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THREE ESSAYS ON TREE FRUIT MARKETING AND TRADE

ABSTRACT

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This dissertation consists of three studies about tree fruit marketing and trade. The first study derives an implicit cost system based on LaFrance and Pope demand system with an empirical application for tree fruit. The economic and econometric approach improves preciseness and accuracy of elasticities for policy analysis. The demand system is estimated using iterative seemingly unrelated regression and tree fruit generalized method of moments with autocorrelation corrections. Elasticities are estimated for fresh and processed tree fruit. Findings indicate that implicit cost system outperformed the Translog system. Also, we conclude that increased U.S. exports drove up the farm level demand and grower prices for fresh tree fruit from 1980 to 2009.

The second study presents an intertemporal economic model to estimate economic impacts of a single tree fruit pest and disease outbreak. The model is designed to examine the economic consequences of pest and disease outbreak on demand and supply with international trade. Our approach is to use a dynamic simulation of the single tree fruit industry under scenarios with and without outbreak to compare the
stream of simulated outcomes and the consequences for measures of economic welfare of producers in the industry and consumers. An empirical application of hypothetical fire blight outbreak in the U.S. pear industry is conducted.

The third study analyzes the effectiveness of advertising and promotional activities conducted by the Pear Bureau Northwest (PBN) on fresh pears during 2007/08 to 2011/12 crop marketing seasons using a nonparametric estimation method. The main results of this study show a predominately positive and significant role of advertising expenditures in promoting all winter pears and D’Anjou pears demand and in gaining positive marginal net returns to pear growers. However, the advertising effectiveness shows interregional disparity and varies promotional types and pear varieties. This study also found domestic demand for all winter pears and D’Anjou pears was significantly related to a number of other factors. We find that prices are more sensitive during economic recession than previously reported.
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CHAPTER 1 INTRODUCTION

This dissertation consists of three separate papers. The first paper is discussed in Chapter 2, focusing on modeling farm level demand for fresh and processed tree fruit (include apple, cherry, pear, and peach/nectarine) using implicit cost system approach and estimate price elasticities. The second paper discussed in Chapter 3 we set up a conceptual model about economics of pest and disease outbreak in tree fruit and we report simulation results of a hypothetical fire blight outbreak in U.S. pear industry and draw policy implications. The last chapter is the third paper, analyzing the effectiveness of commodity promotion program on fresh pears conducted by Pear Bureau Northwest produced in Pacific Northwest from 2007/08 to 2011/12 crop marketing season.

**First paper**

The overall production of tree fruit has increased, with fresh market utilization increasing and processed market utilization decreasing. In 1980, farm level demand for fresh tree fruit was 7508.6 million pounds, which rose to 9625.4 million pounds in 2009. However, farm level demand for tree fruit used for processing declined in the last three decades. The farm level demand for tree fruit used for processing was 6713.4 million pounds in 1980, which declined to 5901.6 million pounds by 2009. One notable phenomenon is that both the grower price and utilized production for fresh tree fruit increases at the same time. No recent studies have provided empirical estimates of elasticities for fresh and processed tree fruit.

The overall objectives of this study are threefold: 1) to develop a farm level demand analysis of selected tree fruit to help our understanding of the utilization, market responsiveness, and economic substitution between fresh and processed tree fruit over the
period 1980-2009; 2) to contribute to the literature in terms of methodology and empirical application of demand system. We combine recently developed consumer theory with production theory through implicit cost system; 3) to estimate more accurate measures of economic responsiveness for policy analysis.

The U.S. national aggregated annual data with farm level price and quantities are used from 1980 to 2009. The fruit are categorized into fresh tree fruit, processed tree fruit and other fruit according to their usage and analysis purpose. The tree fruit under investigation include apples, cherries, pears, peaches, and nectarines; other fruit include all exclude tree fruit. Iterative seemingly unrelated regression method and generalized method of moments are adopted with autocorrelation corrections. The estimated parameters are statistical significant and provide some findings on farm level demand for tree fruit.

