whether the producer's operation was located in a metropolitan county (METRO). Although these marginal effects were statistically significant some of them were very small in magnitude (i.e., VEGSIZE, TDS). The results suggest that producers located in a metropolitan county are 18% more likely to be aware of the TFF program, and producers who used University/Extension publication are 20% more likely to be aware of TFF, given that they are already aware of the PTP program. The marginal effect associated with the education variable (SOMEHS) has a positive sign. This result suggests that producers with some high school education tended to be more likely to be aware of TFF than producers with bachelor degrees. This result runs counter the hypothesis that more educated farmers are more likely to be aware of programs promoting LGF. A possible explanation for this result is that more educated farmers may be more likely to be employed part time off the farm and therefore may have less time to look for alternative marketing opportunities such as LGF. Statistically significant conditional marginal effects for the PTP awareness equation were those associated with age (AGE), education (SOMEHS), percentage of total household income from farming activities (PF_INCOME), and the number of University/Extension educational events or presentations related to produce marketing strategies attended within the past five years (EDUC_EVENTS). Again, some of the statistically significant marginal effects were very small in magnitude (i.e., AGE). The results suggest that, given awareness of the TFF program, producers with some high school education are 35% less likely to be aware of PTP than producers with bachelor degrees, while producers with less than 25% of their income coming from farming are 7% less likely to be aware of the PTP program and, finally, attending an additional educational event increases the likelihood of being aware of PTP by 2.5%.

In summary, producers who are already aware of the PTP program and who have used University/Extension publications to obtain information about how to better market produce in the last 5 years, operate larger fruit and vegetable operations, derive a higher percentage of their sales from direct-to-consumer outlets, and are located in metropolitan counties are more likely to be aware of the TFF program. On the other hand, younger, more educated producers, with more than 25% of their household income from farming, who have attended more University/Extension educational events or presentations related to marketing strategies to sell produce in the past five years are more likely to be aware of the PTP program, given awareness of the TFF program.

Conclusions

The marketing of LGF continues to grow in popularity. The goal of this study is to evaluate fruit and vegetable producer awareness of the two Tennessee programs designed to enhance LGF marketing opportunities – TFF and PTP. A bivariate probit regression was used to measure the association between the characteristics of the producer, the producer's operation, and the county in which the producer's operation is located and producer awareness of these programs.

The factors affecting awareness of TFF and PTP programs differed between the two programs. Use of University/Extension publications, size of the fruit and vegetable operation, percentage of sales from direct-to-consumers outlets, and location in a metropolitan county all significantly affected awareness of the TFF program. On the other hand, attendance at University/Extension education events, age, education, and percentage of income from farming were factors significantly affecting producer awareness of the PTP program. Policymakers such as the Tennessee Department of Agriculture and organizations that operate similar programs in other states, as well as University/Extension personnel may benefit from this information to better market these programs. This information may also help policy makers adjust limited funds to better promote these programs by better targeting their clientele and increasing awareness of the programs across the state.

Attendance at University/Extension educational events or presentations related to produce marketing and the use of University/Extension publications to obtain information about how to better market their produce were significant factors affecting awareness of both the PTP and TFF programs. These results suggest that the partnership between policy makers and Extension may increase effectiveness in spreading the word about state programs promoting LGF. Therefore, it may be important for policymakers to continue working with Extension to increase producer awareness of state programs promoting LGF. Nonetheless, producers who are unaware of the TFF and PTP programs may not be attending University/Extension educational events or presentations related to marketing strategies to sell produce and/or using University/Extension publications. Therefore, reaching these producers will require alternative strategies.

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Appendix

Table 1. Definitions and Descriptive Statistics of Variables (n=316).

Variable	Description	Mean
A. Dependent Variables		
AWARE_TFF	=1 if farmer is aware of Tennessee Farm Fresh, zero otherwise	0.4114
AWARE_PTP	=1 if farmer is aware of Pick Tennessee Products, zero otherwise	0.5380
B. Independent Variables		
AGE	Age of producer in years	60.7089
SOMEHS	=1 if some high school is the highest level of education attained by the farmer, zero otherwise	0.0633
HSGRAD	=1 if high school diploma is the highest level of education attained by the farmer, zero otherwise	0.2152
SOMECOLL	=1 if some college is the highest level of education attained by the farmer, zero otherwise	0.1519
ASSOCDEG	=1 if an associate's degree is the highest level of education attained by the farmer, zero otherwise	0.0949
BACHDEG	=1 if a bachelor's degree is the highest level of education attained by the farmer, zero otherwise	0.2595
GRADDEG	=1 if a graduate degree is the highest level of education attained by the farmer, zero otherwise	0.2152
PF_INCOME	=1 if less than 25% of farmer household income comes from farming	0.6962
EDUC_EVENTS	The number of educational events the farmer has attended in the past 5 years	1.1416
PUBLICATIONS	=1 if the farmer has used University/Extension publications in the past 5 years	0.2975
YOURCNTY	Percent of direct sales to consumers in the county where the farmer operates	68.5158
NEXTCNTY	Percent of direct sales to consumers in neighboring counties of where the farmer operates	23.8070
INSTATE	Percent of direct sales to consumers elsewhere in the state	5.3212
INUS	Percent of direct sales to consumers elsewhere in the country	1.7547
OTHCNTRY	Percent of direct sales to consumers in other countries	0.6013
VEGSIZE	Size of fruit and vegetable operation in acres	10.8920
TDS	Percent of direct sales obtained from direct to consumer outlets	84.4842
TIN	Percent of direct sales obtained from direct to intermediary outlets	7.9114
TRE	Percent of direct sales obtained from direct to retail outlets	7.6044
EASTTENN	=1 if the farmer is located in East Tennessee, zero otherwise	0.3956
MIDTENN	=1 if the farmer is located in Middle Tennessee, zero otherwise	0.4241
WESTTENN	=1 if the farmer is located in West Tennessee, zero otherwise	0.1804
FMRKT10	The number of farmers markets in the county where the farmer operates	1.0475
METRO	=1 if farmer is located in a metropolitan county, zero otherwise	0.4684

Table 2. Variable means for respondents aware of the Tennessee Farm Fresh and Pick Tennessee Products programs and those not aware of the programs.

	Tennessee Farm Fresh		Pick Tennessee Products	
Independent Variables [a]	Not Aware (n=186)	Aware (n=130)	Not Aware (n=146)	Aware (n=170)
AGE	61.6129	59.4154	63.5069***	58.3059
SOMEHS	0.0591	0.0692	0.0822	0.0471
HSGRAD	0.1989	0.2385	0.2192	0.2118
SOMECOLL	0.1613	0.1385	0.1644	0.1412
ASSOCDEG	0.1183*	0.0615	0.1164	0.0765
BACHDEG	0.2473	0.2769	0.2055**	0.3059
GRADDEG	0.2151	0.2154	0.2123	0.2176
PF_INCOME	0.7957***	0.5538	0.8288***	0.5824
EDUC_EVENTS	0.4839***	2.0827	0.2877***	1.8750
PUBLICATIONS	0.1720***	0.4769	0.1507***	0.4235
YOURCNTY	74.5699***	59.8539	78.4041***	60.0235
NEXTCNTY	20.1613**	29.0231	16.5411***	30.0471
INSTATE	3.2957**	8.2192	3.1370**	7.1971
INUS	1.3817	2.2885	1.8151	1.7029
OTHCNTRY	0.5914	0.6154	0.1027	1.0294
VEGSIZE	6.5880***	17.0500	6.9802**	14.2515
TDS	84.3172	84.7231	86.9726	82.3471
TIN	7.7527	8.1385	5.6233*	9.8765
TRE	7.9301	7.1385	7.4041	7.7765
EASTTENN	0.4032	0.3846	0.4178	0.3765
MIDTENN	0.3925	0.4692	0.3699**	0.4706
WESTTENN	0.2043	0.1462	0.2123	0.1529
FMRKT10	1.0645	1.0231	1.1370	0.9706
METRO	0.4194**	0.5385	0.4452	0.4882

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively based on t-tests.
[a] For variable definitions see Table 1.

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Estimating the Optimal Premium Rates for Credential Food Attributes: A Case Study in the Northeast United States

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Abstract

Using data from the *2010 Taste of Place* survey conducted in Vermont and three metropolitan areas in the northeast United States, this study examines consumer willingness to pay (WTP), estimates price elasticity, and calculates the optimal premium rates for selected credence food attributes. The empirical results indicate that respondents' WTP varies significantly across attributes and is closely associated with certain demographic factors. The estimated optimal premium rates and estimation procedures presented in this paper can help producers and retailers identify the optimal premium rates for each attribute in association with geographical or socioeconomic segments of consumers.

Keywords: consumers, willingness-to-pay (WTP), organic, local, made in Vermont

Introduction

Although consumers traditionally judge the quality and value of food products by their physical attributes such as freshness, color, nutrient contents, and taste, recent studies have reported that consumers are paying more attention to social and environmental attributes including environmental impacts of production methods, fairness of trade, and impacts on local farms and communities (Moon et al. 2002; Auger et al. 2003). Such social and environmental attributes are generally referred to as credence attributes – the product features that consumers cannot evaluate or verify before, during or even after consumption (Caswell and Mojduszka 1996). For farmers and retailers, appropriate marketing and pricing policies should consider consumers' valuation and willingness to pay (WTP) for both physical and credence attributes (Marn 2003). Using data collected through a consumer survey in Vermont and three metropolitan areas in the northeast United States, this paper estimates the demand elasticities and optimal premium rates for selected food attributes, with a focus on the "made in Vermont" attribute, and examines the impacts of demographic factors.

Because most of the environmental and social attributes of food products are credence attributes, various labeling systems and regulations have been established to provide verifiability and credibility for these attributes (Golan et al. 2000). Some of the well-known labels include certified organic, rBST-free, and GMO-free. These labels refer either to a specific feature of production like GMO-free or to a "compound attribute" that indicates several basic attributes. For example, "organic" foods are produced without synthetic inputs and, at the same time, are GMO-free.

The increase in labeling options has posed both opportunities and challenges for food producers and retailers. First, producers and retailers need to make judicious choices among overlapping and sometimes competing labels. Because the amount of information that consumers can absorb from food labels is limited, producers and retailers must choose the most important information and avoid providing unclear or unnecessary information (Mueller 1991; Einsiedel 2000). Also, the benefits of a labeling system have to be weighed against its costs (Golan et al. 2000). Second, since a new label generally targets on a new or specific segment of the market (Wedel 2000; Boone and Kurtz 2011), food products with certain labels, such as certified organic, require supporting marketing strategies to realize the potential benefits of the labels. Finally, for food producers who want to sell their products at optimal prices that maximize their profits or total sales, they need to understand consumers' response to price changes and WTP for both physical and credence food attributes.

This study is motivated by the growing needs for information on consumers' WTP for credence food attributes and the lack of such information in the literature. Specifically, this paper calculates the price elasticity of demand for several food attributes, estimates the revenue-maximizing price premiums for these attributes on the basis of the estimated demand elasticities, and highlights the revenue-maximizing price premium for the attribute "made in Vermont" in different market segments. Data used in this study are from the Taste of Place (TOP) survey developed by the Vermont Agency of Agriculture, Food and Markets and the Center for Rural Studies at the University of Vermont in 2010. The survey was designed to collect empirical evidence for helping Vermont's state legislature promulgate labeling rules and develop certification strategies.

Literature Review

The price premium of a product is closely associated with consumers' WTP for its specific attributes. As summarized by Breidert et al. (2006) and Lee (2001), various methods have been developed to measure the WTP. These methods include laboratory and field experiments, direct customer surveys, discrete choice analysis, conjoint analysis, etc. Direct customer survey, the simplest method, is used in this study. Although this method has been criticized for the hypothetical nature of the questions (Mitchell and Carson 1989; Cummings 1995), a study by Loureiro et al. (2003) showed that a consumer who stated that he or she would pay a premium for a product was more likely to actually purchase the product. The main reason for choosing this method for this study is that it allows us to ask about multiple food attributes in the same survey.

Recently, measuring consumers' WTP for social and environmental food attributes such as organic has been an active research area. For example, Moon et al. (2002) conducted a direct consumer survey in the former West and East Berlin and reported that the residents of the two districts had significantly different WTP for environmentally friendly production methods. Batte et al. (2004) used a choice experiment survey in seven central Ohio grocery stores to measure consumer WTP for alternative levels of organic content in breakfast cereals. Bernard et al. (2006) conducted a lab experiment and found that, when the GMO-free attribute is nested in the organic attribute, the incremental WTP for the latter is insignificant.

The WTP for locally produced food has also received considerable attention in recent years. For example, Giraud et al. (2005) used discrete choice analysis to measure WTP for locally grown specialty food products in Maine, New Hampshire, and Vermont. They found that consumers in the three states were willing to pay a small premium for locally made specialty foods and that the premium was not significantly different across the three states. Carpio et al. (2009) evaluated South Carolina (SC) consumers' WTP for "SC grown" products. Their results indicated that consumers in South Carolina were willing to pay an average premium of 27% for local produce and 23% for local animal products. Loureiro et al. (2001) used a direct survey to assess consumer WTP for local, organic, and GMO-free potatoes in Colorado. They found that the WTP for "locally produced" was higher than that for the other two attributes. Burchardi et al. (2005) investigated consumers' WTP and the underlying preferences for locally produced milk and concluded that there was a demand for local milk but the demand was price elastic. Their conclusion was based on aggregated demand without explicit calculation of any demand elasticity.

Another area of WTP studies is rBST-free milk and GMO-free food, both characteristics of organic food. Wang et al. (1997) evaluated consumer WTP for rBST- free milk using data collected from a consumer survey in Vermont. They found that a majority of consumers were willing to pay a premium for rBST-free milk and that the WTP was affected by consumers' sociodemographic factors as well as by consumer attitudes toward the use of rBST. Using a hedonic model, Kolodinsky (2008) studied the effect of attitude on consumers' valuation of rBST-free and organic attributes and found that the effect was significant in 2001 but insignificant in 2004, suggesting that the negative effects of rBST likely decreased over the study period. Onyango et al. (2006) conducted a choice experiment to analyze U.S. consumers' valuation of cornflakes. They found that, compared to products with no labels, consumers would pay 6.5%

less for products labeled "genetically modified corn" and 10% more for those labeled "contains no genetically modified corn."

Although many researchers have studied consumer WTP for food attributes, few studies have used the WTP to forecast market response to price changes or to develop optimal pricing strategies (Hanna and Dodge 1995; Nagle and Holden 2002; Monroe 2003). This study focuses on a less studied but practically important aspect of the WTP research–estimating the demand elasticities and optimal premium rates for selected credence food attributes based on survey data.

Methods

This section describes the survey instrument, introduces the methods for calculating the price elasticity of demand and revenue-maximizing premium prices, and discusses some limitations of the data and approaches used to address the limitations.

The TOP Survey

Data used in this study are from the TOP survey developed by the Vermont Agency of Agriculture, Food and Markets and the Center for Rural Studies at the University of Vermont. The survey was designed to collect empirical information about the demand for a geographical indication (GI) labeling system for Vermont food products and to provide such information to the Vermont legislature. It covered the state of Vermont and three metropolitan regions in the northeast United States: Philadelphia, New York, and Boston. The three metropolitan regions were chosen because residents there had the highest level of visitation to the state of Vermont (Vermont Department of Tourism 2007). With a contact list obtained from the infoUSA Inc., 10,000 household addresses were randomly selected with 2,500 in each region. The primary food shopper in each selected household was asked to answer the survey, either by mail or online. While the survey was mailed to 10,000 households in November 2010, 706 responses were received by December 15, 2010, with 452 from Vermont and 254 from New York, Boston, and Philadelphia metropolitan areas. With 2,225 valid addresses in Vermont and 6,660 valid addresses in the metropolitan areas, the response rate was 20.3% for Vermont, 3.8% for the three metropolitan areas, and 7.9% for the whole survey. The demographic information of the respondents is summarized in Table 1. More information about the survey and descriptive statistics can be found in the preliminary market study report by the Center for Rural Studies at the University of Vermont (2011).

The survey started by soliciting general opinions on labeling local products and then proceeded to ask about preferences and shopping history for specific Vermont food products. These were followed by questions regarding respondents' WTP and preferences for products with different attributes. The question about WTP was posed thusly: "How much more are you willing to pay for a food product that is (a food attribute) comparing to generic food with none of these attributes?" Fifteen different food attributes, listed in Table 2, were included in the survey. Respondents had 11 choices ranging from "Not a penny more" to "Twice as much," with 10 percent spacing. Although the attributes were selected primarily to explore the labeling options for Vermont food products, the results could also be relevant to producers and policy makers outside Vermont as credence attributes become more popular around the country. The rest of this survey covered respondents' association with Vermont and their demographic information, ending with room for additional comments.

Table 1. Demographic information from the TOP survey

		Percent	
		Vermont	**Metro areas**
Gender	Male	62.2	65.0
	Female	37.8	35.0
		(n=437)	(n=243)
Age	18 to 34	2.1	17.6
	35 to 64	44.7	57.1
	65 and greater	53.2	25.2
		(n=426)	(n=233)
Income	Under $50,000	39.0	19.6
	$50,000 to under$100,000	33.8	38.5
	$100,000 to under $125,000	14.9	32.8
	Prefer not to say	12.3	19.1
		(n=423)	(n=235)
Education	Below college	45.2	27.6
	4-year college degree	22.4	35.1
	Graduate or professional degree	32.4	37.2
		(n=438)	(n=242)

Estimation Elasticity and Optimal Price Levels

The WTP data from the survey assume discrete values proportional to the baseline price p_0 ($p_1 = 1.1p_0$, $p_2 = 1.2p_0$, ……, $p_{10} = 2p_0$). At each price level, the total quantity demanded for food products with this attribute can be expressed as the following:

$$(1) \qquad Q_i = \sum_j^{N_i} q_{ij} = N_i \overline{q}_i$$

The total quantity demanded at the i^{th} price level, denoted as Q_i, equals to the summation of individual demand (q_{ij}) from N_i consumers, where j is the index for each consumer. Q_i also equals to the number of consumers (Q_i) still buying at the i^{th} price level times the average quantity ($\overline{q}_i$) they purchase. As a limitation of the survey, respondents were not asked about the quantity of their purchase and the WTP questions were for food in general. As a result q_{ij} and $\overline{q}_i$ are not available in the data set. This study makes a further assumption that consumers' average purchase quantities $\overline{q}_i$ at different price levels are the same. Thus equation (1) can be simplified as:

$$(2) \qquad Q_i = N_i q$$

This assumption could be a potential limitation of the analysis but it seems reasonable for the purpose of the study with a focus on general food rather than any specific product. With N_i from the data, the quantity demanded Q_i can be determined up to an unknown constant q, yielding 10 discrete points on a demand function.

Using the definition of arc price elasticity of demand $E^d(p)$ and plugging in (2) results in the following equation:

$$(3) \quad E^d(p_{i,i+1}) = \frac{Q_{i+1} - Q_i}{p_{i+1} - p_i} \cdot \frac{p_{i+1} + p_i}{Q_{i+1} + Q_i} = \frac{N_{i+1} - N_i}{p_{i+1} - p_i} \cdot \frac{p_{i+1} + p_i}{N_{i+1} + N_i}$$

$$where\ i = 1,2, \ldots \ldots, 10 \quad and\ \ p_{i,i+1} = (p_i + p_{i+1})/2$$

By the aforementioned assumption that consumers' average purchase quantities at all price levels are the same, q can be canceled out. At each price level p_i, N_i can be found from the survey data, and the price elasticity of demand can then be calculated.

Furthermore, the revenue-maximizing price level can be found at the point where the price elasticity of demand $E^d(p) = -1$, meaning that a one percent increase in price would lead to a one percent decrease in demand (Nicholson, 2002). Because we have only discrete $E^d(p)$ values (from equation [3]), an interpolation between the two elasticity values just below and above –1 is performed to estimate the optimal price level ($\hat{p}$) for total revenue maximization.

Because there are no negative WTP options in the survey, all respondents with negative WTP for the attribute (non-buyers at the baseline price) would reply zero WTP and therefore be counted as consumers at the baseline price p_0, causing N_0 to be overestimated. As a result, the first valid elasticity value that we can calculate is at $1.15p_0$ (see equation [3]), and price premiums can be estimated in this study only if they are above $1.15p_0$.

Results

This section first summarizes the major results for all the 15 attributes and then presents a more detailed analysis of the attribute "made in Vermont".

Overall Results for the 15 Attributes

Overall, consumers in the sample show considerable WTP for the food attributes included in the study: the mean WTP ranges from 28.8% to 48.1% above the baseline price for the 15 attributes (Table 2). Although some social and environmental attributes are highly valued by consumers, it is interesting that the compound attribute "certified organic" food, which by its production standards includes the features "environmentally friendly" and "made from traditional methods," received lower WTP than both of the two basic attributes. The same is true for the attribute "imported from a country known for high-quality food," which also received lower WTP than the basic attributes it is intended to represent, such as "has unique flavor that reflects the region where it was made." These results indicate that, although producers intend to use these compound attributes to represent certain basic attributes, consumers may not make the necessary association with the basic attributes without being reminded.

Using the information about WTP, elasticity of demand is calculated at each price level (Table 2). Because the elasticity values at price levels higher than $1.35p_0$ are significantly below –1, they are irrelevant for the purpose of revenue maximization and are therefore not presented in this paper. The price premium of each attribute is within the price range in which elasticity drops below –1 (boldface numbers in Table 2). For example, the price premium for the first attribute "Made on a farm where the farmer and workers make a fair wage" is between $1.15p_0$ and $1.25p_0$.

Table 2. Mean WTP, elasticity of demand, and revenue-maximizing premium price for 15 food attributes, ranked according to the mean WTP

Attribute	**Mean WTP (N)**	$\mathbf{E^D(1.15p_0)}$	$\mathbf{E^D(1.25p_0)}$	$\mathbf{E^D(1.35p_0)}$	**Optimal premium price** $\hat{p}$
Made on a farm where the farmer and workers make a fair wage	48.1% (653)	**–0.814**	**–1.534**	–1.634	$1.176p_0$
Made using environmentally friendly methods	47.9% (653)	**–0.926**	**–1.784**	–1.756	$1.159p_0$
Grown on a family farm	47.7% (655)	**–0.671**	**–1.449**	–1.861	$1.192p_0$
Helping to preserve open farmland	45.7% (625)	**–0.644**	**–1.555**	–2.155	$1.189p_0$
Available at only a certain time of year	45.2% (635)	**–0.560**	**–1.756**	–1.808	$1.187p_0$
Made by a cooperative group of farmers	44.5% (547)	**–0.933**	**–1.734**	–2.242	$1.158p_0$
Has unique flavor that reflects the region where it was made	44.5% (630)	**–0.831**	**–1.351**	–2.460	$1.183p_0$
Produced locally	43.8% (641)	**–0.697**	**–1.280**	–2.330	$1.202p_0$
Made in Vermont	42.6% (655)	**–0.864**	**–1.786**	–2.181	$1.165p_0$
Made using traditional production method	37.1% (610)	–1.226	–2.543	–2.046	
New product that I'm curious about trying	36.2% (627)	–1.242	–2.726	–3.265	
Consistent in flavor from one batch to the next	35.9% (612)	–1.156	–2.441	–2.639	
Certified organic	34.0% (639)	–1.168	–2.635	–3.067	
Imported from a country known for high-quality food	28.9% (613)	–1.511	–2.885	–3.179	
A brand thing that I know	28.8% (629)	–1.208	–3.190	–4.082	

Note: Boldfaced elasticity values are the elasticity values used to estimate the optimal premium price through an interpolation method.

Besides the range estimate, the exact price premium $\hat{p}$, calculated from interpolation between the two ends of the range, is displayed in the last column of Table 2. Based on the elasticity calculation, nine food attributes have premium prices above $1.15p_0$, all of which fall between $1.15p_0$ and $1.25p_0$ (Table 2). As explained in the method section, those attributes showing no positive premium may actually have premiums below $1.15p_0$, which cannot be measured in this study due to the data limitation.

Market Segmentation for "Made in Vermont"

In the overall estimation presented in section 4.1 the GI attribute "made in Vermont" receives an average WTP of 42.6%, ranking ninth among the 15 attributes, though the differences are small. On the basis of the elasticity calculation, "made in Vermont" should command a premium price of $1.165p_0$. If we look deeper into different consumer segments, however, it can be shown that "made in Vermont" commands an even higher price premium in particular consumer groups.

First, it is expected that "made in Vermont" should command higher premium among consumers who are more closely associated with Vermont (i.e. Vermont residents or people who visit Vermont frequently), because, on average, they have clearer knowledge about the desirable attributes of Vermont food products (for example many Vermont food products are from family farms). Also, social considerations such as supporting the local economy would also affect these people's purchasing decisions regarding Vermont products. Data from this survey supported the above hypothesis: people living in Vermont have significantly higher WTP than people living outside the state. For those who live outside Vermont, frequent and occasional visitors of Vermont have higher WTP than those who rarely or never visit. In the subsample of current Vermont residents, the premium price ($1.189p_0$, from Table 3) is higher than the overall result ($1.165p_0$). Although the elasticity calculation did not show any price premium for non-Vermonters on either of the two visitation levels, the elasticity values are lower in absolute value (compared to the overall results in Table 2), at $1.15p_0$ and $1.25p_0$ for frequent and occasional visitors, meaning that when raising the price by certain percentage, producers would lose smaller percentage of consumers who are occasional visitor and larger percentage of consumers who are non-visitors.

Table 3. Mean WTP, elasticity of demand $E^D(p)$, and revenue-maximizing premium price for the "made in Vermont" attribute among consumer groups with 3 levels of association with Vermont

Association with Vermont	Mean WTP (N)	$E^D(1.15p_0)$	$E^D(1.25p_0)$	$E^D(1.35p_0)$	Optimal premium price $\hat{p}$
Vermont Residents	46.6% (441)	**–0.641**	**–1.560**	–2.026	$1.189p_0$
Frequent and occasional visitors	35.3% (109)	–1.144	–1.875	–2.600	
Rarely or never visit Vermont	18.1% (113)	–1.420	–2.941	–2.455	

Note: Boldfaced elasticity values are the elasticity values used to estimate the optimal premium price through an interpolation method.

Second, higher WTP for Vermont products is expected to be found among specialty-store shoppers. Usually when people visit specialty stores, they are looking for high-quality products and so expect higher prices. The data show that, among specialty- store shoppers, “made in Vermont” commands a premium price of $1.211p_0$ (Table 4).

Table 4. Mean WTP, elasticity of demand $E^D(p)$, and revenue-maximizing premium price for the “made in Vermont” attribute among specialty-store shoppers and non–specialty store shoppers

Ever purchased VT product in specialty store or not	Mean WTP (N)	$E^D(1.15p_0)$	$E^D(1.25p_0)$	$E^D(1.35p_0)$	Optimal premium price $\hat{p}$
Yes	48.3% (306)	**–0.665**	**–1.548**	–2.216	$1.211p_0$
No	37.6% (349)	–1.498	–2.602	–2.054	

Note: Boldfaced elasticity values are the elasticity values used to estimate the optimal premium price through an interpolation method.

Third, Vermont food products should command higher premium among farmers’ market shoppers because the “localness” of Vermont food products is consistent with the spirit of farmers’ markets. The results in Table 5 show that people who had purchased Vermont products in farmers’ markets have higher WTP for “made in Vermont” products. The revenue-maximizing premium price is $1.188p_0$ among farmers’ market shoppers (Table 5).

Table 5. Mean WTP, elasticity of demand $E^D(p)$, and revenue-maximizing premium price for the “made in Vermont” attribute among farmers’ market shoppers and non–farmers’ market shoppers

Ever purchased VT product in a farmers’ market or not	Mean WTP (N)	$E^D(1.15p_0)$	$E^D(1.25p_0)$	$E^D(1.35p_0)$	Optimal premium price $\hat{p}$
Yes	4.64 (465)	**–0.665**	**–1.548**	–2.216	$1.188p_0$
No	333 (185)	–1.498	–2.602	–2.054	

Note: Boldfaced elasticity values are the elasticity values used to estimate the optimal premium price through an interpolation method.

Conclusions and Implications

This paper has examined consumers’ WTP for 15 different food attributes using data from the TOP survey and estimated the price elasticity and the optimal premium rate for each attribute. The paper has also reported more detailed analysis on the “made in Vermont” attribute in different market segments.

This study suggests four major conclusions: First, significant WTP for basic social and environmental attributes such as “helping preserving open farmland” and “Made using environmentally friendly methods” were found in this survey. Although some compound attributes, such as "certified organic" and "made in Vermont," are designed to represent these basic attributes, they received much lower WTP than the basic attributes. This clearly shows that information about the quality and production process of food products has not been effectively conveyed to consumers and there is a need for more effective education and promotion efforts. There is a rich literature on consumers' perception of compound food attributes, such as local (Darby et al. 2008), organic (Padel and Foster 2005), and healthfulness (Drewnowski et al. 2010). Although most of these studies have deconstructed compound attributes into fundamental attributes, few have quantified the degree of trust by consumers. The result of this paper shows that more research is needed in this area.

Second, with estimated price elasticity of demand, producers can predict the market's response to price changes. The estimated price elasticities reported in this paper showed that nine out of the 15 food attributes can be expected to earn a price premium at least 15% over the base price ($1.15p_0$), and price premiums for all the nine attributes fell between $1.15p_0$ and $1.25p_0$. Because of the limitation of the data, price premium under 15% could not be measured. This range of price premium rates is consistent with previous estimations. Producers can increase their sales revenue by moving their current price toward the optimal price. For the given production costs, the increase in sales revenue minuses the additional marketing costs is equal to the increase in profit.

Third, for Vermont food producers, the results by different consumer groups showed that Vermont food products command higher premium among consumers who are more closely associated with Vermont, specialty store shoppers, and farmers' market shoppers. These findings yield three suggestions for Vermont food producers: (a) prices may be marked up for these consumers if possible; (b) link the marketing efforts to tourism promotion efforts; and (c) focus more on farmers' markets than the chain supermarkets.

Fourth, while previous studies have shown that the WTP for multiple attributes is not equal to the sum of the WTP for each individual attribute (e.g., Gao and Schroeder 2009), this study confirms the conclusion. This study also suggests that the WTP for a combination of attributes can even be lower than the WTP for a specific attribute included in the combination. For example, the average WTP for "made using environmentally friendly methods" is higher than that for "certified organic." The interaction between different food attributes requires more empirical studies.

Although this study is limited by survey data without quantity information at each WTP price level, the estimation of price elasticity and the premium rate for each attribute may provide useful information to farmers, retailers and policymakers. Also, while many states are promoting local agriculture, the research findings and estimation procedures are expected to provide a useful reference for food producers, retailers and policy makers in Vermont and other states.

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Mexican Meat Demand at the Table Cut Level: Estimating a Censored Demand System in a Complex Survey

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Abstract

Demand elasticities at the table cut level are computed from a Mexican survey of household incomes and weekly expenditures, which is a stratified sample. A censored demand system is estimated incorporating stratification variables and it results in unbiased parameter and elasticity estimates, which can be interpreted as estimates of all Mexican meat-consuming households. Their standard errors are rigorously approximated by bootstrapping. Several indicators of heterogeneous meat-cut demands are found. Volumes traded differ among the table cuts of meats; the probability of buying a particular meat cut changes across meat cuts and geographical regions; and cases of substitutability and complementarity are identified within and across meat categories.

Keywords: stratified sampling, adult equivalent scales, censored demand system, two-step estimation, bootstrap standard errors, Mexican meat consumption, disaggregated elasticities

Introduction

The world meat market is experiencing increasing trends in consumption and trade. From 1997 to 2006, world meat consumption, exports and imports increased 26%, 48%, and 28% respectively (U.S. Department of Agriculture (USDA)). As world meat consumption and trade liberalization increase, it becomes very important for large meat exporters to appropriately understand foreign market characteristics, especially those derived from consumer demand functions. Mexico is a key meat market not only because of the large quantity it imports and its relatively low per capita meat consumption, but also because of its relatively high preference for edible meat offals.

The Mexican meat market is large and rapidly expanding. From 1997 to 2006, Mexico was the fourth largest meat-importing country of the world (after Russia, Japan and the U.S.) accounting for 8% of the total world meat import average of 13,195,000 MT (USDA). During the same period, Mexican meat imports increased by 147% (from 568,000 MT in 1997 to 1,405,000 MT in 2006) and represented the fastest growth among the leading importing countries (USDA). Given that the population growth during this period was 11% (International Monetary Fund (IMF)), this suggests that an increasing per capita Mexican demand may be driving this rapid growth.

Despite the size and rapid growth of the Mexican meat market, per capita meat consumption will likely continue increasing. Mexican per capita meat consumption remains low when compared to the equivalent levels in the U.S. and Canada. From 1997 to 2006, per capita meat consumption in Mexico averaged 60.78 kg/year, while it averaged 121.6 kg/year and 98.38 kg/year in U.S. and Canada respectively (consumption from USDA; population from IMF). Given Mexico's rapid import growth, this indicates potential for continuously increasing imports and highlights the importance of Mexico as a demand market for years to come.

Another key characteristic of the Mexican meat market is its high preference for edible meat offals. Mexican imports of edible meat offals are larger than imports of other meat cuts. For example, imports of edible bovine offals are larger than imports of bovine meat carcasses and half-carcasses, other cuts of bovine meat with bone-in, and ham, bacon, and similar products (Table 1). Similarly, edible swine offal imports are larger than imports of boneless swine meat, swine meat carcasses and half-carcasses, and ham, bacon, and similar swine meat products. Likewise, imports of other chicken cuts and edible offals are larger than whole chicken imports, and ham and similar chicken products. Mexico is a key destination for edible meat offals because its consumers place a higher value for these meat products (Dyck and Nelson 2003, 6).

To appropriately understand foreign meat consumption and international trade, a table cut analysis of meat is necessary (Dyck and Nelson 2003). A practical question for researchers, policy makers, and meat importers and exporters involves estimating the substitution pattern in meat demand at the table cut level. Previous studies on Mexican meat consumption (Henneberry and Mutondo 2009; Erdil 2006; Malaga, Pan, and Duch 2006; Dong, Gould, and Kaiser 2004; Gould et al. 2002; Gould and Villarreal 2002; Golan, Perloff, and Shen 2001; Sabates, Gould,

Table 1. Mexican Bovine, Swine and Chicken Meat Imports by Cut

	2002	2003	2004	2005	2006	2007	Average 2002-07
Mexican Bovine Meat Imports (1000 MT)							
Bovine meat carcasses and half-carcasses	4	2	0	0	0	0	1
Other bovine meat cuts with bone-in	15	15	0	1	5	9	7
Boneless bovine meat	230	251	210	235	266	277	245
Edible bovine offals	56	78	55	77	82	85	72
Ham, bacon, & similar bovine products	6	4	2	2	3	3	4
Total bovine meat	311	350	268	316	355	373	329
Mexican Swine Meat Imports (1000 MT)							
Swine meat carcasses and half-carcasses	17	23	23	19	19	15	19
Swine hams, shoulders & cuts thereof, with bone-in	101	171	226	210	220	219	191
Boneless swine meat	41	74	86	76	83	91	75
Edible swine offals	109	151	173	156	157	157	150
Ham, bacon, & similar swine products	21	37	43	45	48	51	41
Total swine meat	289	457	550	505	527	532	477
Mexican Chicken Imports (1000 MT)							
Whole chicken	1	4	0	11	33	13	10
Boneless chicken	78	125	163	165	182	177	148
Chicken legs & thighs	0	112	125	127	151	131	108
Other chicken cuts & offals	83	83	23	54	44	44	56
Ham & similar chicken products	13	5	0	0	0	0	3
Total chicken	163	321	311	355	410	410	322

Note: The series was computed from chapter 2 (meat and edible meat offal) of the Harmonized System. At the 8-digit level of disaggregation, bovine meat carcasses and half-carcasses include commodities 02011001 and 02021001. Other bovine meat cuts with bone-in include commodities 02012099 and 02022099. Boneless bovine meat includes commodities 02013001 and 02023001. Edible bovine offals include commodities 02061001, 02062101, 02062201 and 02062999. Ham, bacon, and similar bovine products include commodity 02102001 and half of commodity 02109999. Swine meat carcasses and half-carcasses include commodities 02031101 and 02032101. Swine hams, shoulder and cuts thereof, with bone-in include commodities 02031201 and 02032201. Boneless swine meat includes commodities 02031999 and 02032999. Edible swine offals include commodities 02063001, 02063099, 02064101, 02064901 and 02064999. Ham, bacon, and similar swine products include commodities 02090099, 02101101, 02101201, 02101999, and half of commodity 02109999. Whole chicken includes commodities 02071101 and 02071201. Boneless chicken includes commodities 02071301 and 02071401. Chicken legs and thighs include commodities 02071303 and 02071404. Other chicken cuts and offals include commodities 02071302, 02071399, 02071402, 02071403 and 02071499. Ham and similar chicken products include commodities 02090001 and 02109903. All years are calendar years (January to December) except for 2002, which was reported from April to December.

Source: Mexico's Secretariat of Economy, SIAVI Database, computed by authors.

and Villarreal 2001; Dong and Gould 2000; Garcia Vega and Garcia 2000; Heien, Jarvis, and 2001; Dong and Gould 2000; Garcia Vega and Garcia 2000; Heien, Jarvis, and Perali 1989) estimate meat demand at the aggregate level, sometimes within a more general demand system (i.e., including cereals, dairy, fats, fruits, vegetables, etc.).[1] However, estimation of meat demand elasticities using meat aggregates (i.e., beef, pork, and chicken) may be neither appropriate nor useful for Mexico if consumers' tastes and preferences vary across table cuts of meats. In the U.S., meat demand studies at the disaggregated level have provided additional insights about the nature of the demand for meat (see Taylor, Phaneuf, and Piggott 2008; Yen and Huang 2002; and Medina 2000).

Unlike previous studies, the objective of this paper is to estimate demand elasticities at the table cut level (i.e., beefsteak, ground beef, pork steak, ground pork, chicken legs, thighs and breast, fish, etc.) and calculate expenditure, Marshallian and Hicksian price elasticities, which at this level of disaggregation are currently unavailable for Mexico. To accomplish this objective, a censored demand system is estimated in two steps using a survey of Mexican household incomes and weekly expenditures, which is published by a Mexican governmental institution and was collected employing a stratified sampling methodology (see Cameron and Trivedi 2005, 853). The study not only analyzes Mexican meat demand elasticities for table cuts of meats but also uses a relatively recent secondary source of information. It provides a better understanding of the Mexican meat consumption and may be used to identify current and future trends in consumption and trade of specific meat cuts. U.S. meat exporters will find elasticities at this level of disaggregation very beneficial for assessing likely scenarios of price and income changes in Mexico.

In addition, the methodology used provides several advantages over previous studies. Parameter and elasticity estimates are not biased, not only because stratification variables are incorporated in the estimation procedure but also because a censored regression model is employed. Parameters and elasticities can also be interpreted as population estimates or viewed as census estimates because the study uses a stratified sample and cross-sectional survey data that is representative of the entire target population (i.e., Mexican meat-consuming households). The standard errors of parameter estimates are also rigorously approximated by bootstrapping because the data was obtained from a complex survey. In addition, the price imputation approach that is applied is also preferred over a simple average substitution approach. Finally, the study adjusts for household size by using scales to compute per adult-equivalent consumption, which is preferred

[1] Similar to Henneberry and Mutondo (2009), Malaga, Pan, and Duch (2006), Gould et al. (2002), Gould and Villarreal (2002), Golan, Perloff, and Shen (2001), and Dong and Gould (2000), this study assumes that meat and other food commodity groups are separable in the household utility function, and similar to Dong, Gould, and Kaiser (2004), Gould et al. (2002), and Golan, Perloff, and Shen (2001), this study assumes that beef, pork, and chicken are not separable from seafood. Studies on Mexican meat consumption have not formally tested whether commodities can be partitioned into groups so that preferences within groups are described independently of the quantities in other groups. In the literature, there is evidence that separability holds in U.S. meat purchases (Moschini, Moro, and Green 1994), but in Australia it is not clear (Alston and Chalfant 1987). If separability of Mexican meat purchases does not hold, the elasticity estimates in this study may be biased because the substitution pattern among the Mexican food commodities would be broader.

over ignoring or using a simple count or proportion of household members because less parameters are estimated.

Data

To estimate meat demand at the table cut level, this study uses data on Mexican household incomes and weekly expenditures obtained from the National Survey of Household Incomes and Expenditures (or ENIGH by its acronym in Spanish), which is a nationwide survey encompassing Mexico's 31 states and the Federal District. This cross-sectional data is published by a Mexican governmental institution (National Institute of Statistics, Geography, and Information Technology (or INEGI by its acronym in Spanish)) since 1977 (e.g., see Heien, Jarvis, and Perali 1989). This study uses the 2006 survey, which was conducted from August to November. During this period, direct interviews were given through a stratified sampling method and expenditures on food, drinks, cigarettes and public transportation were recorded for one week.

The analysis of ENIGH data implies the use of a stratified sampling methodology instead of a random sampling methodology. In stratified sampling, the population is divided into subgroups (strata), which are often of interest to the investigator, and a simple random sample is taken from each stratum. According to ENIGH–Methodological Synthesis (2006), ENIGH's sampling methods are probabilistic, multi-staged, stratified, and conglomerated. This implies that the sampling units are selected with a known probability from multiple stages, are obtained from dividing the population into groups with similar characteristics, and are made up from the observation units (i.e., household members). In ENIGH 2006, there is a nonresponse rate of 10.55% (ENIGH–Methodological Synthesis 2006, 33–34). From the 20,875 responding households, 16,909 reported consumption of at least one meat cut. Table 2 reports the number of observations (i.e., number of interviewed meat-consuming households), the sum of weights (number of households nationally represented by the interviewed meat-consuming households), and the average household size per stratum in ENIGH 2006. The weight variable is the number of households nationally represented by the interviewed household and it is corrected for the nonresponse by INEGI.

Table 2. Number of observations, sum of weights and average household Size per stratum

Strata	No. of Obs.	Sum of Weights	Avg. hhsize
Str1	7,285	11,473,327	3.99
Str2	3,942	3,241,161	4.13
Str3	1,574	2,837,679	4.52
Str4	4,108	4,554,086	4.28
Total	16,909	22,106,253	4.14

Note: Stratum 1 (Str1) consists of households who live in locations with a population of 100,000 people or more. Stratum 2 (Str2) consists of households who live in locations with a population between 15,000 and 99,999 people. Stratum 3 (Str3) consists of households who live in locations with a population between 2,500 and 14,999 people. Stratum 4 (Str4) consists of household who live in locations with a population of less than 2,500 people.
Source: ENIGH 2006 Database, computed by authors.

Previous studies that use ENIGH data to estimate meat demand in Mexico (Malaga, Pan, and Duch 2006; Dong, Gould, and Kaiser 2004; Gould and Villarreal 2002; Gould et al. 2002; Golan, Perloff, and Shen 2001; Sabates, Gould, and Villarreal 2001; Dong and Gould 2000; Garcia Vega and Garcia 2000; Heien, Jarvis, and Perali 1989) do not take into account the issue of stratified sampling nor provide an explanation for excluding stratification variables. Ignoring stratification variables (e.g., weight and strata) results in parameter estimates that may be biased (not representative of the population) or that may not accurately identify differences among the subpopulations (Lohr 1999, 221–254). For example, not incorporating the variable weight into the analysis is equivalent to assigning a constant weight of 1,307.37 (i.e., 22,106,253/ 16,909) to each observation (Table 2); therefore, assuming each household member represents the same number of households nationally. A histogram of the weight variable from ENIGH 2006 shows this is not the case (Figure 1). Additionally, taking a random sample of 1,000 households from the 16,909 households and not incorporating the weight variable (e.g., see Golan, Perloff, and Shen 2001) will only produce a sample that is representative of the 16,909 households, assuming a constant weight, which is incorrect.

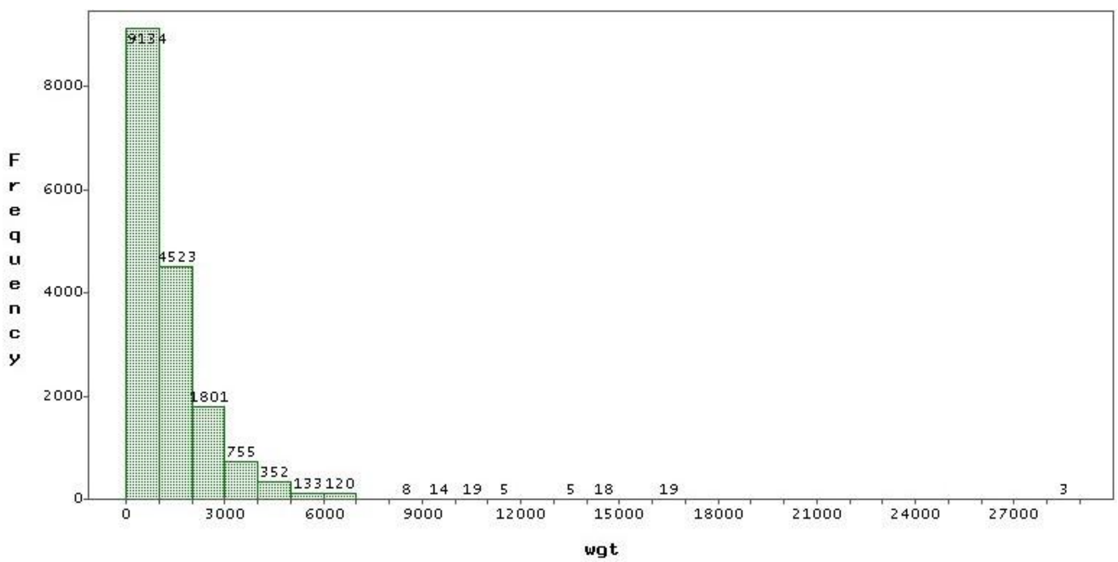

Figure 1. Histogram of the weight variable in ENIGH 2006
Source: ENIGH 2006 Database, computed by authors.

Furthermore, according to DuMouchel and Duncan's (1983) test, the use of stratification variables is necessary when using ENIGH 2006. In DuMouchel and Duncan's (1983) test, the null hypothesis favors the use of the unweighted estimator while the alternative hypothesis favors the use of the weighted estimator (DuMouchel and Duncan 1983, 539). DuMouchel and Duncan (1983, 538) recommend that the data passes this test before using the unweighted estimator over the weighted estimator.

The test is implemented by performing an F test for $\boldsymbol{\gamma} = \mathbf{0}$ in the following regression model estimated by ordinary least squares,

(1) $\mathbf{Y} = \mathbf{X}\,\alpha + \mathbf{W}\,\mathbf{X}\,\boldsymbol{\gamma} + \boldsymbol{\varepsilon},$

where **Y** is a ($n \times 1$) vector of observations in the dependent variable, **X** is a ($n \times p$) matrix of observations in the independent variables, **W** is a ($n \times n$) diagonal matrix whose i^{th} diagonal element is the sample weight w_i, $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$ are ($p \times 1$) vector of parameters, $\boldsymbol{\varepsilon}$ is a ($n\times 1$) random error with $E(\boldsymbol{\varepsilon}) = \mathbf{0}$ and $var(\boldsymbol{\varepsilon}) = \boldsymbol{\sigma}^2\mathbf{I}_n$, and $\mathbf{Z} = \mathbf{W}\,\mathbf{X}$, where the columns of **Z** are further (perhaps unobserved) predictors that should have been included in the regression but were not.

Table 3 shows the F statistic from eighteen DuMouchel and Duncan's (1983) tests that were implemented (one test at a time) by using meat-cut quantities as dependent variables, and a constant, meat-cut prices, and regional and urbanization level dummy variables as independent variables. At the 0.05 significance level, sixteen out of eighteen tests reject the null hypothesis of using the unweighted estimator. Consequently, when working with ENIGH 2006, it is critical to treat the data as a stratified sample (instead of a simple random sample) and incorporate stratification variables into the analysis.

Table 3. DuMouchel and Duncan's (1983) Test Results

Equation	F	p-value
q_1	1.7907	0.0090
q_2	2.0893	0.0011
q_3	1.7377	0.0126
q_4	1.9422	0.0032
q_5	1.3806	0.0976
q_6	4.3003	<0.0001
q_7	3.0603	<0.0001
q_8	1.7962	0.0086
q_9	1.7718	0.0101
q_{10}	4.4449	<0.0001
q_{11}	1.6708	0.0191
q_{12}	8.3251	<0.0001
q_{13}	2.4402	0.0001
q_{14}	9.2035	<0.0001
q_{15}	7.3924	<0.0001
q_{16}	1.9762	0.0026
q_{17}	1.1127	0.3166
q_{18}	3.7224	<0.0001
Critical Values		
$F^*_{25;16,884}(0.01) = 1.77$		
$F^*_{25;16,884}(0.05) = 1.52$		

In addition, among Mexican meat demand studies, there are some such as Malaga, Pan, and Duch (2006) and Dong, Gould, and Kaiser (2004) that restrict their analysis to only strata 1 and 2 (i.e., households who live in locations with a population of 15,000 or more), which in ENIGH 2006 is equivalent to excluding 7,391,765 households of the target population (Table 2). The authors justify the decision of ignoring strata 3 and 4 (i.e., households who live in locations with a population of 14,999 or less) by the difficulty of assigning a dollar value (i.e., a price) to the meat produced at home; in other words, to avoid the problem of "valuation of home-produced goods" that was briefly mentioned by Dong, Gould, and Kaiser (2004, 1099). However, ENIGH does not record consumption of home-produced goods when the households do not make a living by selling home-produced goods (INEGI, personal communication).[2] Because this study is interested in obtaining demand parameters and elasticities that are unbiased and can be interpreted as population estimates (or viewed as census estimates), this study will not exclude any segment of the population.

Censored observations are another issue that arises when working with ENIGH 2006. Censored observations are common in consumer survey data and they occur when the values of observations are partially known. Because ENIGH records food consumption only when households make a purchase and because the collection period is only one week, expenditures on many meat cuts are censored. The values of these observations are partially known because meat-cut consumption is unknown, but information about the households such as income, number of adults, and education is known. Not adjusting for censoring may result in coefficient estimates markedly different (e.g., coefficient estimates shrunk toward zero) from those of a censored regression model (e.g., see Wooldridge 2006, 611).[3]

In ENIGH 2006, prices (unit values) are household specific because they are obtained by dividing the household expenditure on the product by its corresponding quantity. In this study, quantity consists of both meat consumed at home and away from home. Price and quantity are censored for the meat cuts that households did not buy during the week of interview (also known as item non-response). A censored price corresponds to a censored quantity as the result of one week of interview and the way in which ENIGH records food consumption.[4]

This study solves the problem of censored prices and adjusts for quality differences by adopting a regression imputation approach for each of the eighteen meat cuts considered. In particular, non-missing prices of each meat cut is regressed as a function of total income, dummy variables for the education level of the household decision maker, regional dummy variables, stratum dummy variables, the number of adult equivalents, a dummy variable for car, and a dummy variable for refrigerator.[5] This price imputation approach is preferred over a substitution of the miss-

[2] If a household consumes a home-produced good during the week of interview, the consumption is recorded (and therefore included in this study) only if the household makes a living by selling home-produced goods to the public. Unfortunately, once this consumption is recorded, there is not enough information in the survey to distinguish it from expenditures on goods not produced at home. There is not enough information in the survey to determine how many home produced goods were or were not recorded in each stratum.

[3] Because of censoring, how often Mexican households purchase meat cuts cannot be assessed other than during the week of interview. In general, 86% of the house-holds that purchased a specific meat cut did it once a week while 12% and 2% did it twice and three times a week. Households that purchased a specific meat cut four, five, six or seven times a week were found but were not common.

[4] A total of 59,782 meat purchases were reported (counting as different purchases any purchase of meat as well as purchases of the same meat cut by the same household in different places) by 16,909 of the total 20,875 responding households. Only 13 of the 59,782 purchases did not report both price and quantity, but yet reported household expenditure on the meat cut. Only 4,333 of the 59,782 purchases were for consumption away from home. Only 1,216 of the 16,909 meat-consuming households purchased at least one meat cut for consumption away from home.

[5] Each regression uses the SURVEYREG procedure and incorporates the variables strata and weight as documented in SAS Institute Inc. (2004, 4363–4418). Cox and Wohlgenant (1986, 912–913) explain a first-order missing regressor procedure which first regresses the deviation from the regional mean price as a function of household character-

ing price with the corresponding simple average of non-missing prices within each state and strata (e.g., Golan, Perloff, and Shen 2001, 545 and Dong, Shonkwiler, and Capps 1998, 1099).[6]

Table 4 reports the number of non-missing and missing observations, as well as the average prices in 2006 Mexican pesos per kilogram (pesos/kg) of the eighteen meat cuts considered in this study (generally grouped in five categories–beef, pork, processed meat, chicken, and seafood).[7]

Table 4. Number of non-missing and missing observations and average prices

p_i	Num. Non-Missing	Num. Missing	Before p_i Imputed: Mean (Pesos/Kg)	Before p_i Imputed: Std. Err. of Mean	After p_i Imputed: Mean (Pesos/Kg)	After p_i Imputed: Std. Err. of Mean
			Beef			
p_1	6,348	10,561	61.3642	0.2572	60.8785	0.1059
p_2	2,938	13,971	55.6279	0.4059	56.2014	0.0780
p_3	2,795	14,114	52.0036	0.6439	51.4183	0.1199
p_4	734	16,175	36.8413	1.0864	35.8138	0.1046
			Pork			
p_5	892	16,017	50.3311	0.6043	50.3466	0.0417
p_6	1,506	15,403	47.0965	0.5020	46.9521	0.0519
p_7	366	16,543	48.6391	0.9688	47.9718	0.0515
p_8	2,168	14,741	46.8656	0.5416	46.7112	0.0816
			Processed Beef & Pork			
p_9	3,175	13,734	50.7869	0.9072	51.2935	0.1824
p_{10}	4,156	12,753	50.5261	0.4528	48.7871	0.1385
p_{11}	2,384	14,525	31.2680	0.5327	31.4529	0.0849
p_{12}	2,626	14,283	72.5129	1.1257	73.8783	0.2174
			Chicken			
p_{13}	5,057	11,852	35.2406	0.2458	34.6859	0.0969
p_{14}	5,716	11,193	28.5982	0.2876	28.1278	0.0953
p_{15}	760	16,149	22.4321	0.8949	24.8824	0.0924
			Processed Chicken			
p_{16}	2,593	14,316	46.7430	0.5581	46.0728	0.1000
			Seafood			
p_{17}	3,970	12,939	48.7240	0.5964	47.9096	0.1596
p_{18}	713	16,196	81.5472	2.2547	87.1642	0.1806

Note: p_i, $i = 1, 2, \ldots, 18$, where 1 = beefsteak, 2 = ground beef, 3 = other beef, 4 = beef offal, 5 = pork steak, 6 = pork leg and shoulder, 7 = ground pork, 8 = other pork, 9 = chorizo, 10 = ham, bacon and similar products from beef and pork, 11 = beef and pork sausages, 12 = other processed beef and pork, 13 = chicken legs, thighs and breasts, 14 = whole chicken, 15 = chicken offal, 16 = chicken ham and similar products, 17 = fish, and 18 = shellfish. Average exchange rate in 2006 is U.S. \$1 = 10.90 Pesos (Bank of Mexico).
Source: ENIGH 2006 Database, computed by authors.

The mean before price imputation uses only non-missing observations to compute the average while mean after price imputation uses both non-missing observations and imputed (originally

istics, and then determines quality-adjusted missing prices. The simpler regression imputation procedure adopted here produced almost the same meat-cut price variability.

[6] If the latter procedure is adopted, using four strata and Mexico's 31 states plus the Federal District will only provide 128 different values for price imputation and using two strata will only provide 64 different values.

[7] Average prices also incorporate the variables strata and weight, and were computed using the SURVEYMEANS procedure (see SAS Institute Inc. 2004, 4313–4362).

missing) observations. The high number of censored observations is common when meat is analyzed at the disaggregate level (see Taylor, Phaneuf, and Piggott 2008) and even when meat is analyzed at the aggregated level (see Gould et al. 2002; Golan, Perloff, and Shen 2001; Sabates, Gould, and Villarreal 2001; Dong and Gould 2000; Dong, Shonkwiler, and Capps 1998; Heien, Jarvis, and Perali 1989).

Unlike some previous studies, this study solves the problem of censored quantities (which are treated as zeros) by using a censored regression model. The study incorporates estimation techniques from stratified sampling with the two-step estimation of a censored system of equations proposed by Shonkwiler and Yen (1999) and later illustrated by Su and Yen (2000). Additionally, estimating standard errors of parameter estimates in complex surveys is different and more difficult than estimating standard errors of parameter estimates in simple random samples. Because of the survey design, estimating them in the same manner is incorrect (Lohr 1999, 289–318 and 347–378).

For similar reasons, using the standard errors of parameter estimates obtained from weighted least squares (WLS) is also incorrect (Lohr 1999; Devaney and Fraker 1990; Kott 1990). Consequently, this study estimates standard errors of parameter estimates by using the nonparametric bootstrap procedure, which is both rigorous and practical (see Cameron and Trivedi 2005, 360 and SAS Institute Inc.). In general, the bootstrap is a resampling technique that can be used to estimate standard errors of parameter estimates when other techniques are inappropriate or not feasible.

A final issue incorporated into this study is that of using the number of adult equivalents rather than ignoring or using a simple count or proportion of household members (e.g., Malaga, Pan, and Duch 2006; Dong, Gould, and Kaiser 2004; Golan, Perloff, and Shen 2001). Adult equivalence scales are used to compute the number of adult equivalents per households by taking into account how much an individual household member of a given age and gender contributes to household expenditures or consumption of goods relative to a standard household member. Adult equivalents are computed so that the consumption of households are comparable. For instance, meat consumption in different households cannot be directly compared without computing per capita meat consumption because bigger households will naturally have a tendency to consume more meat than smaller households. To solve this issue, this study uses the National Research Council's recommendations of the different food energy allowances for males and/or females during the life cycle as reported by Tedford, Capps, and Havlicek (1986) to compute the number of adult equivalents and then the per capita meat consumption (i.e., per-adult-equivalent consumption).

Theoretical Framework

Shonkwiler and Yen's (1999) consistent censored demand system is used to estimate the meat demand parameters and compute Marshallian and Hicksian price elasticities as well as expenditure elasticities at the table cut level of disaggregation. Shonkwiler and Yen's (1999) censored demand model is preferred over Heien and Wessells' (1990) procedure because the latter is based on a set of unconditional mean expressions for the censored dependent variables which are inconsistent. In particular, "[a]s the censoring proportion increases, the [Heien and Wessells' (1990)] procedure produces significant parameter estimates in most cases but performs very poorly in that few 95% confidence intervals contain the true parameters" (Shonkwiler and Yen, 1999, 981).

Shonkwiler and Yen's (1999) two-step procedure, which is explained in more detail below, does not incorporate the theoretical restrictions of adding-up, homogeneity, and symmetry.[8] However, the model is designed to take into account censored observations, which is critical when analyzing Mexican meat demand at the disaggregated level. Furthermore, Shonkwiler and Yen's (1999) censored demand system is very flexible and practical, which allows for incorporating estimation techniques used in stratified sampling theory.

For an arbitrary observation t, $t = 1, 2, \ldots, T$, from the i^{th} equation, $i = 1, 2, \ldots, M$, the censored system of equations with limited dependent variables is written as follows:

$$(2) \quad \begin{aligned} y_i &= d_i\, y_i^*, \\ y_i^* &= \mathbf{x}_i'\,\boldsymbol{\beta}_i + \varepsilon_i, \\ d_i &= \begin{cases} 1 \text{ if } d_i^* > 0, \\ 0 \text{ if } d_i^* \leq 0, \end{cases} \\ d_i^* &= \mathbf{z}_i'\,\boldsymbol{\alpha}_i + v_i; \end{aligned}$$

where y_i and d_i are (1×1) observed dependent variables, y_i^* and d_i^* are (1×1) corresponding latent or unobserved variables, $\mathbf{z}_i' = (1 \;\; z_{i2} \ldots z_{iK_1})$ and $\mathbf{x}_i' = (1 \;\; x_{i2} \ldots x_{iK_2})$ are $(1 \times K_1)$ and $(1 \times K_2)$ vector of explanatory variables respectively, $\boldsymbol{\alpha}_i = (\alpha_{i1} \;\; \alpha_{i2} \ldots \alpha_{iK_1})'$ and $\boldsymbol{\beta}_i = (\beta_{i1} \;\; \beta_{i2} \ldots \beta_{iK_2})'$ are $(K_1 \times 1)$ and $(K_2 \times 2)$ vector of parameters respectively, and ε_i and v_i are (1×1) random errors.

Shonkwiler and Yen (1999) explain that if it is assumed that for each i the error terms $(\varepsilon_i \; v_i)'$ are distributed as bivariate normal with $\text{Cov}(\varepsilon_i, v_i) = \delta_i$; then, the mean of y_i is

$$(3) \quad \text{E}(y_i|\mathbf{x}_i, \mathbf{z}_i) = \Phi(\mathbf{z}_i'\,\boldsymbol{\alpha}_i)\,\mathbf{x}_i'\,\boldsymbol{\beta}_i + \delta_i\,\phi(\mathbf{z}_i'\,\boldsymbol{\alpha}_i).$$

Then, using equation (3), the system in equation (2) can be written as

$$(4) \quad y_i = \Phi(\mathbf{z}_i'\,\boldsymbol{\alpha}_i)\,\mathbf{x}_i'\,\boldsymbol{\beta}_i + \delta_i\,\phi(\mathbf{z}_i'\boldsymbol{\alpha}_i) + \xi_i, \quad i = 1, \ldots, M,$$

where $\xi_i = y_i - \text{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)$ and $\text{E}(\xi_i) = 0$.

[8] The adding-up restriction is not imposed because the left-hand side of the system of equations consists of meat-cut quantities, not shares (see equation (4)). However, the adding up is imposed when computing the Marshallian and Hicksian price elasticities as well as expenditure elasticities (see equations (8) and (9)). Since the adding-up restriction is not imposed and the system of equations compensate for censoring by incorporating the probability of consuming meat cut i (i.e., the standard normal cumulative distribution function appropriately evaluated) and the standard normal probability density function (appropriately evaluated), the homogeneity and symmetry conditions cannot be imposed. In fact, the parameter estimates reported by Su and Yen (2000) and Shonkwiler and Yen (1999) reflect that these restrictions were not imposed.

Shonkwiler and Yen (1999) suggest the following two-step procedure for the system in equation (4): (i) obtain maximum-likelihood probit estimates $\hat{\boldsymbol{\alpha}}_i$ of $\boldsymbol{\alpha}_i$ for $i = 1, 2, \ldots, M$ using the binary dependent variable $d_i = 1$ if $y_i > 0$ and $d_i = 0$ otherwise; (ii) calculate $\Phi(\mathbf{z}_i' \hat{\boldsymbol{\alpha}}_i)$ and $\phi(\mathbf{z}_i' \hat{\boldsymbol{\alpha}}_i)$ and estimate $\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \ldots, \boldsymbol{\beta}_M, \delta_1, \delta_2, \ldots, \delta_M$ in the system

(5) $$y_i = \Phi(\mathbf{z}_i' \boldsymbol{\alpha}_i)\, \mathbf{x}_i' \boldsymbol{\beta}_i + \delta_i\, \phi(\mathbf{z}_i' \boldsymbol{\alpha}_i) + \xi_i, \quad i = 1, \ldots, M,$$

by maximum likelihood (ML) or seemingly unrelated regression (SUR) procedure,[9] where

(6) $$\xi_i = \varepsilon_i + [\, \Phi(\mathbf{z}_i' \boldsymbol{\alpha}_i) - \boldsymbol{\Phi}(\mathbf{z}_i' \hat{\boldsymbol{\alpha}}_i)]\, \mathbf{x}_i' \boldsymbol{\beta}_i + \delta_i\, [\phi(\mathbf{z}_i' \boldsymbol{\alpha}_i) - \phi(\mathbf{z}_i' \hat{\boldsymbol{\alpha}}_i)].$$

The differentiation of the mean of y_i, equation (3), with respect to a common variable in $\mathbf{x}_i$ and $\mathbf{z}_i$, say $x_{ij} = z_{ij}$, gives

(7) $$\frac{\partial \mathrm{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)}{\partial x_{ij}} = \Phi(\mathbf{z}_i' \boldsymbol{\alpha}_i)\, \beta_{ij} + \mathbf{x}_i' \boldsymbol{\beta}_i\, \phi(\mathbf{z}_i' \boldsymbol{\alpha}_i)\, \alpha_{ij} - \delta_i\, (\mathbf{z}_i' \boldsymbol{\alpha}_i)\, \phi(\mathbf{z}_i' \boldsymbol{\alpha}_i)\, \alpha_{ij}.$$

Following, Su and Yen (2000), the elasticities are derived from equation (7). For example, the elasticities of commodity i with respect to price p_j, total meat expenditure m, and demographic variable r_l are (e.g., see Yen, Kan, and Su 2002)

(8) $$e_{ij} = \frac{\partial \mathrm{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)}{\partial p_j} \frac{p_j}{\mathrm{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)},$$
$$e_i = \frac{\partial \mathrm{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)}{\partial m} \frac{m}{\mathrm{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)},$$
$$e_{il} = \frac{\partial \mathrm{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)}{\partial r_j} \frac{r_l}{\mathrm{E}(y_i|\mathbf{x}_i, \mathbf{z}_i)}.$$

These elasticities can be evaluated using parameter estimates and sample means of explanatory variables. Since ENIGH is a stratified sample, means of explanatory variables are computed incorporating the variables strata and weight.[10] The elasticity of commodity i with respect to demographic variable r_l is "not strictly defined... [but] allows convenient assessment of the significance of corresponding variables in a complex functional relationship" (Su and Yen 2000, 736). Finally, the compensated or Hicksian elasticities of commodity i with respect to price p_j can be obtained from Slutsky equation in elasticity form. That is,

(9) $$e_{ij}^{c} = e_{ij} + e_i \frac{p_j \mathrm{E}(y_j|\mathbf{x}_j, \mathbf{z}_j)}{m}.$$

[9] See Zellner (1962).
[10] See SAS Institute Inc. (2004, 4313–4362).

Empirical Results

The univariate maximum-likelihood probit parameters α_i, $i = 1, 2, \ldots, M$ are estimated by multiplying the contribution of each observation to the likelihood function by the value of the weight variable.[11] Table 5 reports the parameter estimates from the first five equations as well as their corresponding bootstrap standard errors.[12] The variable *m* stands for total meat expenditure, and the binary variables *NE*, *NW*, *CW*, *C* and *urban* stands for the Northeast, Northwest, Central-west, and Central regions, and the urban sector.[13] Note that the excluded dummy variables from each equation are the Southeast region (SE) and the rural sector (rural). From a total of 450 parameters estimated in the first step (25 parameters estimated at a time for 18 equations), 204, 157, and 137 parameters are statistically different from zero at the 0.20, 0.10, and 0.05 significance levels respectively.[14] Considering only parameter estimates corresponding to binary variables, from a total of 90 parameters estimated, 68, 59, and 51 are statistically different from zero at the 0.20, 0.10, and 0.05 significance levels respectively.[15] These significant determinants of the probability of consuming meat cut *i* are reported in Table 5 (see Appendix).

Moreover, the partial effect of continuous variable z_{ik} (e.g., $p_1, \ldots, p_{18}$ or m) on the probability of buying meat cut *i*, which is given by $\phi(\mathbf{z}_i' \boldsymbol{\alpha}_i)\,\alpha_{ik}$, can be estimated from Tables 4 and 5.[16] For example, an increase of one peso/kg in the price of pork leg and shoulder decreases the probability of consuming beefsteak by 0.0035, other things held constant. Similarly, the partial effect of binary variable z_{ik} (e.g., *NE*, *NW*, *CW*, *C*, *urban*) changing from 0 to 1 on the probability of buying meat cut *i* is given by $\Phi(\alpha_{i1} + \alpha_{i2}z_{i2} + \ldots + \alpha_{i(k-1)}z_{i(k-1)} + \alpha_{ik}(1) + \alpha_{i(k+1)}z_{i(k+1)} + \ldots + \alpha_{iK_1}z_{iK_1}) - \Phi(\alpha_{i1} + \alpha_{i2}z_{i2} + \ldots + \alpha_{i(k-1)}z_{i(k-1)} + \alpha_{i(k+1)}z_{i(k+1)} + \ldots + \alpha_{iK_1}z_{iK_1})$. For instance, the

[11] See SAS Institute Inc. (2004, 3754).

[12] The parameter estimates as well as their corresponding bootstrap standard errors for the other thirteen equations are available from the authors upon request.

[13] The Northeast region (NE) of Mexico consists of the states of Chihuahua, Cohahuila de Zara-goza, Durango, Nuevo León, and Tamaulipas. The Northwest region (NW) of Mexico consists of the states of Baja California, Sonora, Baja California Sur, and Sinaloa. The Central-West (CW) region of Mexico consists of the states of Zacatecas, Nayarit, Aguascalientes, San Luis Potosí, Jalisco, Guanajuato, Querétaro Arteaga, Colima, and Michoacán de Ocampo. The Central region (C) of Mexico consists of the states of Hidalgo, Estado de México, Tlaxcala, Morelos, and Puebla, and Distrito Federal. Finally, the Southeast region (SE) of Mexico consists of the states of Veracruz de Ignacio de la Llave, Yucatán, Quintana Roo, Campeche, Tabasco, Guerrero, Oaxaca, and Chiapas. These are the major geographical regions of Mexico used by Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). Similarly, SAGARPA defines the urban sector as stratum 1 and stratum 2 while it defines the rural sector as stratum 3 and stratum 4.

[14] Given that the survey is complex, this study estimates standard errors of parameter estimates using the bootstrap procedure. A researcher, who naively estimates standard errors treating the survey as a simple random sample and uses Wald Chi-Square statistic from SAS default procedure to determine the statistical significance of the parameter estimates, would report that out of 450 parameters estimated in the first step, 439 are statistically different from zero at the 0.01 significance level. Devaney and Fraker (1990) and Kott (1990) explicitly caution about the limitations of standard regression packages when applied to complex surveys.

[15] As a goodness-of-fit measure, the overall percent of correctly predicted observations from the eighteen probit models are 69.11%, 82.42%, 81.93%, 95.65%, 94.71%, 91.06%, 97.84%, 87.04%, 81.21%, 75.32%, 85.87%, 84.46%, 73.03%, 68.04%, 95.50%, 84.55%, 76.46%, and 95.74% respectively.

[16] Average total meat expenditure is 33.0374 pesos per capita per week. The standard error of average total meat expenditure is 0.3450.

probability of consuming whole chicken in the Northeast region is about 0.3163 lower than the Southeast region, holding everything else constant.

Table 6 (see Appendix) reports the regional probabilities of buying meat cut *i* during the week of interview, $P(d_i = 1|\mathbf{z}_i)$. For some meat cuts the difference among the regional probabilities is about 1.5 times greater. For example, the probability of buying beefsteak in the Central-West region (0.4923) is about 1.5 times greater than the Northwest region (0.3202). Likewise for the probability of buying other beef in the Northeast (0.2352) and the Southeast (0.1555) regions, and the probability of buying chorizo in the Northeast (0.2283) and Southeast (0.1535) regions. In some cases the difference among the regional probabilities is larger (about 7 or 11 times greater). Probability comparisons can also be made across meat cuts in a single region or across both meat cuts and regions. The results suggest that Mexican meat-cut demands are heterogeneous.

In the second step, the estimation of the system of censored demand equations is based on the full system of M = 18 equations because the parametric restriction of adding-up is not imposed in the model (see also Yen, Kan, and Su 2002, 1801). Given that in stratified samples the weighted estimator is consistent (Wooldridge 2001, 464), all observations are weighted by the weight variable prior to estimation. However, "[if we] use weights, w_i, in the weighted least squares estimation, [we] will obtain the same point estimates...; however, in complex surveys, the standard errors and hypothesis tests the software provides will be incorrect and should be ignored" (Lohr 1999, 355). Consequently, standard errors of parameter estimates in this study are estimated using the bootstrap procedure. Table 7 (see Appendix) presents the SUR parameter estimates for the first five equations as well as their corresponding bootstrap standard errors from the system of eighteen equations.[17] From a total of 468 parameter estimated in the second step, 200, 128, and 67 parameters are statistically different from zero at the 0.20, 0.10, and 0.05 significance levels respectively.[18]

Tables 8 and 9 (see Appendix) respectively report the Marshallian and Hicksian price elasticities. The expected negative sign is obtained for all Marshallian and Hicksian own-price elasticities. In addition, there are as many positive price elasticities (160 Marshallians and 178 Hicksians) as there are negatives (164 Marshallians and 146 Hicksians). Positive cross-price elasticities suggest cases of substitute meat cuts while negatives suggest cases of complement meat cuts. Moreover, the signs of the Marshallian (Table 8) and Hicksian (Table 9) price elasticities are the same in all but 18 cases. In general, further cases of (gross and net) substitutability and complementarity are identified within and across the traditional categories (i.e., beef, pork, chicken, and fish). For example, within categories, cases of substitutability are found in Mexico. Ground beef is a (gross and net) substitute of beefsteak (and vice versa). Chicken ham and similar products are (gross and net) substitutes of ham, bacon and similar products from beef and

[17] The parameter estimates from the second step estimation as well as their corresponding bootstrap standard errors for the other thirteen equations are available from the authors upon request.

[18] If the standard errors of parameter estimates are calculated by treating the survey as a simple random sample and the statistical significance of the parameter estimates is determined by using the *t* statistic from SAS default procedure, then from a total of 468 parameter estimated in the second step, 314, 352, 372, and 393 are statistically different from zero at the 0.01, 0.05, 0.10, and 0.20 significance levels respectively.

pork (and vice versa). Within categories, cases of complementarity are also found in Mexico. Other beef cuts (i.e., excluding beefsteak, ground beef, and beef offal) are (gross and net) complements of beefsteak (and vice versa). Pork leg and shoulder is a (gross and net) complement of pork steak (and vice versa). Across categories, cases of substitutability are found in Mexico. Pork steak is a (gross and net) substitute of beefsteak (and vice versa). Chicken offal is a (gross and net) substitute of beef offal (and vice versa). Across categories, cases of complementarity are also found in Mexico. Fish is a (gross and net) complement of whole chicken (but not vice versa).

Elasticity estimates at the table-cut level of disaggregation are currently not available for Mexico. Only an indirect comparison with previous Mexican elasticity estimates at aggregate level (see Table 10 in Appendix) or a direct comparison with U.S. elasticity estimates at the disaggregated level are possible. However, model functional forms, sample sizes, and time period under consideration (among other things) influence elasticity estimates to differ from one study to another. For example, the Marshallian beef-beef elasticity in past studies ranges from –1.4300 in Malaga, Pan, and Duch (2006) to –0.4610 in Erdil (2006). In this study, there are sixteen Marshallian beef-beef elasticity estimates ($\hat{e}_{ij}$, i, j = 1, 2, 3, 4). The own-price elasticity estimates from the beef cuts ($\hat{e}_{ij}$, i, j = 1, 2, 3, 4, i = j) range from −4.8186 for beef offal to −1.0270 for beefsteak while the cross-price elasticity estimates from the beef cuts ($\hat{e}_{ij}$, i, j = 1, 2, 3, 4, $i \neq j$) range from −1.8100 between offal and beefsteak to 0.4889 between offal and ground beef (Table 8). The Marshallian pork-pork elasticity estimates in past studies range from –1.5100 in Malaga, Pan, and Duch (2006) to 0.0270 in Dong and Gould (2000). The sixteen Marshallian pork-pork elasticity estimates in this study consist of the own-price elasticity estimates ($\hat{e}_{ij}$, i, j = 5, 6, 7, 8, $i = j$), which range from −15.9428 for ground pork to −4.4711 for pork steak, and the cross-price elasticity estimates ($\hat{e}_{ij}$, i, j = 5, 6, 7, 8, $i \neq j$), which range from −1.9708 between other pork and ground pork to 1.6971 between the quantity consumed of other pork and the price of pork leg and shoulder. The Marshallian processed meat-processed meat elasticity estimates in past studies range from –0.7830 in Golan, Perloff, and Shen (2001) to −0.7755 in Dong, Gould, and Kaiser (2004). In this study, the own-price elasticity estimates from the processed beef and pork cuts ($\hat{e}_{ij}$, i, j = 9, 10, 11, 12, $i = j$) range from −3.1156 for other processed beef and pork to −0.7832 for ham and bacon while the cross-price elasticity estimates from these cuts ($\hat{e}_{ij}$, i, j = 9, 10, 11, 12, $i \neq j$) range from − 0.6150 between the quantity consumed of chorizo and the price of ham and bacon to 0.2719 between quantity consumed of ham and bacon and the price of sausages. The Marshallian chicken-chicken elasticity estimates in past studies ranges from −1.4300 in Malaga, Pan, and Duch (2006) to −0.1300 in Dong and Gould (2000). In this study, the own-price elasticity estimates from the chicken cuts ($\hat{e}_{ij}$, i, j = 13, 14, 15, 16, $i = j$) range from −9.1730 for offal to −1.2640 for whole chicken while the cross-price elasticities from the chicken cuts ($\hat{e}_{ij}$, i, j = 13, 14, 15, 16, $i \neq j$) range from −0.2035 between offal and whole chicken to 1.1161 between offal and chicken ham. The Marshallian own-price elasticity for fish and shellfish range from −2.1500 in Golan, Perloff, and Shen (2001) to –0.6348 in Dong, Gould, and Kaiser (2004). In this study, the own-price elasticity estimate for fish is −0.9825 and for shellfish is −7.5997 while the cross-price elasticity estimates are 0.6658 between fish and shellfish and −0.0001 between shellfish and fish.

These elasticity estimates have a wider range of values and identify further cases of gross substitutability and complementarity within the traditional categories (i.e., beef, pork, chicken, and fish). In general, the own-price elasticities had the largest magnitudes, which is common in demand studies at the differentiated level (see Chidmi and Lopez 2007 and Nevo 2001). It suggests that Mexican consumers are very price sensitive with respect to the consumptions and changes in the own prices of these commodities. Own-price elasticities with large magnitudes result from the fact that in the model Mexican consumers can substitute a beef cut with another beef cut, a pork cut with another pork cut, and so on, which allows the consumers to be more price sensitive. In other words, the own-price elasticities of aggregated meat categories (i.e., beef, pork, and chicken) tend to be more inelastic because consumers are given less potential substitutes, not only across meat categories but most importantly within a meat category. Consequently, consumers might be more reluctant to substitute an aggregated meat category. On the other hand, when disaggregated commodities are considered, there are more potential substitutes. In this study, there are more potential substitutes across and within categories. Consequently, consumers have more choices (especially within a meat category); therefore, own-price elasticities tend to have large magnitudes.

Few studies have reported U.S. elasticity estimates at the disaggregated level. A comparison of this study's findings with U.S. estimates may also provide additional insight about the nature of the Mexican demand for meat at the table cut level. Yen and Huang (2002, 329) reported own- and cross-price conditional elasticity estimates for four beef cuts (steak, roast, ground beef, other beef) and one aggregated meat category (other meat). The Marshallian beefsteak-beefsteak elasticity estimate of −1.0270 in this study (Table 8) is close to the estimate of −1.1100 reported by Yen and Huang (2002, 329). This indicates that U.S. and Mexican beefsteak consumers may respond similarly to changes in the beefsteak price. Unlike Yen and Huang (2002, 329), the Marshallian own-price elasticity estimates for ground beef and other beef in this study are elastic while the Yen and Huang's (2002, 239) estimates are inelastic. This is not surprising because Yen and Huang (2002) only considered five meat products while this study considered eighteen.

Medina (2000) also studied the U.S. demand for meat at the table cut level. Medina (2000, 123) reported Hicksian own- and cross-price elasticity estimates for nine meat products (roast, steak, other beef, ground beef, chicken, turkey, other poultry, pork, and fish) under four income groups ($0-$24,999; $25,000-$49,999; $50,000-$74,999; and over $75,000). Provided that the average total income of the meat-consuming households in Mexico is 36,384 pesos per month or U.S. $3,338,[19] selective Hicksian elasticity comparisons can also be made with the $25,000-$49,999 household income group reported in Medina (2000, 123). In general and as expected, this study's Hicksian elasticity estimates (Table 9) are more elastic than Medina's (2000, 123) estimates because it considers more table cuts of meats. Interestingly, most of the time, the cases of net substitutability and complementarity among the meat cuts were the same. For example, in both studies net substitutes (Table 9) include beefsteak and ground beef (and vice versa), beefsteak and whole chicken (and vice versa), beefsteak and fish (and vice versa). Similarly, in both

[19] The average total income estimate of the 16,909 meat-consuming households is 36,384 pesos per month or U.S. $3,338 with a standard error of average total income of 484.70 pesos per month or U.S. $44.47. The average total income estimate of the 20,875 responding households is $35,955 pesos or U.S. $3,298.62 per month with a standard error of the average total income of 444.35 pesos or U.S. $40.77 per month.

studies net complements include beefsteak and other beef (and vice versa), and other beef and fish (but not vice versa). In the case of the Marshallian eslasticity estimates (Table 8), this study's findings and Yen and Huang (2002) also found ground beef and beefsteak to be gross substitutes (but not vice versa), and other beef and beefsteak to be gross complements (but not vice versa).

Figure 2 presents the expenditure elasticity estimates. All of them have the expected positive sign and are statistically different from zero at the 0.05 significance level (except for ground beef), which means all the meat cuts are "normal" products and that consumption of all meat cuts are expected to increase as the economy grows. Additionally, since all the expenditure elasticities are less than one, none of the meat cuts is considered a "luxury" commodity. The expenditure elasticities range from 0.1846 for ground pork to 0.9733 for beefsteak. In addition, most pork-cut elasticities have a lower value (therefore more "necessary" goods in terms of their tastes and preferences) than most beef-cut elasticities and chicken-cut elasticities, except for processed-meat-cut expenditure elasticities (i.e., chorizo; ham, bacon and similar products from beef and pork; beef and pork sausages; other processed beef and pork; and chicken ham and similar products).

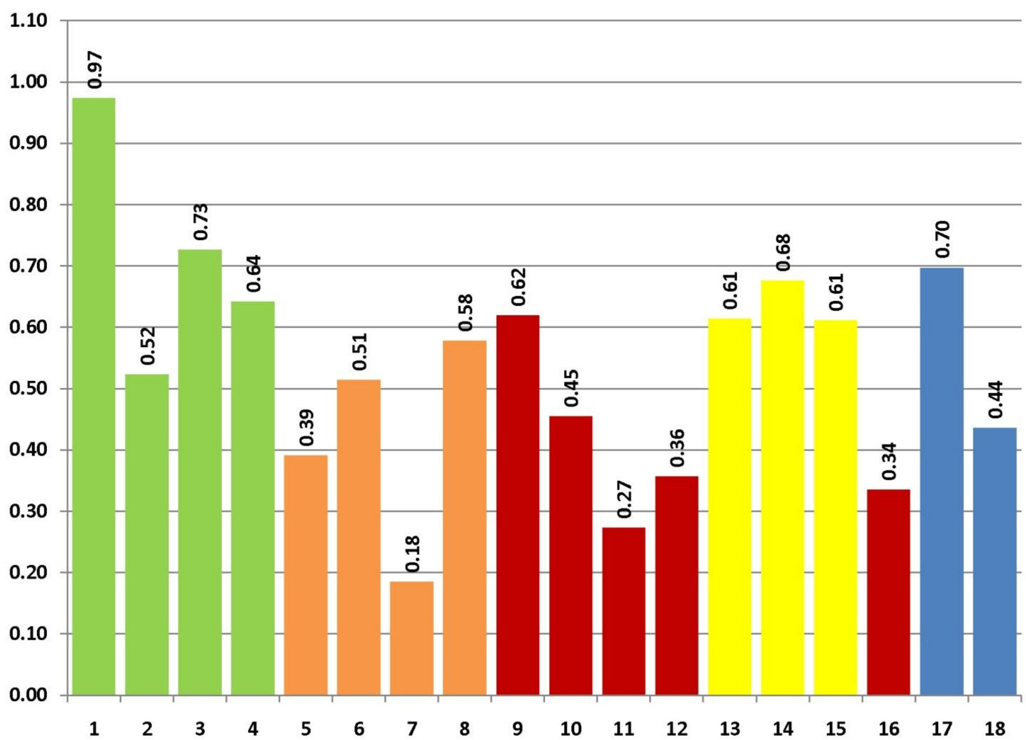

Figure 2. Expenditure Elasticities

Note: Bars depict $\hat{e}_i$, $i = 1, 2, \ldots, 18$, where 1 = beefsteak, 2 = ground beef, 3 = other beef, 4 = beef offal, 5 = pork steak, 6 = pork leg and shoulder, 7 = ground pork, 8 = other pork, 9 = chorizo, 10 = ham, bacon and similar products from beef and pork, 11 = beef and pork sausages, 12 = other processed beef and pork, 13 = chicken legs, thighs and breasts, 14 = whole chicken, 15 = chicken offal, 16 = chicken ham and similar products, 17 = fish, and 18 = shellfish. All expenditure elasticities are statistically different from zero at the 0.05 significance level except for ground pork. Significance levels were estimated with the bootstrap procedure at 1,000 resamples.

In past studies (Table 11), the beef expenditure elasticity estimates ranges from 0.1040 in Gould and Villarreal (2002) to 1.3059 in Dong, Gould, and Kaiser (2004). In this study (Figure 2), the expenditure elasticity estimates from the beef cuts range from 0.5228 for ground beef to 0.9733 for beefsteak. In past studies the pork expenditure elasticity estimates range from 0.1000 in Gould and Villarreal (2002) to 1.1728 in Dong, Gould, and Kaiser (2004) while in this study the expenditure elasticity estimates from pork cuts range from 0.1846 for ground pork to 0.5776 for other pork. Similarly, in past studies the processed meat expenditure elasticity estimates range from 0.5420 in Golan, Perloff, and Shen (2001) to 1.1512 in Dong, Gould, and Kaiser (2004) while in this study the expenditure elasticity estimates from processed beef and pork cuts range from 0.2728 for beef and pork sausages to 0.6190 for chorizo. Likewise, in past studies the fish (or seafood) expenditure elasticity estimates range from 1.1554 in Dong, Gould, and Kaiser (2004) to 1.2470 in Golan, Perloff, and Shen (2001) while in this study the shellfish elasticity estimate is 0.4361 and the fish elasticity estimate 0.6970. These results indicate that most expenditure elasticity estimates in this study fall within the range from past studies.

Yen and Huang (2002, 329) also reported conditional meat expenditure elasticity estimates for some table cuts of beef in the U.S. The Mexican beefsteak, other beef, and ground beef expenditure elasticity estimates of 0.9733, 0.7260, and 0.5228 from this study (Figure 2) follow the same respective descending order than the U.S. steak, other beef, and ground beef expenditure elasticity estimates of 1.1850, 1.0400, and 0.9780 reported by Yen and Huang (2002, 329). This means that in both the U.S. and Mexico beefsteak is the "most luxurious" beef cut while other beef is the "most necessary" beef cut.

Conclusions

Mexico is an important market for meat exporters because it is one of the leading meat importing countries in the world with a relatively high preference for meat offal and growing per capita meat consumption. Several of our findings suggest that Mexican meat consumption is more appropriately analyzed when considering table cuts of meats rather than meat aggregates. Volumes traded differ among the table cuts of meats; the probability of buying a particular meat cut changes across meat cuts and regions; and there are cases of (gross and net) substitutability and complementarity within and across the traditional meat categories (i.e., beef, pork, chicken, and seafood). Interestingly, the U.S. and Mexican beefsteak consumers seem to respond similarly to changes in the beefsteak price. The Marshallian own-price beef elasticity estimates (except for beefsteak) from this study seem to be more elastic than U.S. estimates. Interestingly, the several cases of (gross and net) substitutability and complementarity seem be the same in both the U.S. and Mexico. However, the substitution and complementarity patterns need to be further investigated as more studies on disaggregated elasticities are conducted in the U.S. and Mexico.

Our results also indicate that consumption on all meat cuts is expected to increase as the Mexican economy grows. In addition, all Mexican meat cuts are considered "normal" commodities but pork cuts appeared to have the most inelastic expenditure elasticities (except for processed meat cuts). Interestingly, in both the U.S. and Mexico beefsteak seems to be the "most luxurious" beef cut while other beef seems to be the "most necessary" beef cut. Similar comparisons between the U.S. and Mexico for pork and chicken cuts could be conducted if the meat demand studies in the U.S. would disaggregate these meat cuts. Unfortunately, few studies on the U.S. meat demand and no study on Mexican meat demand have conducted an analysis at the table cut level of disaggregation.

Unlike previous studies on the U.S. and Mexico meat demands, this study reports demand elasticities for eighteen table cuts of meats. The study is also unique in that it uses a relatively recent survey of households' incomes and weekly expenditures and it incorporates stratification variables into the analysis. Not treating the data as a stratified sample results in parameter estimates that may not only be biased (not be representative of the population) but also have incorrect standard errors. Given that the study employs cross-sectional survey data that is representative of the entire target population (i.e., Mexican meat-consuming households) and applies estimation techniques from stratified sampling theory, the elasticities reported can be interpreted as census estimates. Finally, data issues, such as censored observations and the number of adult equivalents, are incorporated into the analysis as well. This study has also the advantage of using a consistent two-step estimation procedure of a censored demand system. Since the data used in the study is not a simple random sample but a stratified one, the study incorporates estimation techniques from stratified sampling theory. For instance, it incorporates stratification variables (strata and weight) in preliminary data preparation, in each of the two-step estimation procedure, and in computing standard errors.

Furthermore, this study also has the advantage of having used data at the household level, which provides additional insights about the nature of the demand for meat. By analyzing individual households with micro-data, microeconomic models enable better estimation of demand parameters and improvement of forecasts over those using macro-data, which assumes aggregate household behavior is the outcome of the decision of a representative household. Consequently, the demand elasticity estimates reported in this study might be more precise than the aggregated estimates reported in previous studies. More importantly, the study may be used to perform a forecast and simulation analysis of Mexican meat consumption at the table cut level. That is, the study may be helpful in identifying current and future trends and growth rates in consumption and imports of specific table cuts of meats in Mexico.

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Appendix

Table 5. ML Parameter Estimates from Univariate Probit Regressions (Step 1)

Var.	Beefsteak		Ground Beef		Other Beef		Beef Offal		Pork Steak	
	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.	Param. Est.	Bootstr. Std. Err.
cont.	-0.6046	0.5169	-0.7441†	0.4906	-0.2887	0.5569	-0.6048	0.6586	0.4161	0.7201
p_1	-0.0011	0.0016	0.0047*	0.0017	-0.0047*	0.0018	-0.0005	0.0026	-0.0016	0.0020
p_2	0.0012	0.0023	-0.0012	0.0033	-0.0063*	0.0025	-0.0019	0.0033	-0.0038	0.0032
p_3	-0.0010	0.0019	-0.0000	0.0018	-0.0005	0.0022	-0.0008	0.0032	0.0017	0.0025
p_4	-0.0028	0.0029	-0.0036	0.0035	0.0064‡	0.0036	0.0007	0.0060	-0.0067†	0.0043
p_5	0.0101‡	0.0058	-0.0007	0.0040	0.0057†	0.0039	-0.0079†	0.0062	0.0026	0.0073
p_6	-0.0091*	0.0031	-0.0032	0.0034	-0.0069*	0.0034	0.0016	0.0037	-0.0060	0.0050
p_7	0.0084	0.0066	0.0082	0.0062	0.0003	0.0083	0.0028	0.0083	-0.0046	0.0100
p_8	0.0030†	0.0021	-0.0019	0.0021	-0.0055*	0.0028	-0.0001	0.0045	-0.0007	0.0029
p_9	0.0011	0.0010	0.0002	0.0010	-0.0014†	0.0009	-0.0065*	0.0029	0.0003	0.0013
p_{10}	0.0012	0.0013	0.0015	0.0013	0.0011	0.0012	-0.0007	0.0023	-0.0067*	0.0023
p_{11}	0.0007	0.0025	0.0007	0.0027	-0.0070*	0.0026	-0.0020	0.0037	0.0031	0.0040
p_{12}	-0.0008	0.0009	-0.0021†	0.0014	0.0003	0.0008	-0.0030†	0.0020	-0.0024†	0.0017
p_{13}	-0.0011	0.0019	-0.0024	0.0019	-0.0007	0.0020	0.0005	0.0026	-0.0046†	0.0033
p_{14}	-0.0002	0.0021	0.0001	0.0029	0.0015	0.0022	-0.0018	0.0041	-0.0048	0.0037
p_{15}	0.0029	0.0034	0.0057	0.0039	0.0064	0.0045	0.0012	0.0048	0.0047	0.0043
p_{16}	-0.0057*	0.0019	-0.0057*	0.0021	-0.0016	0.0018	0.0005	0.0028	-0.0037†	0.0027
p_{17}	0.0000	0.0011	0.0009	0.0011	0.0006	0.0012	-0.0040‡	0.0021	0.0007	0.0011
p_{18}	-0.0092*	0.0020	-0.0128*	0.0020	-0.0062*	0.0018	-0.0016	0.0024	-0.0061*	0.0028
m	0.0112*	0.0027	0.0085*	0.0006	0.0097*	0.0006	0.0037*	0.0009	0.0045*	0.0007
NE	-0.2030‡	0.0998	-0.1764†	0.1256	0.2429*	0.1046	-0.0361	0.1626	-1.1071*	0.1617
NW	0.0207	0.1259	1.1140*	0.1447	0.6158*	0.1393	0.0177	0.2380	-1.3065*	0.2121
CW	0.3399*	0.1007	0.1291	0.1031	0.2278*	0.0925	-0.3667*	0.1408	-0.4446*	0.1182
C	0.1808‡	0.0967	0.2106‡	0.1051	0.2959*	0.1058	0.0590	0.1413	-0.1934†	0.1313
urban	0.4952*	0.0590	0.5259*	0.0601	0.1378*	0.0589	0.1952*	0.0902	0.3051*	0.0826

Note: Number of bootstrap resamples = 1,000. Bootstrap significance levels of 0.05, 0.10 and 0.20 are indicated by asterisks (*), double daggers (‡) and daggers (†) respectively.

Table 6. Probability of Consuming Meat Cut i by Region

Table entries estimate $P(d_i = 1|\mathbf{z}_i)$.

	NE	*NW*	*CW*	*C*	*SE*	Mexico	Min.	Max.
$P(d_1 = 1\|\mathbf{z}_1)$	0.3621	0.3202	0.4923	0.4126	0.3386	0.3977	0.3202	0.4923
$P(d_2 = 1\|\mathbf{z}_2)$	0.1590	0.3928	0.1596	0.1457	0.1159	0.1757	0.1159	0.3928
$P(d_3 = 1\|\mathbf{z}_3)$	0.2352	0.2348	0.1630	0.1601	0.1555	0.1753	0.1555	0.2352
$P(d_4 = 1\|\mathbf{z}_4)$	0.0535	0.0392	0.0257	0.0560	0.0538	0.0463	0.0257	0.0560
$P(d_5 = 1\|\mathbf{z}_5)$	0.0173	0.0076	0.0418	0.0541	0.0819	0.0487	0.0076	0.0819
$P(d_6 = 1\|\mathbf{z}_6)$	0.0391	0.0549	0.0869	0.0615	0.1109	0.0758	0.0391	0.1109
$P(d_7 = 1\|\mathbf{z}_7)$	0.0100	0.0076	0.0181	0.0256	0.0309	0.0216	0.0076	0.0309
$P(d_8 = 1\|\mathbf{z}_8)$	0.0625	0.0682	0.1371	0.1807	0.1318	0.1360	0.0625	0.1807
$P(d_9 = 1\|\mathbf{z}_9)$	0.2283	0.1989	0.2056	0.1882	0.1535	0.1887	0.1535	0.2283
$P(d_{10} = 1\|\mathbf{z}_{10})$	0.2131	0.1935	0.2710	0.3690	0.1477	0.2620	0.1477	0.3690
$P(d_{11} = 1\|\mathbf{z}_{11})$	0.1520	0.2385	0.1534	0.1572	0.0745	0.1480	0.0745	0.2385
$P(d_{12} = 1\|\mathbf{z}_{12})$	0.1437	0.0804	0.1350	0.2233	0.1503	0.1621	0.0804	0.2233
$P(d_{13} = 1\|\mathbf{z}_{13})$	0.3034	0.2600	0.2016	0.5468	0.2906	0.3552	0.2016	0.5468
$P(d_{14} = 1\|\mathbf{z}_{14})$	0.1997	0.1696	0.3597	0.2481	0.4859	0.3128	0.1696	0.4859
$P(d_{15} = 1\|\mathbf{z}_{15})$	0.0128	0.0277	0.0247	0.0855	0.0613	0.0532	0.0128	0.0855
$P(d_{16} = 1\|\mathbf{z}_{16})$	0.2921	0.2189	0.1520	0.1052	0.1217	0.1487	0.1052	0.2921
$P(d_{17} = 1\|\mathbf{z}_{17})$	0.2784	0.2008	0.2437	0.2394	0.2629	0.2436	0.2008	0.2784
$P(d_{18} = 1\|\mathbf{z}_{18})$	0.0694	0.0102	0.0476	0.0209	0.0670	0.0396	0.0102	0.0694

Note: i = 1, 2, …, 18, where 1 = beefsteak, 2 = ground beef, 3 = other beef, 4 = beef offal, 5 = pork steak, 6 = pork leg and shoulder, 7 = ground pork, 8 = other pork, 9 = chorizo, 10 = ham, bacon and similar products from beef and pork, 11 = beef and pork sausages, 12 = other processed beef and pork, 13 = chicken legs, thighs and breasts, 14 = whole chicken, 15 = chicken offal, 16 = chicken ham and similar products, 17 = fish, and 18 = shellfish.

Table 7. SUR Parameter Estimates from System of Equations (Step 2)

Variable	Beefsteak ($i=1$) Param. Est.	Beefsteak ($i=1$) Bootstr. Std. Err.	Ground Beef ($i=2$) Param. Est.	Ground Beef ($i=2$) Bootstr. Std. Err.	Other Beef ($i=3$) Param. Est.	Other Beef ($i=3$) Bootstr. Std. Err.	Beef Offal ($i=4$) Param. Est.	Beef Offal ($i=4$) Bootstr. Std. Err.	Pork Steak ($i=5$) Param. Est.	Pork Steak ($i=5$) Bootstr. Std. Err.
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)$	1.6951*	0.3939	0.6607	0.4387	2.0916*	0.7051	13.0161	16.0844	1.5472†	0.8903
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_1$	-0.0038*	0.0015	-0.0002	0.0007	-0.0038*	0.0022	-0.0057	0.0080	0.0051†	0.0040
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_2$	0.0000	0.0008	-0.0130*	0.0046	0.0053*	0.0031	0.0176	0.0230	0.0022	0.0069
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_3$	-0.0016*	0.0007	-0.0005	0.0006	-0.0109*	0.0040	0.0035	0.0090	-0.0019	0.0028
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_4$	0.0008	0.0013	0.0006	0.0016	-0.0019	0.0026	-0.0497*	0.0168	0.0075	0.0115
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_5$	-0.0067*	0.0024	0.0022†	0.0023	0.0044†	0.0050	0.0504	0.0884	-0.0235*	0.0105
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_6$	0.0050*	0.0021	0.0030‡	0.0016	0.0009	0.0044	-0.0061	0.0183	0.0027	0.0108
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_7$	-0.0072*	0.0021	-0.0011	0.0027	-0.0236*	0.0080	-0.0320	0.0333	-0.0017	0.0090
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_8$	-0.0020*	0.0007	0.0014	0.0011	-0.0036	0.0034	-0.0006	0.0036	0.0045‡	0.0025
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_9$	-0.0007*	0.0003	-0.0002	0.0002	0.0021	0.0022	0.0528	0.0738	-0.0024‡	0.0014
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{10}$	-0.0009‡	0.0004	-0.0003	0.0004	-0.0003	0.0009	0.0035	0.0077	0.0062	0.0115
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{11}$	-0.0007	0.0007	-0.0009	0.0007	0.0070*	0.0030	0.0208	0.0238	-0.0035	0.0055
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{12}$	0.0005	0.0004	0.0007	0.0006	-0.0008†	0.0007	0.0192	0.0345	0.0028	0.0043
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{13}$	-0.0014*	0.0008	0.0009	0.0011	-0.0025‡	0.0017	-0.0097†	0.0069	0.0052	0.0080
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{14}$	-0.0002	0.0005	0.0017	0.0022	-0.0008	0.0011	0.0085	0.0202	0.0021	0.0087
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{15}$	-0.0018†	0.0010	-0.0011	0.0009	-0.0006	0.0027	-0.0026	0.0171	-0.0043	0.0071
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{16}$	0.0032*	0.0011	0.0014	0.0011	0.0019†	0.0014	-0.0053	0.0066	0.0090	0.0069
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{17}$	-0.0002	0.0007	-0.0007‡	0.0004	-0.0016†	0.0010	0.0206	0.0455	-0.0009	0.0013
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,p_{18}$	0.0049*	0.0016	0.0021	0.0017	0.0014	0.0021	0.0162	0.0179	0.0058	0.0103
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,m$	-0.0003	0.0018	0.0005	0.0009	0.0010	0.0020	-0.0215	0.0410	-0.0033	0.0072
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,NE$	0.1933*	0.0552	0.1172*	0.0624	0.1733‡	0.1201	-0.2618	0.4762	0.9236	1.9232
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,NW$	0.0432	0.0487	-0.0280	0.1539	-0.0402	0.1721	-1.1865*	0.4623	1.4056	2.2352
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,CW$	-0.0888	0.0734	-0.0384	0.0437	-0.0149	0.0911	2.0145	4.2729	0.5291	0.7748
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,C$	-0.0698	0.0504	0.0683†	0.0541	0.1229	0.1251	-0.9158	0.7403	0.1874	0.3540
$\Phi(\mathbf{z}_i'\hat{\alpha}_i)\,urban$	-0.2890*	0.0938	-0.1448†	0.0895	-0.0609	0.0614	-1.4360	2.2463	-0.2713	0.5124
$\phi(\mathbf{z}_i'\hat{\alpha}_i)$	-0.8134*	0.2837	-0.1105	0.1768	-0.3410	0.3433	-8.2907	13.4497	-1.1200	1.9879

Note: Number of bootstrap resamples = 1,000. Bootstrap significance levels of 0.05, 0.10 and 0.20 are indicated by asterisks (*), double daggers (‡) and daggers (†) respectively.

Table 8. Marshallian Price Elasticities

i\j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	-1.0270*	0.1874†	-0.4383*	-0.1690	0.1565	-0.3042†	-0.1590	0.0375	0.0174	-0.0030	-0.0186	-0.0346	-0.2778*	-0.0361	0.0325	-0.1666†	-0.0394	-0.6354*
2	0.3941*	-3.4594*	-0.1164	-0.1068	0.4419	0.3923	0.3808	0.1548	-0.0236	0.0619	-0.0916	-0.0081	0.0032	0.2245	0.1064‡	-0.1294	-0.0950	-0.9724*
3	-1.2609*	0.2100	-1.7451*	0.2404	1.2346*	-0.5032	-3.3987*	-1.0235*	0.1885	0.0609	0.2369	-0.1490	-0.3109*	0.0158	0.2704	0.1163	-0.1758	-0.6919*
4	-1.8100*	0.4889	-0.3440	-4.8186*	-1.3840	0.8117†	-1.5508	-0.2194	0.6108	-0.2380	0.5040	-0.7262‡	-0.6557‡	-0.4232†	0.4998	-0.2088	-1.3958*	1.1782
5	0.7866	-0.7295†	0.0720	-0.2287	-4.4711*	-1.1063	-1.6662†	0.7246†	-0.4432†	-0.5834‡	0.0896	-0.1335	-0.1423	-0.5410†	0.2138†	0.8314*	0.0147	-0.9145†
6	-1.2086*	-0.5236	0.0135	0.4876†	-0.7959	-4.8375†	0.9168	0.3153	-0.1748	-0.3171	0.0492	0.5835*	0.1087	-0.4584†	0.0094	0.1924	0.1516	0.3673
7	-2.4904*	-0.5660	0.2482†	0.1254	-1.9010	-0.8229	-15.9428‡	-0.2945	0.1764	-0.0677	0.6991‡	-1.4896*	-0.2333	-0.5569†	-0.3212	-0.6395	-0.4851†	-0.6696
8	-0.1314	0.4929	0.3194	0.3868†	1.4251‡	1.6971*	-1.9708†	-8.3019*	0.6219	0.0730	0.5472	-0.4080	-0.2200	-0.3565†	0.0529	-0.8650†	-0.2177	0.4907
9	0.1705	-0.0911	0.1114	-0.0318	0.9794‡	-0.3901	0.0174	-0.1277	-1.2275*	-0.6150	-0.0932	-0.3774*	-0.1623	-0.2235†	-0.3070*	-0.3966†	-0.0510	0.0536
10	0.2400†	-0.7629*	0.4232*	-0.2591	0.1586	0.1704	-1.3375*	0.1069	0.0478†	-0.7832*	0.2719‡	0.2156	0.0995	0.1305‡	-0.4764*	0.2149	0.0845‡	0.4884
11	-0.3879*	-0.1636	0.1905*	-0.5674‡	1.0437*	-0.8304‡	0.4634†	0.6703*	0.0787‡	-0.0091	-1.8406†	-0.1287‡	-0.0014	-0.1101	-0.2771	0.3034	0.2344*	0.6494
12	0.1538	-0.7593†	0.0713	-1.2194*	-2.2317*	0.0021	0.5628	-0.3655	0.1009	-0.6053*	0.0806	-3.1156*	0.5946*	-0.0236	-0.6132*	0.2790‡	0.0330	0.3075
13	-0.2773‡	0.0030	0.0300	-0.4099*	0.2920	0.3180†	0.6752*	-0.0566	0.0603	0.1820*	-0.0051	0.1125	-1.2841*	-0.1555*	-0.0368	0.1865‡	0.0551†	0.0615
14	0.3895†	-0.3419†	-0.2401	-0.1481‡	-0.0380	0.0698	-0.2241	0.0332	-0.0866	-0.2281†	-0.1014	0.0320	0.0290	-1.2640*	0.1768†	-0.0120	-0.7013*	-0.0068
15	0.0033	0.2217	0.0484	0.3276	0.7168	0.4577	-1.7283	0.1402	-2.0678	-2.6776	1.0031	0.2440	-0.1783	-0.2035	-9.1730*	1.1161†	-0.4770	-0.0833
16	-0.0592	0.2251	0.0547	0.1362	2.1079*	0.2196	-1.7323*	0.6956†	0.0533	0.1333	0.2558†	0.0448	0.2076†	0.0365	0.1239	-1.2713*	0.0404	0.1742
17	-0.0347	-0.1137	0.0638	-0.1373	0.9090*	-0.6018†	-1.6105‡	0.1549	-0.0718	0.2375†	0.1125	0.0456	-0.0525	0.1371	0.2298‡	0.1382	-0.9825*	0.6658*
18	-1.0742‡	0.5885†	-0.6597*	0.1389	0.8832	0.3021	0.2106	-0.5493	0.0255	0.2046	0.4451†	0.0774	-0.1591	-0.0278	0.1831	1.1353‡	-0.0001	-7.5997*

Table 9. Hicksian Price Elasticities

i\j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	-0.8317*	0.2510‡	-0.3507*	-0.1528	0.1727	-0.2745	-0.1534	0.0933	0.0527†	0.0471	0.0054	0.0143	-0.1292‡	0.0772	0.0506	-0.1248	0.0591	-0.6028*
2	0.4990*	-3.4253*	-0.0693	-0.0981	0.4506	0.4083	0.3838	0.1848	-0.0046	0.0888	-0.0787	0.0182	0.0830	0.2853†	0.1161‡	-0.1069	-0.0421	-0.9549*
3	-1.1152*	0.2574	-1.6797*	0.2525	1.2467*	-0.4810	-3.3945*	-0.9820*	0.2148	0.0983	0.2549†	-0.1125	-0.2001†	0.1003†	0.2839	0.1475	-0.1023	-0.6676‡
4	-1.6814*	0.5308	-0.2862	-4.8079*	-1.3733	0.8313†	-1.5471	-0.1827	0.6341	-0.2050	0.5199	-0.6940‡	-0.5577†	-0.3486	0.5117	-0.1812	-1.3309*	1.1997
5	0.8650	-0.7040†	0.1072	-0.2222	-4.4646*	-1.0944	-1.6640†	0.7470†	-0.4291†	-0.5633‡	0.0993	-0.1139	-0.0827	-0.4956†	0.2210†	0.8482*	0.0542	-0.9014
6	-1.1054*	-0.4900	0.0598	0.4962†	-0.7873	-4.8218†	0.9197	0.3448	-0.1562	-0.2907	0.0619	0.6093*	0.1872	-0.3985†	0.0190	0.2144	0.2036†	0.3845
7	-2.4533*	-0.5540	0.2649†	0.1284	-1.8980	-0.8173	-15.9417‡	-0.2839	0.1831	-0.0582	0.7037‡	-1.4803*	-0.2051	-0.5354†	-0.3177	-0.6316	-0.4664†	-0.6634
8	-0.0155	0.5306†	0.3714	0.3964†	1.4347‡	1.7147*	-1.9675†	-8.2689*	0.6428	0.1027	0.5615	-0.3790	-0.1318	-0.2892	0.0636	-0.8402†	-0.1592	0.5101
9	0.2947†	-0.0507	0.1672	-0.0215	0.9897‡	-0.3712	0.0210	-0.0922	-1.2050*	-0.5832	-0.0779	-0.3463‡	-0.0678	-0.1515	-0.2955*	-0.3701†	0.0116	0.0743
10	0.3313*	-0.7333*	0.4641*	-0.2516	0.1662	0.1843	-1.3349*	0.1329	0.0643‡	-0.7598*	0.2831*	0.2385	0.1688‡	0.1835*	-0.4679*	0.2344†	0.1305*	0.5036†
11	-0.3331‡	-0.1458	0.2151*	-0.5628‡	1.0483*	-0.8221‡	0.4655†	0.6859*	0.0886*	0.0049	-1.8339†	-0.1150‡	0.0403	-0.0783	-0.2720	0.3151	0.2621*	0.6585
12	0.2254	-0.7360†	0.1034	-1.2135*	-2.2258*	0.0130	0.5649	-0.3451	0.1138	-0.5869‡	0.0894	-3.0977*	0.6491*	0.0179	-0.6066*	0.2944‡	0.0691	0.3194
13	-0.1541	0.0431	0.0852	-0.3996*	0.3023	0.3368†	0.6788*	-0.0214	0.0825†	0.2136*	0.0101	0.1434	-1.1904*	-0.0840‡	-0.0254	0.2129*	0.1173*	0.0821
14	0.5252*	-0.2978†	-0.1793	-0.1368†	-0.0267	0.0905	-0.2202	0.0720	-0.0621	-0.1933	-0.0847	0.0659	0.1323†	-1.1853*	0.1894†	0.0170	-0.6328*	0.0158
15	0.1260	0.2615	0.1034	0.3378	0.7270	0.4764	-1.7247	0.1752	-2.0457	-2.6461	1.0182	0.2747	-0.0850	-0.1323	-9.1617*	1.1423†	-0.4151	-0.0629
16	0.0082	0.2470	0.0849	0.1417	2.1135*	0.2299	-1.7304*	0.7149†	0.0655	0.1506	0.2641†	0.0617	0.2588‡	0.0755	0.1301	-1.2569*	0.0743	0.1854
17	0.1051	-0.0683	0.1265	-0.1257	0.9207*	-0.5805†	-1.6065‡	0.1949	-0.0465	0.2733‡	0.1298	0.0806	0.0539	0.2182	0.2427*	0.1681	-0.9119*	0.6891*
18	-0.9867†	0.6169†	-0.6204*	0.1462	0.8904	0.3154	0.2131	-0.5244	0.0413	0.2271	0.4559†	0.0993	-0.0925	0.0230	0.1912	1.1540‡	0.0440	-7.5851*

Note: i, j = 1, 2, …, 18, where 1 = beefsteak, 2 = ground beef, 3 = other beef, 4 = beef offal, 5 = pork steak, 6 = pork leg and shoulder, 7 = ground pork, 8 = other pork, 9 = chorizo, 10 = ham, bacon and similar products from beef and pork, 11 = beef and pork sausages, 12 = other processed beef and pork, 13 = chicken legs, thighs and breasts, 14 = whole chicken, 15 = chicken offal, 16 = chicken ham and similar products, 17 = fish, and 18 = shellfish. Number of bootstrap resamples = 1,000. Bootstrap significance levels of 0.05, 0.10 and 0.20 are indicated by asterisks (*), double daggers (‡) and daggers (†) respectively.

Table 10. Marshallian Beef-Price, Pork-Price, and Chicken-Price Elasticities in Mexican Meat Demand Studies

	Model	Period	Beef-Beef	Beef-Pork	Beef-Chicken	Beef-Fish
Henneberry and Mutondo (2009)[a]	SAIDS	1995-2005	-1.0330	0.1030	-0.1550	NA
Erdil (2006)[b]	AIDS	1961-1999	-0.4610	NA	NA	NA
Malaga, Pan, and Duch (2006)[c]	Censored QUAIDS	2004	-1.4300	0.0300	0.2700	NA
Dong, Gould, and Kaiser (2004)[d]	Censored AIDS	1998	-0.6276	-0.1014	0.0680	-0.0452
Golan, Perloff, and Shen (2001)[e]	Censored AIDS	1992	-1.0800	NA	NA	NA

	Model	Period	Pork-Beef	Pork-Pork	Pork-Chicken	Pork-Fish
Henneberry and Mutondo (2009)[a]	SAIDS	1995-2005	0.0490	-0.9230	-0.2280	NA
Erdil (2006)[b]	AIDS	1961-1999	NA	-0.0180	NA	NA
Malaga, Pan, and Duch (2006)[c]	Censored QUAIDS	2004	0.1000	-1.5100	0.2600	NA
Dong, Gould, and Kaiser (2004)[d]	Censored AIDS	1998	-0.3670	-0.1322	-0.1056	-0.0507
Golan, Perloff, and Shen (2001)[e]	Censored AIDS	1992	NA	-0.5600	NA	NA
Dong and Gould (2000)[f]	Double-Hurdle	1992	NA	0.0270	NA	NA

	Model	Period	Chick-Beef	Chick-Pork	Chick-Chick	Chick-Fish
Henneberry and Mutondo (2009)[a]	SAIDS	1995-2005	-0.1410	-0.3380	-0.6540	NA
Erdil (2006)[b]	AIDS	1961-1999	NA	NA	-0.2200	NA
Malaga, Pan, and Duch (2006)[c]	Censored QUAIDS	2004	0.5300	0.1200	-1.4300	NA
Dong, Gould, and Kaiser (2004)[d]	Censored AIDS	1998	0.1064	-0.0274	-0.8251	-0.0818
Golan, Perloff, and Shen (2001)[e]	Censored AIDS	1992	NA	NA	-0.6400	NA
Dong and Gould (2000)[f]	Double-Hurdle	1992	NA	NA	-0.1300	NA

[a] Henneberry and Mutondo (2009) used a source-differentiated almost ideal demand system to estimate meat demand in the U.S., Canada, and Mexico. They reported elasticities for beef, pork, and poultry.
[b] Erdil (2006) did not explain whether Marshallian or Hicksian own-price elasticity. He also reported own-price elasticity of ovine meat.
[c] Malaga, Pan, and Duch (2006) also estimated censored LA/AIDS and QUAIDS models for the years 1992, 1994, 1996, 1998, 2002.
[d] Dong, Gould, and Kaiser (2004) extended the Amemiya-Tobin approach to demand systems estimation using an AIDS specification. They reported simulated Marshallian price elasticities of beef, pork, poultry, processed meat and seafood.
[e] Golan, Perloff, and Shen (2001) used a generalized maximum entropy (GME) approach to estimate a nonlinear version of the AIDS with nonnegativity constraints. They reported elasticities for beef, pork, chicken, processed meat, and fish.
[f] Dong and Gould (2000) provided estimates of unit value impacts on quantity demanded of poultry and pork.

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Understanding Markets for Grass-Fed Beef: Taste, Price, and Purchase Preferences

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Abstract

We use results of a consumer taste test conducted in Portland, Oregon, and choice-based conjoint analysis to examine consumer attitudes about grass-fed beef compared to conventional grain-fed: taste preferences, willingness to pay, and willingness to buy frozen meat in bulk. We consider the effect of demographic, attitudinal, and shopping location characteristics of consumers. A baseline, uninformed consumer will pay \$0.90-\$0.94/pound more for grass-fed ground beef; knowledge about production and nutritional factors increases the premium. A majority of participants would buy in bulk if they knew a producer or a friend referred them; 72% will buy frozen beef.

Keywords: grass-fed beef, consumer preference, conjoint analysis, willingness to pay, freezer beef

[1] Lead authorship is shared by the first two authors.

Introduction

Increased consumer interest in grass-fed, naturally raised, locally produced meats is based on perceptions and evidence about "healthier" fats, reduced environmental impacts, and increased animal welfare associated with meats not raised in confinement systems on grain-based diets (Daley et al. 2010; National Trust 2012; Schmidt 2010; Umberger et al. 2009; Varnold et al. 2011); this interest is also part of the broader local food movement (Martinez et al. 2010). Livestock producers who would like to produce and sell grass-fed meats must carefully weigh the risks of shifting their production and marketing systems, given the significant and often costly supply chain challenges of getting this type of meat to market. Knowing, in general, that consumer demand for grass-fed is "up" is not enough: producers require geographically relevant information not only about consumer demand and price elasticity, but also how and where consumers will buy the product (such as by the cut or by the carcass, direct or at a store, at mainstream or natural food retailers).

Achieving the consumer-oriented convenience of conventional meats, sold fresh, by the cut, in vacuum packaging, year-round, is neither easy nor cost-effective for many small producers. Producers report that inventory management logistics and the need for a diversified customer base to sell the entire animal at a price point that will compensate for extra costs are two critical barriers to entry into this market niche (Fanatico and Rinehart 2006; Gwin 2009; Gwin, Evans, and Brewer 2011). Selling animals by the whole, half, or quarter, direct to consumers, in one delivery of frozen cuts, is one way small producers can avoid these two problems (Thiboumery and Lorentz 2009). Some restaurants have chosen to buy whole carcasses direct from farmers and ranchers; consumer interest in such "bulk" sales appears at least anecdotally to be rising (Jackson 2009). Yet it is unclear how many people, even those who buy local, grass-fed meat by the cut, are willing to purchase this way.

In this paper, we focus on a few key questions. What are consumer taste preferences and willingness to pay (WTP) for local grass-fed beef versus conventional grain-fed beef? Do those differ for consumers who shop primarily at natural food stores versus mainstream food stores? Are consumers willing to buy beef in bulk, and what demographic, attitudinal, or shopping location characteristics make them more or less willing? Our answers to these questions come from results of a consumer taste test we conducted in Portland, Oregon.

Our study provides several new insights into the market for grass-fed beef. First, we examine consumer interest in buying grass-fed beef in bulk, a valuable and potentially necessary strategy for direct sales by producers. Second, we expand understanding of WTP for grass-fed beef relative to conventional beef by exploring the effect of consumers' prior knowledge and uncovering the underlying consumer attitudes that result in WTP a premium for grass-fed beef. Finally, we expand understanding of the impact of taste preference on WTP by incorporating consumer ratings of the beef they tasted directly into the choice model.

Background

Understanding consumer WTP is very important to niche markets that rely on premium prices to compensate for higher production costs. It was once suggested the per pound cost of producing forage fed beef may be as much as 25% higher than producing conventional beef (Mayer 1999). Grass-fed production can be more expensive, especially in parts of the country with less year-round quality forage (Mathews and Johnson 2010). For example, an enterprise budget prepared for a California grass-fed enterprise notes that pasture can be the limiting factor for grass-fed systems, and that producers may need to increase grazing acreage, feed harvested forage, or decrease herd size, all of which add to costs; producers also assume additional risk when they retain ownership of cattle until finish weight (Larson, Thompson, Klonsky, and Livingston 2004). Yet even in circumstances and regions in which grass-fed beef is less expensive to produce than conventional beef, post-farmgate supply chain costs are still likely to be high, as for any smaller-scale, niche product (Gwin and Thiboumery 2012; Hardesty and Leff 2009; King et al. 2010). Producers must find a customer base that will pay a high enough price for the product to cover their costs and some profit margin. Identifying the price premium consumers will pay, as well as the types of consumers who will pay it and who will use a direct sales channel, is therefore essential to producers.

Other WTP research around natural and/or grass-fed beef has found varied responses. Studies that evaluated sensory properties in blind tests have generally found fewer US consumers prefer grass-fed to conventional beef – for example, Feuz and Umberger (2001) found that only 23% of consumers sampled in Chicago and San Francisco preferred grass-fed to corn-fed steaks. One reason is historic: U.S. consumers have long been habituated to the taste and eating experience of grain-finished beef. Another reason, research-specific, may be that studies have generally focused on muscle cuts (e.g. steaks) or ground beef made from a single muscle cut, often resulting in lower fat content for the grass-fed beef among other sensory differences (Cox et al. 2006; Feuz et al. 2004; Sitz et al. 2005; Xue et al. 2010). However, Cox et al. (2006) found that during a home-use test, the percentage of consumers preferring grass-fed beef increased and the significantly different preference for grain-fed was eliminated. The authors suggest that this is because home cooking eliminated some sensory differences. It is also important to keep in mind that even 23% of the national consumer base far exceeds the demand that can be satisfied by current domestic grass-fed supply. To satisfy annual market demand for 23% of the population would require about 6 million head of cattle/year. Yet the grass-fed sector currently harvests between 150,000 and 170,000 head of cattle per year (Williams 2010).

Providing consumers with information on production practices and/or nutritional properties affects WTP. Earlier studies in which consumers were informed about beef production method, specifically, what the cattle were fed, did not find a higher WTP for grass-fed. Yet in more recently conducted studies, providing production information increased WTP for grass-fed beef relative to grain-fed beef (Lusk and Parker 2009; McCluskey et al. 2005; Thilmany, Umberger, and Ziehl 2006; Umberger, Boxall, and Lacy 2009; Xue et al. 2010). McCluskey et al. (2005) found that consumers would choose beef with higher Omega-3 levels given information about its healthful properties. Umberger, Boxall, and Lacy (2009) also found that providing health information increased WTP. Conner and Oppenheim (2008) found that providing environmental and welfare information did not change WTP for pasture-raised meats, but as they noted, their study participants had pre-existing knowledge of and interest in environmental values and pasture-raised products.

Allowing consumers to taste samples also influences WTP. When included in consumer studies the sensory rating is generally the most important contributor to WTP. In several series of experiments auctioning two wines (Combris et al. 2009), WTP results were quite different for a blind tasting versus seeing origin-labeled products without tasting, but WTP from a tasting *and* origin labels closely followed WTP from the blind tasting: consideration of origin was of little importance relative to sensory evaluation. However, origin is primarily a signal of sensory quality and consumers valuation of grass-fed beef could be quite different even with equal liking as animal welfare or health properties might result in higher WTP. Marin and Durham (2007) found that sensory liking overrode quality perception perceived in natural corked versus screw-cap wines. The experimental auctions conducted by Umberger, Boxall, and Lacy (2009) to evaluate grass-fed beef premiums or discounts also included a tasting opportunity. They found that total bids and premiums, when positive, were lower when the participants tasted grass-fed steaks before bidding. Yet it is clear that at least a sub-population of consumers prefers the taste of grass-fed beef (Cox et al. 2006), which creates an opportunity to develop a niche market for that taste preference in addition to the value consumers place on production practices and possible health benefits. This is important information in evaluating a niche market for grass-fed beef.

Our study further explores the sensory ratings of consumers and also looks more carefully at the potential for a niche market for grass-fed beef by simulating product choice under a variety of conditions to differentiate market segments. Finally, our analysis accounts for a participant's prior knowledge of grass-fed beef: our WTP findings, higher than found in other, earlier studies, likely reflects an overall increase in consumer knowledge about grass-fed beef production and nutritional qualities. Consumers in earlier studies may truly have had no prior knowledge. We attempt to clarify the impact of prior and additional information.

Methods

A sensory consumer test was conducted at the Food Innovation Center in Portland, OR. Participants were selected using an on-line screener, which they found by word of mouth or through a Craig's List advertisement. Only consumers who eat ground beef in the form of burgers were selected. Through screening questions, a sample was recruited that was about equally split between people that shop in mainstream food stores and those that shop primarily at natural food stores and/or food cooperatives. This stratification of the sample was employed to ensure that sufficient variation was obtained in the characteristics of the consumers to evaluate how those characteristics might influence WTP for grass-fed beef. This information and related consumer characteristics are used in the econometric model to analyze WTP for grass-fed and conventional ground beef.

As is standard in consumer tests, the sensory evaluation took place first to avoid biasing the taste impression due to consumers guessing test intention and product source. On the test day, ground beef patties were prepared by weighing out approximately 3 oz. of raw product, which was then formed into a patty and refrigerated until just prior to cooking. Each patty was salted evenly across the top with 0.2g of salt. Ground beef samples were baked on parchment paper on a sheet tray of 10 samples per tray, in a 450° F oven to an internal temperature of approximately 160° F. The samples were served to the consumer one to two minutes after portioning.

Participants were given two coded beef samples simultaneously on a tray. The first instruction was to cut the samples and give a color rating of each on a nine point scale; they were then asked to write down their taste preference (with a no preference option) and then to rate various quality characteristics (color, juiciness, tenderness) and their liking of each sample on a nine point scale ("dislike extremely" to "like extremely"). They recorded their liking rating according to its code before proceeding with the rest of the questions. This step allowed for the blind tasting aspect and normal sequence of the sensory test to be preserved while enabling the participants to refer to their liking rating later in the survey.

After the sensory questions were completed participants were asked several questions about their beef purchasing experience to gauge their willingness to buy beef directly from producers. They then answered six choice questions about which of the two samples they would choose to buy at various price combinations (with an option not to buy either). Before answering these choice questions they were told that one of the samples they tasted was grass-fed and the other conventionally produced. They were provided with the sample codes so that they could match each sample with their overall liking of that sample from the sensory evaluation. The participants were also split into two groups to receive either a low or a high information explanation of grass-fed and conventional production practices. The first briefly explained the forage diet of grass-fed beef[2] and the second added information about production practices and nutritional characteristics.[3] Only then did participants answer the six questions in which prices varied between the offerings. When those were completed, participants were presented with a paper ballot[4] with Likert scale questions to assess attitudes on the environment, health, animal welfare, food, and nutrition.

This procedure allowed us to analyze participants' propensity to choose grass-fed or conventional beef given (a) differences in both price and information about beef production methods, and (b) participants' individual characteristics, including their liking for the samples

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[2] Actual text: "The sample labeled Grass-fed came from an animal whose diet was only grass and forage. These animals cannot be fed grain or grain byproducts. The sample labeled Conventional means the beef was purchased at a retail supermarket from conventional sources."

[3] Actual text: "The sample labeled Grass-fed came from an animal whose diet was only grass and forage. These 'animals cannot be fed grain or grain byproducts and must have continuous access to pasture during the growing season.' Grass-fed beef has also been found to have higher levels of Omega-3 fatty acids which have been shown to reduce the risk of certain cancers and brain disorders. These cattle were also raised without antibiotics or hormones. The sample labeled Conventional means the beef was purchased at a retail supermarket from conventional sources. In the United States beef cattle are typically finished with a grain diet in a feedlot. Ground beef can come from a variety of sources and may come from dairy as well as beef cattle."

[4] The paper ballot was used to save time on these questions.

they tasted. Consumer variable statistics and demographic information for our sample presented in Table 1.

Table 1. Model Variable and Demographic Information

Consumer characteristics variable	Description	Population (Std. Dev.) → Mean after Adjustment for Mainstream Shopper
LIK6	Liking (9 point scale) – 6 (like slightly)	6.07 (1.94) → 0.07
PRICE	Prices for beef, $2.50,$3.50,$4.50;$0 do not buy	2.33 (1.78)
MOR	More information (0=less information, 1=more)	0.509
NAT	Regular natural food store or food co-op shopper	0.554
KNB	Prior Knowledge of Grass Fed (0=Not at all 16.9%, 1=Somewhat 67.0%, 2=Very well informed 16.1%)	0.991 (0.575)
ORU	Organic buying loyalty (% of produce purchases) (adjusted to make ORU=0 for non-natural store shopper)	47 (27) → 18.9
AGU – age	Distribution of Age Range Selected by Individual	41.4 (14) → -2.96
	18-24 25-29 30-34 35-39 40-45 45-49	
	8.9% 15.2% 16.1% 8.0% 10.7% 10.7%	
	50-54 55-59 60-64 65-69 70+	
	8.9% 8.9% 7.1% 3.6% 1.8%	
INU - income in $10,000 units	Distribution of Income Range Selected by Individual	5.26 (3.3) → -0.047
	<$19,999 $20-$29,999 $30-39,999 $40-49,999	
	16.1% 10.7% 15.2% 13.4%	
	$50-59,999 $60-79,999 $80-99,999 $100,000+	
	10.7% 16.1% 8.0% 9.8%	
Factors (adjusted → to make factor value=0 for non-natural store shopper)		
SEU	Seasonal and Local Buyer	0 (1) → 0.430
ENU	Environment	0 (1) → 0.095
FDU	Nutrition Ingredient Concerns	0 (1) → 0.222
FRU	Farm Preservation	0 (1) → -0.067
DMU	Domestic Animal Welfare	0 (1) → 0.344
Non-Model Demographic Sample Distribution		
Gender	Female	0.500
Race or Ethnicity	White	0.917
	Black	0.009
	Asian	0.037
	Hispanic	0.018
	No answer	0.018
Education	High school	0.045
	Current student	0.098
	Two-year degree	0.205
	Bachelor's degree	0.411
	Advanced degree	0.241
Children	Presence of children in household = 1, No = 0	0.464

* Variables are adjusted to equal 0 for the baseline consumer who is a mainstream (not natural food store or food cooperative) shopper, age 41.3, income $53,100.

Results and Discussion

Taste Preferences

There was not a statistically significant preference for either the conventional or grass-fed ground beef. However, unlike similar studies, there was a slight, insignificant preference for grass-fed: 54% preferred the grass-fed ground beef, 44% preferred the conventional ground beef, and 2% had no preference. The two types of ground beef were rated similarly for overall liking.

Whether participants primarily shopped at natural food stores or mainstream food stores did not have a statistically significant effect on their taste preferences, though mainstream shoppers were found to have directionally higher overall liking for the grass-fed beef and rated it higher than conventional beef in terms of sensory attributes. This is interesting, because it suggests that natural food store shoppers aren't necessarily a target market for grass-fed producers.

Willingness to Pay

Factors influencing consumer preference for grass-fed or conventional ground beef are evaluated as a choice-based conjoint analysis (CBCA), following Lancaster's theory of value and random utility theory (Cohen 1997; Lancaster 1966; Louviere and Woodworth 1983; McFadden 1974). According to Lancaster's theory, a product's utility is an additive utility based upon the utility of the products' attributes. To measure that utility, a random utility model is typically used which assumes that the utility U_{ij} of an individual *i* for a product *j* is composed of systematic and random components. The systematic component v_{ij} is observable and a function of the product attributes and individual characteristics. The random component ε_{ij} is unobservable influences. The utility of good *j* for consumer *i* can be expressed as:

(1) $U_{ij} = v_{ij} + \varepsilon_{ij}$

Since only the systematic component of the model above is observable, it can be specified as a function of product attributes and individual characteristics:

(2) $v_{ij} = \alpha_j + \beta\, p_j + \gamma_j z_i + u_{ij}$

where α_j is the marginal utility obtained due to the attributes of choice *j*, β is the change in marginal utility due to price p_j, and γ_j is the change in marginal utility of an attribute due to individual characteristics.

We built two models to evaluate WTP for grass-fed beef and to examine the consumer characteristics that contribute to WTP a premium for grass-fed beef. The base model examines whether providing information about grass-fed beef production methods and potential health benefits increases WTP a premium for the grass-fed product. It also allows us to test whether self-assessed prior knowledge of grass-fed beef production (not at all, somewhat, or well-informed), regular food shopping location (natural store or mainstream), as well as price and liking could provide a simple way to examine grass-fed WTP. We developed a second, expanded model to look more closely at consumer attitudes that could lead to a preference for grass-fed beef.

In both WTP models, the attributes of the choices are production method (grass-fed or conventional) and price. Variables which vary among individuals are considered consumer characteristics. In the choice set for each participant, only relative price changed for each set of questions. The participants vary in characteristics provided by the screener, sensory liking, and information they provided (answers to questions) that could affect how they value grass-fed and conventional beef.

Prior to analysis, the grass-fed versus conventional attribute variable was effects coded, with the grass-fed variable coded as 1 for the grass-fed choice, 0 for the conventional choice and -1 for the do not buy choice. A do not buy variable is coded 1 for the do not buy choice and 0 for the other two choices. This arrangement allows the parameter estimates to be viewed against the conventionally produced choice as a baseline. The parameter on the 'Do not buy' variable can best be interpreted in this arrangement as representing the utility (or disutility) of not buying: it captures the utility of the conventional product to the baseline mainstream consumer, but it could also capture a desire to give an answer and thus cannot be considered as purely the conventional product value.[5] There are other equally correct approaches to coding the do not buy choice and product attributes that will produce the same predictions and log-likelihood values. Our primary reason for using this combination is to emphasize the difference between conventional and grass-fed. Price is entered in dollars per pound as shown to the participants, and at 0 for the do not buy choice.

The interactive consumer characteristic variables are created by multiplying the consumer characteristic variables by the effects coded grass-fed variable and additional effects are coded with a conventional variable (1 if conventional, 0 if grass-fed, and -1 on the do not buy choice). The effects coded variable for conventional product is used to create the interactive variables for conventional product for ease of interpretation.

Base Model

The base model (Table 2) restricts consumer differences (z_i) to how much they liked the respective beef product (LK6), whether they received high or low information (MOR), whether they considered themselves knowledgeable about grass-fed beef (KNU), and whether they were a natural store shopper (NAT).

In the models, explanatory variables are transformed to make the baseline consumer a "mainstream" consumer with respect to the Portland area: a consumer that declared no prior knowledge, got the low information treatment, and typically shops at a conventional supermarket. We also transformed the liking score by subtracting 6 (a rating of "like slightly") from the

[5] Note that because of the effects coding the full base 'utility' of the 'Do not buy' choice is the sum of its own parameter and the negative of the parameter for grass fed beef.

score which results in a value of 0 for the baseline consumer. Thus the baseline parameter values and inferred premiums are based on that individual with a liking level of "like slightly."

Table 2. Base Model

Variable	Parameter Estimate	Std. Error	Premium = Parameter / Price Par.	Variable Description
GRS	0.995 ***	0.329	0.94 ***	Grass-fed versus conventional
NONE	-2.444 ***	0.690		Not buy choice
PRICE	-1.061 ***	0.107		Price
Interactive Variables-Consumer Characteristics				
CNV*LK6	0.783 ***	0.101	0.74 ***	Liking (Like slightly=0) on Conventional
CNV*MOR	-0.054	0.189	-0.05	More production information on conventional
CNV*KNH	-0.445 **	0.185	-0.42 **	Knowledge of grass-fed on Conventional
CNV*NAT	0.315	0.196	0.30	Natural Store shopper on Conventional
GRS*LK6	0.511 ***	0.064	0.48 ***	Liking (Like slightly=0) on grass-fed
GRS*MOR	0.588 ***	0.157	0.55 ***	More information on grass-fed
GRS*KNH	0.620 ***	0.146	0.58 ***	Knowledge of grass-fed
GRS*NAT	0.169	0.160	0.16	Natural Store shopper on grass-fed

Log-Likelihood Constants only =-510.7
Log-Likelihood Model =-346.2
***Significant difference in impact between grass and conventional at 1% level, ** at 5% level, * at 10% level.

A significant positive (negative) parameter estimate for a variable means that the variable increases (decreases) the probability that the baseline mainstream consumer will choose that product. We estimate how much *more or less* a consumer will pay for the chosen product by dividing the characteristic parameter by the parameter estimate for PRICE. Because our effects coding makes the conventional product the baseline, the first value in the fourth column of Table 2, α_j/β from equation (2), is how much more the unknowledgeable, less informed, mainstream store shopping consumer is WTP for the grass-fed product than for the conventional product given equal liking. Premiums listed for interactive variables tell us how the grass-fed or conventional beef WTP value varies with those consumer characteristics.

Prior knowledge clearly matters. The consumer with some prior knowledge about grass-fed beef would pay \$0.55 per pound in addition to the \$0.94 cent premium for grass-fed and \$0.42 per pound less for the conventionally produced beef. If the knowledge variable is excluded from the model, a larger significant parameter for the natural store shopper would result, indicating that they are willing to pay significantly more for the grass-fed beef. Thus it appears that it is primarily the *knowledge* that the natural store shopper has that makes him/her willing to pay more. The consumer who received more detailed information about the two production practices would pay \$0.59 per pound more for the grass-fed and no more for conventional beef. As noted earlier, other studies have usually found information about production practices and health to increase WTP for grass-fed beef. As in other studies, we varied the information given to consumers and noted a WTP premium associated with more information.

Expanded Model

We developed a second, expanded model (Table 3) to look more closely at attitudes that could lead to a preference for grass-fed beef. This model allows us to examine which consumer characteristics change the utility of grass-fed versus conventional beef and thus identify which consumers are more likely to pay a premium for grass-fed.

Table 3. Expanded Model

Variable	Parameter Estimate		Std. Error	Premium = Parameter / Price Par.		Variable Description
GRS	1.073	***	0.358	0.90	***	Grass-fed versus conventional
NONE	-3.074	***	0.745			Not buy choice
PRICE	-1.199	***	0.119			Price
Interactive Variables-Consumer Characteristics						
CNV*LK6	0.716	***	0.105	0.60	***	Liking (Like slightly=0) on conventional
CNV*MOR	0.006		0.210	0.01		More information on conventional
CNV*KNH	-0.382	*	0.211	-0.32	*	Knowledge of grass-fed on conventional
CNV*AGU	0.034	***	0.009	0.03	***	Age in years on conventional
CNV*INU	-0.111	***	0.036	-0.09	***	Income on conventional
CNV*ORU	0.000		0.005	0.00		Organic purchasing level (%) on conventional
CNV*SEU	-0.016		0.107	-0.01		Seasonal/Local on conventional
CNV*FDU	-0.039		0.116	-0.03		Environmental buyer on conventional
CNV*FDU	-0.140		0.110	-0.12		Nutrition/Ingredient concern on conventional
CNV*FRU	-0.145		0.106	-0.12		Farm Preservation Concern on conventional
CNV*DMU	0.031		0.093	0.03		Animal Welfare concern on conventional
CNV*GBFU	0.013		0.008	0.01		Frequency of buying gr. beef on conventional
GRS*LK6	0.663	***	0.075	0.55	***	Liking (Like slightly=0) on grass-fed
GRS*MOR	0.515	***	0.178	0.43	***	More information on grass-fed
GRS*KNH	0.456	***	0.176	0.38	**	Knowledge of grass-fed on grass-fed
GRS*AGU	-0.007		0.008	-0.01		Age in years grass-fed
GRS*INU	0.080	***	0.030	0.07	***	Income ($10,000) on grass-fed
GRS*ORU	0.007	*	0.004	0.01	*	Organic purchasing level (%) on grass-fed
GRS*SEU	0.222	**	0.092	0.19	**	Seasonal/Local on grass-fed
GRS*ENU	0.124		0.088	0.10		Environmental buyer on grass-fed
GRS*FDU	-0.086		0.090	-0.07		Nutrition/Ingredient concern on grass-fed
GRS*FRU	-0.080		0.090	-0.07		Farm Preservation Concern on grass-fed
GRS*DMU	0.298	***	0.082	0.25	***	Animal Welfare concern on grass-fed
GRS*GBFU	0.002		0.006	0.00		Frequency of buying ground beef on grass-fed

Log-Likelihood Constants only =-510.7
Log-Likelihood Model =-312.0
***Significant difference in impact between grass and conventional at 1% level, ** at 5% level, * at 10% level.

The consumer attitudinal score variables for this model were developed using the Likert scale questions asked at the end of the consumer test. Those questions were reduced to representative scores using principal components analysis (PCA). The benefit of using PCA to assess attitudes is that multiple questions are used to measure an individual's level of concern or interest about an issue rather than relying on a single question, which might measure an individual's attitude less accurately due to the wording or context. PCA essentially distills multiple variables into a smaller number of related components. For this analysis the majority of the questions have been used and developed in previous studies. Durham (2007) used PCA to incorporate health concerns and environmental attitudes into analysis of what motivates organic purchases. That study drew upon Roberts (1996), who segmented consumers for their environmental orientations, and Kraft and Goodell (1993) who did the same for health conscious consumers. McCluskey, Durham, and Horn (2009) extended the question set to assess food interest and nutritional attitudes as well as concerns about animal welfare and farm preservation. For this study, some additional Likert questions were added to enhance assessment of domestic animal welfare concerns and food interest. See the appendix for the questions used and details on the methodology. The factor scores produced by the PCA and utilized in the analysis are defined as *Seasonal and Local Buyer* (SEU), *Environmentalism* (ENU), *Nutrition Ingredient Concerns* (FDU), *Farm Preservation* (FRU), and *Animal Welfare* (DMU) based on the questions contributing most strongly to the score.

As in the base model these variables are adjusted to a mainstream shopper baseline. This transformation is accomplished by taking the average attitudinal score for shoppers that did not select natural food supermarkets or food coops when reporting where they shopped (i.e., mainstream supermarket shoppers) and subtracting that average from the original attitudinal score. In the third column of Table 1, the first number reported is our study population's average for the variable followed by its standard deviation in parentheses. If those are followed by an arrow (→), the next number is the average once the transformation has taken place. For most of the attitudinal scores the mainstream supermarket shopper was below the sample population mean which was 0 since these are standardized variables. The other variables added to the model, age, income, and organic buying percentage are also transformed. Age is transformed by subtracting the mean age, income by subtraction of mean income (in $10,000 units), and organic percentage by its mean value for mainstream shoppers. The variables entered into the model are the effects coded grass-fed variable and price for each choice, a do not buy variable, and interactive variables created by multiplying the effects coded grass and conventional variables by the individual characteristics. As before the variables for liking of the respective products (LK6), more information received (MOR), and prior knowledge (KNU) are included, but not Natural Store Shopper; added to these are interactive with age, organic purchasing level, the five attitudinal scores (SEU, ENU, FDU, FRU, DMU), and frequency of ground beef consumption (GBFU).

In this model, the impact of knowledge drops off and is replaced by the actual attitudes associated with knowledge that might impact the grass-fed choice. Having more information is still important for grass-fed selection. We would note that attitudes about some topics are quite similar for mainstream and natural shoppers (for example, farm preservation), while these two groups vary more dramatically on others (for example, farm animal welfare). The two attitude scores that are influential include support for seasonal/local food and small businesses, and concern for farm animal welfare. Demographic variables that are influential include consumer age, which increased selection of conventional beef, and income, which increased preference for grass-fed and decreased preference for conventional, indicating wealth effects and/or that grass-fed is considered a premium product. More loyal organic produce consumption does not significantly impact the choice of either. As expected, liking remained a key and essentially equivalent influence on WTP for both types of beef.

Interestingly, the grass-fed to conventional WTP differential resulting from greater knowledge declines somewhat in this model. This indicates that the knowledge variable was encompassing the information from additional variables, which supports the idea that the attitudinal concern underlies the knowledge impact. We drop the natural store shopper variable from the expanded model because it was not significant once the prior knowledge variable was added to this model or the previous model.

Results indicated that participants were willing to pay a premium for grass-fed ground beef versus conventional, grain-fed beef. Mainstream food shoppers were willing to pay a premium of $0.94/pound. Natural food store shoppers could only be identified as willing to pay more for grass-fed beef in models which did not include the grass-fed knowledge or other more detailed consumer attitude variables, and even then the natural store shopper variable did not explain much of the premium. The natural store shopper variable by itself will be associated with many consumer characteristics, possibly including age and income as well as individual attitudes and beliefs. The consumer attributes more strongly associated with natural store shoppers than with mainstream store shoppers are those that were associated with higher willingness to pay for grass-fed beef. Other studies of WTP have noted that store type became less significant when attitudinal information was included in the model (McCluskey, Durham, and Horn 2009). Conner and Oppenheim (2008) found lower mean WTP for pasture raised livestock at grocery stores versus food co-operatives, associated with lower scores on health, animal welfare, and environmental concerns.

Figure 1 graphically depicts the relative impacts of consumer characteristics on WTP for the two types of beef sampled. Liking had the largest impact on WTP, yet the size of that impact did not differ significantly based on whether a sample was grain-fed or grass-fed.

WTP calculations can sometimes be questioned when consumers are not actually buying. However, research has shown that while the baseline total WTP may be biased upwards, the marginal difference between related goods is not (Lusk and Schroeder 2004). The possibility of bias in the baseline WTP is the reason for coding the variables in order to look at differences between conventional and grass-fed and what shifts the value of each rather than look at the overall price of either. The premiums and variation in value due to consumer heterogeneity are our focus.

While the relative premiums are of great interest, it may be more informative to look at how the basic model predicts how consumers will choose among grass-fed and conventional beef based on price and across the knowledge and information variables. These results are shown in Figures 2 and 3.

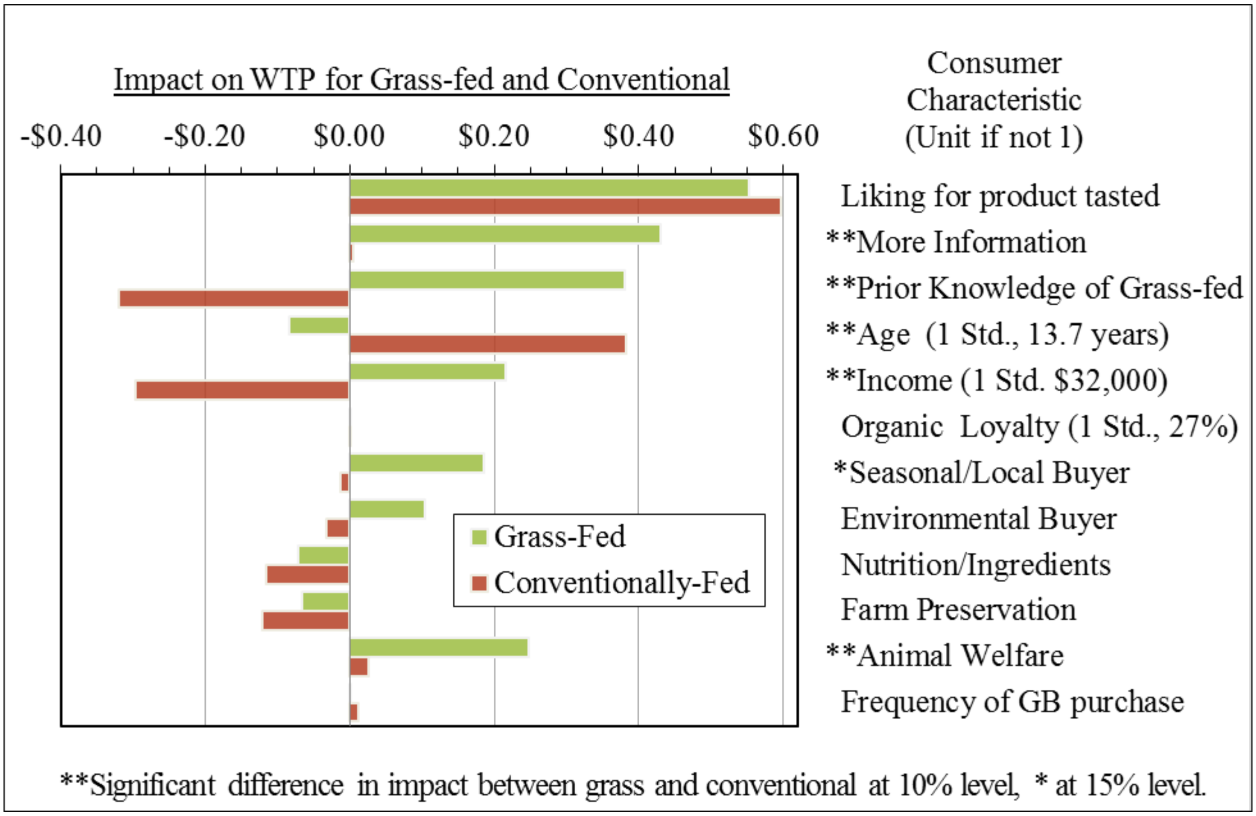

Figure 1: Impact of consumer characteristics on WTP

Figure 2 compares three of the possible price combinations used in the WTP choice set: conventional at $1 less than grass-fed at $3.50 per pound, both samples at $3.50 per pound, and grass-fed at $4.50 per pound with conventional at $2.50 per pound. When grass-fed is priced at $4.50 per pound and conventional at $2.50 per pound, a $2 per pound price difference, the model predicts that 48% would choose grass-fed, 37% would choose conventional, and 15% would not buy. This sizeable preference for grass-fed at a significantly higher price is likely influenced by the fact that our consumer sample had a high proportion of natural food shoppers, and half of them received additional information on grass-fed before making their choices.

Figure 3 shows the impact of information and prior knowledge. Consumers having some prior knowledge of grass-fed has a larger effect than if they are given more information in increasing the probability they will pay a premium for grass-fed beef. In the left hand pie chart we see that a smaller proportion would select the grass-fed at a $2 per pound price difference than in our unadjusted sample in the right hand pie chart in Figure 2, because for the pie chart on the left hand side of figure 3 the consumer depicted is our baseline mainstream shopper with no prior knowledge, who did not receive additional information, at the same price difference.

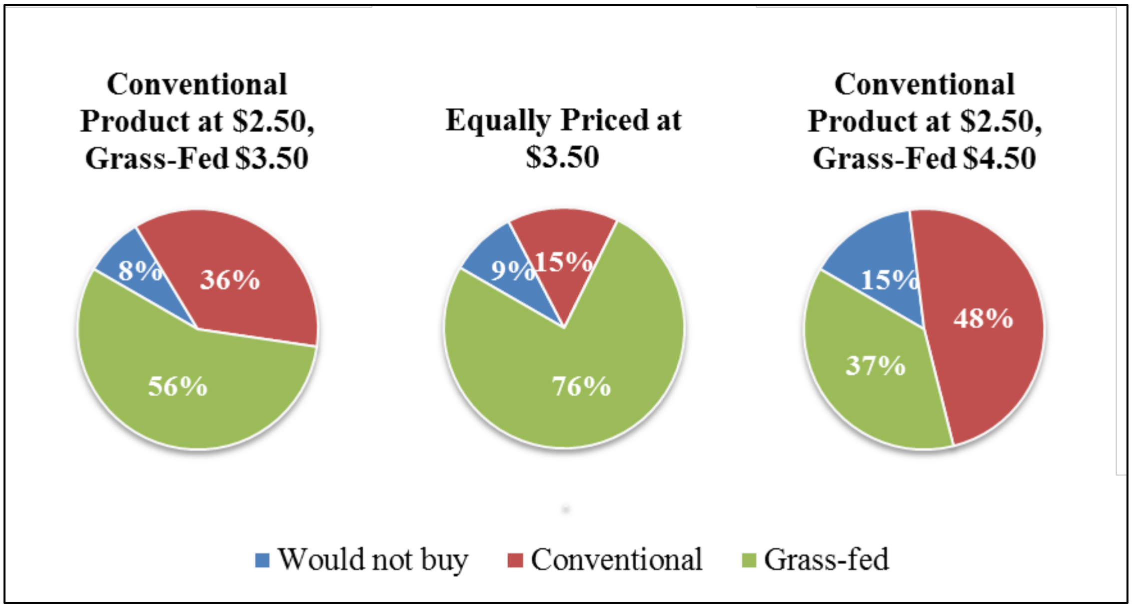

Figure 2: Impact of price: percent of consumers choosing grass-fed, conventional, or neither, at given prices

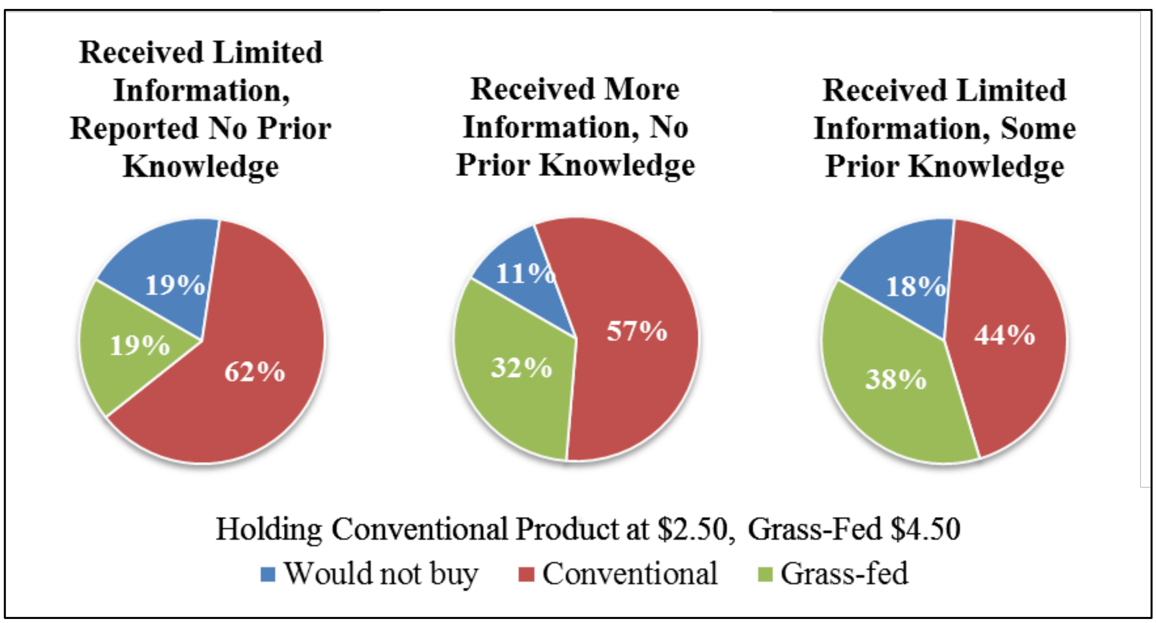

Figure 3: Impact of information and prior knowledge: percent of consumers by product choice

Our WTP results compared with other geographic areas

We expected to find WTP results that matched or exceeded those found from similar taste tests conducted elsewhere in the country, because our study area, Portland, Oregon, is a "leading trend" market in terms of natural, local/regional, and sustainable food, a characterization consistent with what we learned about our study participants. Most were aware of and interested in "sustainable" food production, including grass-fed meats, regardless of typical shopping location: 72% of mainstream food store shoppers said they were at least somewhat informed about the possible benefits of grass-fed beef and cattle production. Mainstream shoppers expressed a very favorable view of grass-fed beef: 86% perceived it as healthy, 60% as more humane than conventional beef, 62% as better for the environment than conventional beef, 50% as flavorful, and 56% as safe. A large majority – 64% of mainstream shoppers and 84% of natural food store shoppers – said that food safety concerns had had an impact on them, and a slight majority of all participants (51%) have switched to natural or organic beef in the last few years due to those concerns.

Given this consumer base, a higher-than-average WTP would not have been surprising. Indeed, compared with earlier studies, our results are much more favorable to grass-fed. Our study estimated WTP a premium of $0.90-94 per pound for grass-fed ground beef, approximately 35-40% higher than WTP for conventional at equal sensory liking. A decade ago, Feuz and Umberger (2001) found quite the opposite: WTP was 26% lower for grass-fed beef compared with grain-fed beef.

Yet when compared with more recent studies, our WTP results are fairly average. We expect this is due to an increase, over the last decade, in general consumer knowledge of grass-fed meat production and exposure to grass-fed meat products. More recent studies have found WTP premiums for grass-fed ranging from approximately -37% (Sitz et al. 2005) to about 180% (Evans, Brown, Collins, D'Souza, Rayburn, and Sperow 2011).[6] WTP results also vary based on whether the test is done with ground beef or muscle cuts (steaks): comparisons using steaks (Cox et al. 2006) found a smaller premium for grass-fed than comparisons using ground beef, as this study did. This is consistent with the fact that most U.S. consumers expect steaks to be marbled, for both flavor and marbling's relationship to tenderness; grass-fed steaks tend to be less marbled than grain-fed steaks. The difference is much less noticeable in ground beef, and our WTP results for grass-fed are much higher than when steaks were used (-9.5% and 3.0%; Cox et al. 2006). That our results were lower than those of other ground beef research (Evans et al. 2011) may in part be due to the other ground beef research being conducted not in a large metropolitan area but in a smaller, university town where participants may be more educated (even more so than in Portland) about alternative food choices in general and grass-fed specifically. It is also important to remember when comparing the size of WTP effects that there has been a great deal of heterogeneity in the WTP and preference literature related to alternative versus conventional meats, with respect to participants' demographic profiles, sample selection methodologies, and how premiums have been calculated.

[6] We calculated the -37% premium from domestic conventional WTP of $3.95 versus WTP of $2.48 for an Australian grass-fed sample (Sitz et al. 2005). We calculated the 180% premium from (Evans et al. 2011) ground beef estimates of $0.44 for grain-fed versus $1.23 for grass-fed.

The most distinguishing feature of our study, in comparison with others, is that we found prior knowledge, in lowering the value of conventional as well as raising the value of grass-fed beef, to be more influential than information provided during the test. Furthermore, few studies have considered whether interest in farm animal welfare is influencing consumer choice. While other studies have more clearly differentiated between production information and nutrition information, they have not examined consumer attitudes regarding production practices. In our model the factor representing concern about farm animal welfare is associated with a higher premium for grass-fed. Somewhat to our surprise, the nutrition and ingredient concern variable was not so associated. This may be explained by a more direct response through the information and knowledge premiums or because ground beef is not generally considered a health food.

Willingness to Buy in Bulk

To understand market potential, grass-fed beef producers and marketers need to have at least an estimate of how many consumers will pay how much of a price premium for their product. Yet information about demand based on purchase format – specifically, how many consumers are willing to buy frozen cuts in bulk (by the whole, half, or quarter carcass) – is almost as critical as price premium information, especially for small-scale operations selling fewer than 100 head per year. The significant cost associated with processing, packaging, distribution, inventory management, and retailer-required margins for small-volume, unconventional meats can drive up the overall cost of production, hence the price for consumers. Selling in bulk, direct to consumers, can lower these costs. But how many consumers are willing (and able) to buy in bulk?

Nearly a quarter of our study participants (24%) responded that they had previously purchased beef, as a whole, half, or quarter carcass, direct from a rancher, at least once, a surprisingly high result, even though the question was about beef in general and not only grass-fed beef. Of the other 76% who had not purchased beef this way, 69% would consider purchasing bulk beef if they knew a producer that sold it or if a friend recommended a source. Price matters, too: 73% would consider purchasing this way if it were less expensive than the beef they are currently buying. Also notable is that 72% of all participants were willing to purchase frozen beef. This creates more options for producers; fresh product is more perishable and must be sold much more quickly, which complicates distribution logistics.

Participants who had not yet purchased bulk beef were asked why (by selecting all that applied from a given set of potential reasons). The most chosen reason, selected by 58% of respondents to that question, was that there is too much meat associated with such a purchase; the second, selected by 55%, was that they lack the freezer space for so much meat. The “too much meat” problem is a serious challenge for producers: 50% of participants said they purchase three pounds of beef or less per month. At that rate, even a quarter of a beef (more than 100 pounds) would be fairly overwhelming.

Whether participants primarily shopped at natural food stores or mainstream food stores did not have a statistically significant effect on whether they had purchased beef in bulk or were willing to do so. Natural food store shoppers were more likely than mainstream shoppers to consider buying in bulk if they knew the producer. Only a few other factors were significantly related to willingness to buy in bulk: current bulk buyers tended to be older and shop at warehouse stores. Prospective bulk buyers tended to be older and eat more beef than average.

Conclusions

Our study of consumer preferences and WTP for grass-fed beef has four primary findings. First, our WTP results for grass-fed beef are within the bounds of those found elsewhere in the country, when compared only with more current studies. We suggest recent WTP estimates are higher than older studies due to an increase in general consumer knowledge about grass-fed over the years. Second, if participants in this study are representative of the Portland Metro region, there is significant interest in the region in buying beef in bulk, i.e., sacrificing some convenience to purchase grass-fed beef. Third, we confirm other research findings that whether a consumer typically shops at natural food stores or mainstream stores does not matter to WTP or willingness to buy in bulk. Fourth, we find that knowledge about production and nutritional qualities, and also attitudinal variables, are what matter instead. For example, the premium consumers are WTP for grass-fed beef increases when consumers know something about possible health benefits associated with it. When knowledge and attitudinal variables are known and included in the model, the effect of shopping location drops away.

We acknowledge that our results are drawn from a very small sample. Furthermore, our results may not extend far beyond the Portland metro region, except for other, similarly progressive, food-oriented areas. Most participants in our study had previously tried grass-fed beef, suggesting that this product is available and familiar locally and possibly that the participants are adventurous when it comes to food. Finally, our WTP/premium estimates, though relatively large, are not necessarily high enough to assure a profit for grass-fed producers. Producers will need to find consumers that are not only willing to buying grass-fed beef for its taste, production practices, and potential nutritional benefits, but are willing to pay enough of a premium to cover the additional production and supply chain costs for this unconventional product.

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Appendix

The following questions, listed by the score they contributed to most strongly, were included in the principal components analysis.

Domestic Animal Welfare: "It is important to treat farm animals humanely," "I'm concerned about the welfare of domestic farm animals," and "I buy free range chicken eggs."

Environmental: "I have switched products for environmental reasons," "I will not buy a product if the company who sells it is ecologically irresponsible," "I have purchased products because they cause less pollution," "I do not buy household products that harm the environment," "I have convinced members of my family or friends not to buy some products that are harmful to the environment."

Farm Preservation: "I'm concerned about the survival of family farms in the United States," "I am concerned about the loss of family farms in my region," "I would vote for referendums or initiatives to preserve farmland."

Health Concern (dropped from analysis because not significant): "I read more health-related articles than I did 3 years ago," "I worry that there are harmful chemicals in my food," "I'm concerned about my drinking water quality."

Nutrition/Ingredients: "I avoid foods from animals produced with hormones or antibiotics," "I am interested in information about my health," "I avoid foods containing nitrites or preservatives," "My daily diet is nutritionally balanced."

Seasonal Food/Local Business: "I buy 'environmentally friendly' products even if they are more expensive," "I buy from small and local businesses," "I seek out seasonal and local ingredients," "I like to eat out in restaurants that feature local and seasonal foods," "I buy food from local farms and ranches whenever I can."

A few questions contribute to more than one category: "I buy free range chicken eggs" contributes to Seasonal/Local; "I buy food from local farms and ranches whenever I can" contributes to Farm Preservation. The PCA was performed SAS 9.3 using the factor procedure, retaining eigenvalues greater than 1, with varimax rotation and Kaiser normalization. Additional details are available from the authors.

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Local Food in Maryland Schools: A Real Possibility or a Wishful Dream?

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Abstract

"Farm to school" and "farm to cafeteria" programs have proliferated around the United States. In 2008, Maryland passed the Jane Lawton Act, an unfunded program encouraging schools to serve Maryland produced food in schools. Like many other states, Maryland is seeking new markets, such as educational institutions, to enhance the viability of small and medium farms. However, school lunches are subject to numerous constraints, including regulations and budget concerns. Distribution channels for local food sales are not well developed. Thus the success of local food usage in Maryland schools program is not certain. Using primary quantitative and qualitative data collected by the research team, this paper identifies scale and socioeconomic barriers to the use of local food in schools. We posit that policy support and increased involvement by extension would enhance the likelihood of long term success of serving local food in schools.

Keywords: Local food, agriculture in the middle, farm to school, small farms, distribution of local food, school lunch, logistic model, farm to school, farm to cafeteria

Introduction

A national discussion about food is in process, with attention centering on the complementary themes of obesity, food quality, and nutrition. Prominent examples include the White House "Let's Move" campaign targeting childhood obesity, as well as Jamie Oliver's reality television show "Food Revolution," featuring students in West Virginia, who seemingly had not previously encountered fresh vegetables (Lee 2010; Hale 2010). By focusing on childhood obesity and health, these two separate activities direct attention to the nutritional quality of lunches served to children in K-12 schools. The ongoing debates about school lunches complement long running discussions about the U.S. food system, which extend beyond childhood obesity and health. One key aspect of the discussion targets consumers' knowledge wedge between the source of food (farms) and the food they eat (see for example, Hinrichs 2003). The argument is as follows: most food is bought in supermarkets, much of it packaged and not resembling the plant or animal it comes from, and consequently consumers have lost their connection to the land and the farmer. The last dimension of the food discussion results from the desire to preserve an agricultural sector that supports small and medium-sized farms, which have been declining in number across the nation.

The "farm-to-school" movement touches on each of these aspects of our food system, as reflected in the statement that such programs produce "*…healthy children, healthy farms, and healthy communities"* (farmtoschool.org). We prefer to think about the issue as "local food in schools," which recognizes that use of local food in school lunches does not have to rely on direct sales between farmers and schools. Serving locally produced food in school lunches can potentially accomplish several ends. First, through increased access to fresh and healthy foods, students may broaden their horizons and awaken a taste for different types of foods. Secondly, many farm-to-school programs contain an educational component, typically consisting of lessons or field trips to nearby farms, and fosters an understanding of the link between the farm and the food they eat. Finally, schools potentially provide small and medium sized farmers with a new high valued market outlet; speaking generally, these farmers require high valued markets, such as those accruing from direct marketing or short channel sales, which bring in more revenue than sales through traditional wholesale channels.

The feasibility of serving school lunches made with local ingredients, however, depends on factors that extend beyond philosophy towards the food system. Practically speaking, a school lunch is the complex result of the intersection of numerous constraints, many of which are binding. In addition to facing nutritional guidelines as specified in the *Dietary Guidelines for Americans*, published every five years (the last update was 2010), participating schools also operate within a set of budgetary constraints created by federal and state regulations (HHS and USDA, 2005; MDSE, 2010). A School Nutrition Association study of 48 large school districts across the United States, 2008-09, found that the average cost to produce a lunch meal was $2.90, with a range from $1.50 to $3.87 (School Nutrition Association, 2008a). With revenue from all sources varying from $2.52 to $2.77, the average potential cumulative loss faced by schools in the United States is $4.5 million/day based on 30 million school lunches provided (School Nutrition Association, 2008b). A study by USDA of 356 schools for the academic year 2005-06 similarly found that the full costs of producing a complete lunch exceeded the federal subsidy for a free lunch (FNA and USDA 2008).

This paper adds to the literature in several ways. Our state of focus, Maryland, is new to serving local foods in schools. Maryland is an interesting state to study from both the demand and supply side. The median income in the state's counties ranges from $39K to $101K per year, and the percent of students eligible for free lunch varies from 8 to 64 percent (ERS 2010b). Local policy, via the Jane Lawton Farm to School Act (2008), encourages schools to serve Maryland raised products in lunches for one week during the "Maryland Homegrown Week." On the supply side, Maryland farmers are likely to have many of the skills needed to market local foods to schools, since direct marketing requires flexibility and an understanding of working outside of the typical farm-to-wholesale-to-retail market channels. In 2007, forty-one percent of the farms in Maryland had annual sales between $10,000 - $500,000, which is the group most likely to seek new nontraditional market outlets (ERS and USDA 2010a).

In contrast to the bulk of the previous research documenting grass roots efforts to develop farm to school programs, our aim is to assess the feasibility, ex-ante, of serving local food in Maryland schools, primarily from the demand side. We consider different facets, such as regulatory and budgetary constraints, in an assessment of the feasibility of local foods in Maryland schools. To do so, we analyze primary data (quantitative when possible, otherwise qualitative) from public and private K-12 school food service directors in the state of Maryland.

Local Foods in Lunches: the Perspective of Maryland Schools

For local foods to be part of school lunches, two basic criteria must be met: (1) serving local food has to work both logistically and financially and (2) schools need to be interested in bringing local food to their students. Turning first to the budget, in Maryland, as in other states, school lunch service1 is self-supporting[1] (Eidel 2010). Federal reimbursements provide schools with a set amount per lunch for free, reduced price, and full priced lunches (Ralston et al. 2008). The 2010-11 school year reimbursement amounts are listed in table 1; these amounts can be adjusted in the periodic reauthorizations of the Child Nutrition Act. From a cost side, according the Maryland State Department of Education, food costs approximately $1.15 per meal. Given the breakdown of expenses related to school lunch costs, we place an upper limit on the total cost per complete meal in Maryland (including indirect costs and other types of overhead) as roughly $3.38.

[1] The revenues for the lunch service come from complete lunches and a la carte items.

Table 1. Revenues from complete school lunches in Maryland

Lunch Subsidies	**Free Lunch**	**Reduced Price**	**Full Price**
		-per lunch -	
Federal share	$2.68	$2.28	$0.25
Maryland share	0.01	0.01	0.01
Family cash outlay	0.00	0.40	1.80 – 3.00
Total Revenue	2.69	2.69	2.06–3.26

Notes: The state share is an imputed amount, based on state contributions. The full price for lunches varies by school district across Maryland. The reimbursement rates are set annually by the Food and Nutrition Services of the USDA. These rates are for the 2009-2010 school year, and apply to schools located in the continuous states with less than 60 percent free lunch eligible students. Reimbursement rates are $0.02 higher in each category for schools with 60 percent or more students eligible for free lunches.
Source: personal communication, S. Eidel (Maryland State Department of Education) 2010; Federal Register, 2009.

Table 2. Breakdown of school lunch service costs in Maryland

Cost for:	**Share of Expenses**
Food	34
Labor	37
Administrative	16
Indirect	4
Utilities/maintenance	6
Other	3

Notes: Average percentages for Maryland. Food costs vary among school districts depending on the number of free and reduced lunches, labor costs vary depending on benefits paid or not paid to cafeteria workers, and many schools have different arrangements for indirect and utilities/maintenance expenses. Source: Personal communication with S. Eidel (Maryland State Department of Education), April 8, 2010.

Schools face procurement constraints as well. Fresh fruits and vegetables may be purchased through the Defense Department procurement produce system, and schools are required to make food purchases from the lowest bidder. These rules have implications for adoption of local food by schools: food sold locally is generally produced on smaller farms that do not sell through the Defense Department. Thus, local food likely has higher costs when considering the sum of price and transactions costs. Maryland law does allow schools to pay a 5% price preference above the lowest bid for local food grown in Maryland (Maryland HB 883, 2006). However, the standard procurement contracts may require some adjustment to accommodate local food usage in schools.

The need to balance costs and revenues for school lunches creates several incentives, not all of which are compatible with improving the nutritional quality of school lunch service. First, schools increase revenues by offering a la carte food items at lunch or in vending machines. Anecdotal evidence suggests that schools reduce labor costs by eliminating benefits for employees or outsourcing the entire food service operation. Schools also have strong incentives to use low cost federal commodities, which were valued at about $0.20 per meal in 2009; these products are less costly than purchasing similar products in the open market (MacDonald et al. 1998). Critics have suggested that the federal commodities are higher in fat and less healthy. However, others rebut the criticism, stating that federal commodities are subject to dietary guidelines and are healthy unprocessed foods (Ralston et al. 2008; Eidel 2010). Private schools that do not participate in the school lunch program face a different set of constraints. Following the dietary guidelines is optional, and lunch is either financed through tuition, out of which the food service receives an operating budget, or students pay a fee for lunches. Regardless of the funding mechanism, the lunch program has to satisfy budgetary requirements.

Survey of Public and Private Schools Reveals Interest in Local Food

In order to understand whether local foods might fit into lunch service in Maryland schools, we collected both quantitative data from a survey of public and private schools and qualitative data from interviews with food service directors. While most previous "farm-to-school" ventures focused on public schools (see, for example, Izumi et al. 2006; Hurst 2009; Kloppenberg 2008), we included private schools in our study. We believed, ex ante, that private schools were subject to fewer procurement constraints than public schools and thus would be more flexible and possibly provide greater opportunities for Maryland farmers.

The quantitative findings are based on data obtained from surveys of public and private school food service directors. The instrument was developed by the research team in consultation with the Maryland State Departments of Agriculture and Education. In Maryland, the public school lunch program is administered by each school district, which is organized by county and Baltimore City. In total, there are 24 school districts in the state. Of the private schools in the state, we distributed surveys to the population of schools with more than 150 students (approximately 300 schools). Between the private and public schools, those surveyed included high, elementary, and middle schools, and thus the survey findings cover all grades between kindergarten and high school seniors. The response rates were 75 percent for public schools (18 school districts) and 22 percent for private schools (50 schools). Our investigation of those who did not respond suggests that many non-respondents rely on local companies that prepare lunch offsite and deliver to schools. Parents order lunch from the local company, through a portal from the school website. In contrast, many schools – particularly the larger ones – use a food service company such as Sodexho or have a staff onsite to prepare food. Technical details on the survey methodology are included as an Appendix.

Descriptive statistics of select survey results are presented in Table 3, and are separated for private and public schools. Nearly all public schools and slightly less than half of the private schools that responded served local food during 2008; note that this response does not reflect the intensity of local food usage. One possible explanation for the different intensity of local food usage between public and private schools (94 percent vs. 48 percent) is the result of efforts of the Maryland State Departments of Agriculture and Education, mostly geared towards public schools, to promote Maryland Homegrown Week. Few schools reported purchasing directly from farmers. A larger share of primary vendors to the public schools carries local foods, while both private and public schools procure more than half of their needed food supplies from one vendor.

Table 3. Descriptive statistics of select survey responses

Variable	Public School	Private School
	percent (standard deviation)	
Bought local food in 2008	94 (24)	48 (51)
Bought direct from farmer	35 (49)	35 (48)
Food service "very interested" in local food	59 (51)	51 (51)
Parents "very interested" in local food	24 (44)	54 (51)
Students "very interested" in local foods	12 (33)	25 (44)
Primary vendor offers local food	76 (44)	44 (50)
Buys more than half of supply needs from one vendor	89 (32)	70 (46)
Very interested in buying local from farmer in future	47 (51)	48 (51)
Very interested in buying local from distributor in future	82 (39)	50 (51)

Notes: N=18 for public schools, N=43 for private schools.

The efficiency of the performance of market channels for local products to schools hinges upon the ease with which schools and farmers can exchange products, including factors related to (1) locating products, (2) locating buyers, (3) pricing products, (4) delivering to buyers, and (5) receiving deliveries. Perceived impediments to these factors inhibit a school's use of local foods. School food service buyers were provided with a long list of factors, and asked to indicate which factors were major obstacles, moderate obstacles, or not an obstacle to their use or increased use of local foods. Private and public schools, as Table 4 shows, view different factors as major obstacles to increasing their use of local food.

For public schools, seasonal availability, lack of supply, and menu planning presented the greatest problem, while private schools indicated that knowledge of the timing and availability of local foods was their largest obstacle. A possible explanation is that, without the type of support for local foods in school lunches provided by the state, the majority of private schools have little knowledge of how to access local foods.

Table 4. Perceived major obstacles to schools for increasing local food usage.

Type of Obstacle	**Public school**	**Private school**	**All schools**
		percent	
Supply factors			
Seasonal availability	73	34	46
Lack of local supply	50	34	33
Developing relationships with farmers	20	26	24
Distributor does not offer local	13	36	27
Pricing of local foods	18	32	27
Consistent product quality	25	19	21
Lack of partially processed products	32	18	22
Business factors			
Delivery considerations	35	32	33
Menu planning	50	18	12
Extra staff time needed to prepare fresh	38	26	30
Lack of information about where and when local foods are available	7	45	33

Note: The perceived major barriers in this table consider each barrier across all respondents.

Model of Local Food Use in Schools

The survey results indicate how schools view each factor independently. However, when making decisions about using local foods, schools implicitly consider all factors simultaneously. In order to capture this decision, we model a school's decision to serve (and therefore purchase) local food as a discrete choice, where the dependent variable takes the value of 1 if the school buys local food and 0 if it does not. The factors thought to explain this decision compose a vector, x, so that

(1) Prob (y = 1) = F(x′β), and
(2) Prob (y = 0) = 1 - F(x′β),

where x′β takes a linear form. Choosing a logistic distribution, equation (1) becomes

$$(3)\ \text{Prob}\ (y = 1) = \left(\frac{e^{\beta' x}}{1 + e^{\beta' x}}\right).$$

The marginal effects from the logit model are given by

$$(4)\ \frac{\partial E[y]}{\partial x} = \left(\frac{e^{\beta' x}}{1 + e^{\beta' x}}\right)\left(1 - \frac{e^{\beta' x}}{1 + e^{\beta' x}}\right)\beta,$$

where this expression is calculated at the means of the variables in x.

As previously discussed, schools are faced with the task of providing students with lunches that satisfy several constraints, including USDA nutrition guidelines, school lunch budget rules, and student tastes and preferences. Local foods, when part of a lunch, must fit into this framework as well. Some factors are constant for all schools, such as needing to meet the USDA nutrition guidelines, and thus are not a unique part of an individual school's decision. However, many factors do vary by school, and probably influence the likelihood that a school will use local foods in lunch. First, we hypothesize that higher interest in local foods will translate to a higher likelihood of using local foods; thus, we incorporated three dichotomous variables that reflect whether the food service, parents, and students are "very interested" in local foods. Note that levels of parent interest and student interest are not obtained directly from parents or students, but from the food service director. However, it is likely that, if the food service responds to parents or students, all that matters is their perception of how interested parents and students are.

One budgetary factor likely to influence the use of local foods is the percent of students eligible for a free lunch. More students receiving free lunches means that fewer students are paying full price, and such schools have a smaller stream of revenue (per student) to fund lunch service. We hypothesize that median income in the county will have also an impact on the likelihood of local food usage. Recognizing that there is likely correlation between median income and percent of students eligible for free lunches, a multiplicative interaction term between the two variables was included. Another factor thought to be important is whether a school (or district) uses one vendor for more than half of their purchases, which we hypothesize will reduce the likelihood of buying local foods.

The final factor considered is the intensity of obstacles to incorporating local foods that each school perceives; to incorporate this information, a measure of perceived intensity was created from the responses to questions about supply and business barriers. Each question allowed the respondent to indicate whether the proposed barrier was a "major barrier," "moderate barrier," or "not a barrier." Each response of major barrier was awarded a score of 1, the response moderate barrier was 0.5, and not a barrier was assigned a value of 0. We created a variable that summed up the responses to each barrier for each school. The barrier scores ranged from a low of 0.5 to a high of 17.5. The mean index was 7.6, with a standard deviation of 4.09. This measure provides a fairly comprehensive measure of a school's perception of how easily they can procure local food.

Technical difficulties with the data limited the scope of our analysis. For example, because without a measure of the intensity of local food usage, it was not possible to hold constant for different levels of usage or tease out differences between high, moderate and low local food usage schools. However, to the best of our knowledge, only one school district in the state has incorporated local foods into their regular menu. Beyond that, we have little understanding of the differences in levels of usage by schools. Limitations notwithstanding, the estimated logistic model is a reasonable predictor of the likelihood of a school buying local food.

We estimate two models – one examines the likelihood of a school buying local food, while the other explores the likelihood of a school buying local food directly from a farmer. The first is: Pr(school buying local food) = F(food service interest, food service director perception of parent interest, food service director perception of student interest, whether a school buys more than

50% from one vendor, median county income, percent of students free lunch eligible, interaction between median income and percent free lunch eligible, and barrier index). The second model estimated is: Pr (school buying local food directly from a farmer) = F(whether a school buys more than 50% from one vendor). [2]

The results of the two models and some post regression diagnostics are shown in Table 5.

Table 5. Results of logistic regressions: (1) buying local food and (2) buying from a farmer

Dependent variable: buys local	**Odds Ratio (standard error)**	**Marginal effects**	**Discrete change**
Buys at least 50% from one vendor	0.79 (1.02)	-0.01	-0.01
Median county income	1.00* (0.00)	-0.00	-0.99
Median income*free lunch (interaction term)	1.00 (0.00)	0.00	0.31
% eligible for free lunch	0.71* (0.12)	-0.02	-0.99
Barrier index	0.66* (0.13)	-0.03	-0.81
Food service interest	9.17** (11.69)	0.15	0.19
Parent interest	1.56 (2.23)	0.03	0.03
Student interest	2.24 (3.33)	0.05	0.05
Pseudo r2 = 47%			
Number of observations 45			
LR chi2(8) = 23.76			
Prob > chi2 = 0.0025			
Dependent variable: buys from farmer			
Buys at least 50% from one vendor**	0.24 (0.20)	-0.33	-0.33
Pseudo r2 = 6%			
Number of observations 36			
LR chi2(1) = 3.00			
Prob > chi2 = 0.08			

Notes: *Indicates significance of 5 percent; **Indicates significance of 10 percent. Discrete change is measured as difference in probability of buying local food (model 1) or directly from farmer (model 2) as the variable moves from the lowest to highest possible values, with other variables measured at the mean. Marginal effects are calculated with other variables measured at their mean. The dependent variable = 1 for a school that states it purchases local food and 0 for school s stating that local food is not purchased.

[2] Initially, we estimated model (2) using the same list of explanatory variable as the first model; the model's fit was extremely poor. However, one of our research goals is to identify the conditions under which a school will be more likely to buy directly from a farmer. Thus we estimated the model with just one explanatory variable, which actually provides us with a result that has policy implications.

Fitting the model predicting the odds of buying directly from a farmer revealed that none of the variables that had a statistical effect on the odds of buying local food had any impact on buying from a farmer. The data suggest that the one factor with a statistical effect is whether the school procures more than half of its supply from one vendor; these schools are less likely to buy directly from a farmer. The logic behind this is that schools heavily reliant on one wholesaler typically have warehouses designed to receive large delivery trucks (e.g., 18 wheelers) and, as a result, discourage the delivery of produce from individual farmers in small vehicles such as pick-up trucks. Currently, there are three school districts in Maryland with a large central warehouse. The result is included because this finding has implications for policy promoting the use of local foods in schools, which will be discussed later in the paper.

Post regression diagnostics shed further light into the statistical results. Note that Long (1997) argues that marginal effects are not appropriate when the independent variables are binary, and suggests using a measure of discrete change in such cases. A discrete change for a change in X of ε is calculated as $Pr(Y = 1|X, X_k+\varepsilon) – Pr(y=1|X, X_k)$ (*SPost* command prchange). The discrete changes will equal marginal changes when the changes in Xk are small, or when the changes in the independent variable occur in a roughly linear portion of the probability curve (Long 1997) In this case, we estimated the change in probability of a school buying local food as the independent variable increased from its minimum level to its maximum level.

Given that most economics literature reports marginal effects for dummy variables, we have included marginal effects in addition to the discrete changes for the binary and continuous variables. The two measures yield similar findings regarding the impact of food service interest on the probability of school purchases of local food. The marginal effect of food service interest is 0.15, and the change in predicted probabilities (holding other variables constant at their means) when moving from food service is not very interested (i.e., indicator variable = 0) to food service is very interested (i.e., indicator variable = 1) is 0.19. The impact of percent of students eligible for free lunches varies by the measure used: the marginal effect is -0.02, while the discrete change of going from the minimum (8 percent of students) to the maximum (64 percent of students) is -0.99. However, both indicate that as the percent of students eligible for free lunch increases, the probability of a school buying local food decreases. The impact of the barrier index is similar: the marginal effect is -0.03, and the discrete change is -0.81.

Interpreting the results so far suggests that two local factors are critical to successful use of local foods in schools in the state of Maryland: food service directors' interest in the idea of local foods and food service directors' perceptions of the barriers that make the process difficult. This finding suggests that (1) if the director is interested, and (2) the barriers can be reduced, schools in Maryland are open to the idea of serving local food in their cafeterias. From the side of needing to balance revenues and costs, increasing the reimbursement rate for free and reduced price lunches would increase the likelihood of using of local food in Maryland schools.

Insights from Interviews with Food Service Directors

In order to gain deeper insight into local foods in Maryland schools, qualitative data were collected through interviews with food service directors on the phone and at the Future Harvest

Conference (West Virginia 2010). A member of the research team followed up with school food service directors who answered the survey and stated they were also willing to be interviewed. Fourteen interviews were conducted – seven with private schools and seven with public schools. The interview methodology followed standard protocols for qualitative data collection, and relied on an interview instrument that was developed by the research team in consultation with the Maryland State Department of Education. The questions covered topics such as interest in local foods, what schools need to increase their use of local food, whether schools have worked directly with farmers, and whether farmers wanting to sell their products have ever contacted the school. Note that response bias tilts the qualitative data towards local foods, since the research team contacted only those food service directors who (1) answered the survey and (2) indicated that they were willing to be contacted for an interview.

Those interviewed reveal a wide variation regarding interest in local food, as well as the feasibility of serving local food in schools. Most public school foodservice directors indicated some interest in local foods, yet the level varied widely. For example, many schools consider local food exclusively during "Maryland Homegrown Week," while Baltimore City schools have already integrated local food into the school lunch program. For example, out of Baltimore City's total budget of $35 million, $1.3 million was spent on local products, and all the fruits and vegetables served are produced in Maryland (Geraci 2009). All of the private schools interviewed indicated interest in local foods, although this response is likely not representative of all private schools in Maryland. Several private schools work closely with farmers, while others have a preference for local and make extra efforts to procure local produce or meat. Most of the private schools contract out their foodservice, and these firms tried to incorporate local foods in the menu. Directors from both public and private schools mentioned that the harvest season in Maryland is not completely in sync with the school year, but that issue became less of a concern after they began using local foods in the school.

Public school food service directors attending the Future Harvest conference (2010) reported a myriad of obstacles to using local foods, which differed across school districts. This is evident starting with delivery; large counties have one distribution site for deliveries, while smaller counties have numerous delivery locations. Thus, large counties buy large quantities of food, and have it delivered to one location. In many cases, because of the sheer volume they purchase, they seek to reduce transaction costs of procurement and of multiple deliveries and so will only accept deliveries from a distributor. However, they have inserted clauses into their purchasing contracts that encourage the purchase of local foods by distributors when economical.

In contrast, smaller school districts often require small deliveries to multiple locations, and thus can receive deliveries directly from farmers or small distributors. Differences are apparent with food preparation, as well, with staff of some school districts well trained, while other districts struggle with language barriers and so are unable to effectively communicate with their staff.
Access to local food varies and is problematic for many schools. Not all distributors carry local products, and buying directly from farmers is not always feasible. Many schools require produce that has been cleaned, sliced, diced and prepped, and farmers are not always set up for this type of processing. Private schools face additional problems. Those operating their food service have problems, at times, finding farmers and distributors willing to sell small quantities, while those

who have contracted out foodservice are unable to purchase directly from growers and must procure all food through the contractors' corporate headquarters. One example of sourcing difficulties is readily explained by a food service director of a private school, who stops at a farmer's home in the morning, on his way to school, to pick up local apples. While he would prefer to have the product delivered to his school, the farmer is unwilling to deliver such a small quantity.

A final significant problem that private schools face is related to insurance. Maryland law requires that farms selling value added food (i.e., food that has been peeled, sliced, or prepped) carry product liability insurance. Private schools stated that farmers they do business with must have two million dollars in liability insurance; most farmers who sell at a local farmers market do not carry this type of insurance.

Policy Implications and Discussion

The research has yielded results that can potentially inform federal and state policies regarding local foods in schools. Several barriers to serving local food in Maryland schools were identified. The first is a socioeconomic barrier: schools with a higher percentage of free lunch eligible students were less likely to use local foods. This has short and long run implications. In the short run, the food service director faces variable and fixed costs. As a result, the additional free lunch students reduces the fixed cost deficit faced by many school systems, potentially freeing up funds, which can be used to purchase local foods. In the long run, however, because all costs are variable, the ability of the food service director to purchase local foods is limited if federal reimbursement is less than the full cost of meals, especially if the local food is more expensive or perceived to be more expensive. Thus the costs of local food (either cost of the food or the higher costs associated with procurement, processing, and preparing) can be more easily borne by schools with fewer free lunch eligible students. This suggests that the relationship between free and reduced lunches and the ability to incorporate local food into the school lunch menu deserves additional research.

Next, the analysis points to a scale barrier: schools that buy more than half of their products from one vendor were less likely to buy directly from farmers. New distribution channels may have the potential to broaden the availability of local food for school use. For example, as several farmers suggested, the establishment of a drop-off point for farmers would make it possible for a distributor to collect a large quantity of Maryland products at one time. This would both reduce farmer cost (i.e., those who currently drive around to several schools would no longer have to do so) and increase the size of the school market. These two factors might result in increased farm production to meet the demand for local food. Aggregating supply from small growers would also enhance the ability of smaller school systems to purchase local food directly from farmers. A centralized facility where fruits and vegetables could be partially processed would also increase sales to schools already facing labor shortages. These ideas are supported by experiences through the U.S. regarding scaling up through aggregation and distribution centers for local food (Day-Farnsworth et al. 2009) and in Minnesota for partial processing of local fruits and vegetables (Berkenkamp 2006).

The study also suggests that the greater the barriers a school food service buyer perceives, the less likely will local foods be served in her school. The types of barriers identified differ for public and private schools. Public schools have greater awareness of the possibilities for local foods in their schools, yet have significant financial constraints. Private schools, in contrast, have a smaller base of knowledge, but also face budget constraints. Schools could address these issues by (1) contracting with farmers in advance, so they can bypass the spot markets; (2) relying on a central drop-off and distribution site, or even a local auction; and (3) processing foods, or contract out processing, during the height of the season (i.e., summer) and store for use throughout the year.

A role for Maryland cooperative extension is clear. Some suggestions are as simple as information provision. Understanding how local foods can work in a school setting can be enhanced by providing information about products demanded by schools to farmers, and information about product availability by season and producer to schools. Such lists of buyer and seller names would reduce search costs for both sides. A similar need has been identified in Minnesota (Berkenkamp, 2006). More elaborate solutions might include Maryland extension lending expertise towards the development of new distribution channels in the states, via a central drop off location.

While the findings are specific to the state of Maryland, they do add to the body of knowledge in our profession regarding local foods and school use of food. The results provide guidance for several stakeholder groups: Maryland extension, in their role as supporters of small and medium farms in the state; the Maryland State Department of Education, in their role working with schools on their lunch programs; and state and federal policymakers, creators of unfunded farm to school programs, who may have visions about how to modify current legislation so that schools can better incorporate local foods into their lunch programs.

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Appendix:

Summary of the Survey Methods Collection

The survey of *public school K-12 food service directors* was developed by researchers from the University of Maryland, Penn State University, and USDA's ERS. The survey included over 30 questions to study the current use of local foods in public schools, the level of stakeholder interest, whether schools procured directly from local farmers, interest in procuring local foods in the future (as well what types of agricultural products they were interested in procuring), barriers to using local foods in school meals, and perceptions of the effectiveness of the Maryland Farm to School legislation. Some basic characteristics of the food service operation were also collected.

The survey was implemented in late 2009 and early 2010. The list of 24 County and Baltimore City directors was obtained from Maryland State Department of Education. Because the vast majority of Maryland counties and Baltimore City procure agricultural and food products and then process and cook those products at a central location, distributing the school meals to each school, we targeted the food service directors as having the most knowledge about the use of local foods in school meals.

The survey was conducted via Survey Monkey over a two month period from December, 2009 through January 2010. Food service directors received a pre-notification letter, the invitation to take part in the survey, and approximately 2 follow-up emails. In some cases, personal contact via telephone was also made. Three-quarters (18 out of 24) directors responded to the survey. One director was excluded from responding due to county rules governing surveys of staff

The survey of *private school K-12 food service directors/principals* was developed by researchers from the University of Maryland, Penn State University, and USDA's ERS. The survey included over 45 questions to study the current use of local foods in private schools, the level of stakeholder interest, whether schools procured directly from local farmers, interest in procuring local foods in the future (as well what types of agricultural products they were interested in procuring), barriers to using local foods in school meals, and perceptions of the effectiveness of the Maryland Farm to School legislation. Basic characteristics of the food service operation and school were also collected.

The survey was implemented in early 2010. Less was known about the private schools than the public schools. A list of over 310 schools with over 150 students (assumptions were made by the researchers as to the minimal student enrollment for the presence of food service) was developed using lists of schools from the Maryland State Department of Education and various online resources. Researchers did not have access to food service director names, so the survey was directed to the school's food service director or the principal.

The survey was conducted via Survey Monkey over a two month period from late January through March, 2010. Food service directors/principals received a pre- notification letter and letter invitation to take part in the survey via mail (with a link to the online site), and 2 follow-up postcards. Incentives were included in the survey; respondents who completed the survey were entered in a raffle for 1 of 2 $50 gift certificates. Of the valid addresses/schools, 50 valid surveys were completed, resulting in a 22 percent return rate. Although the letters and survey encouraged schools without kitchens to complete the survey (they were directed through a different set of questions about local food and food service), our examination of the websites of the valid non respondents suggest these schools use a local company for lunches. Parents order lunch online, monthly, and the company delivers a prepared lunch to the students.