The key results of this paper suggest implicit cost system outperformed the Translog system which implies that the non-linear system is better than linear system for tree fruit. The own-price elasticities are negative and are less than one, reflecting that both fresh and processed tree fruit satisfy the law of demand and they are price inelastic. At the same time, fresh tree fruit and processed tree fruit are substitutes at farm level. The international market explains the price changes at the U.S. farm level through the wholesale market. International consumers prefer more U.S. fresh tree fruit, which drives up the prices and quantity demanded at the farm level. U.S. consumers buy more processed tree fruit imported from international market. This explains the farm level price change and allocation of tree fruit between fresh and processed market.
Second Paper

The objectives of this study are twofold: 1) to develop a partial equilibrium model of tree fruit demand and supply with international trade to estimate the economic consequences of a disease or pest introduction or outbreak (henceforth termed outbreak) in tree fruit; 2) to construct an empirical model that calculates the economic consequences of a disease and/or pest outbreak in selected tree fruit (apples, pears, cherries, or peaches and nectarines) that measures consumer and producer welfare effects from such outbreaks.

A hypothetical fire blight outbreak in the U.S. pear industry is used to illustrate the utility of the model. The model considers three effects for the hypothetical fire blight outbreak for the pear industry and looking forward more than 40 years after the events. The three effects include supply shock, sanction ban, and consumer shock with nine scenarios. The more severe the fire blight outbreak, the worse the consequences are for the pear industry. At the same outbreak level, scenarios with consumer shocks and sanction ban imposed have the highest magnitude impacts, followed by the scenarios with sanction ban imposed, and then scenarios with supply shocks. We find that more severe the fire blight outbreak, the worse the consequences are for the pear industry. At the same outbreak level, scenarios with shocks from both international market and domestic consumers have highest magnitude impacts, followed by scenarios with shocks from international market, and then scenarios with outbreaks. The national may benefits from the shocks in the short run, but in the long run, both the domestic and foreign parts are worse off from the outbreaks.
Commodity promotion programs are important for each of the commodity commissions. The Pear Bureau Northwest, established in 1931 as a non-profit marketing organization representing pear growers and packers/shippers in Oregon and Washington, promotes, advertises and develops markets for fresh pears grown in Oregon and Washington (approximated 84% of all fresh grown in the United States). Expenditures on domestic promotion have run about $1.02 million annually in recent years.

The overall objectives of this study are threefold: 1) Estimate price elasticites and advertising and promotion expenditure elasticities through pears wholesale demand, in particular, we investigate new promotional types, full ad buys and layered ad buys; 2) Estimate returns to investments in advertising and promotional activities undertaken by pear producers through the Pear Bureau; 3) Compare interregional differences in the impact of advertising and promotional efforts on wholesale demand and investment returns.

The key results of this paper show a predominately positive and significant role of advertising expenditures in promoting D’Anjou pears and all winter pears demand and in gaining large magnitude of marginal net returns to growers. But the advertising effectiveness varies across regions, promotional types, and pear varieties. Full ad buys performed significantly better in marginal net returns than did layered ad buys. Demos played limited role in promoting fresh pear demand. As a particular interest of this study, the marginal net returns of the 5 crop marketing seasons are significant higher than those in last report covered seven crop marketing seasons from 1998/99 to 2002/03. This may be associated with the impact of economic recession since 2008 that consumers are more
price sensitive to fresh pears and advertising expenditures. We find that the own price
elasticities are elastic in most of regions, which is different with previous report that own
price are inelastic in all regions. In addition, this paper also found that domestic demand
for fresh pears is significantly related to a number of other factors. Pear demand was
significantly impact by their own prices, orange prices, apple prices, banana prices,
patterns of seasonal availability of pears, as well as patterns of habit information.
CHAPTER 2 IMPLICIT COST SYSTEM APPROACH TO FARM LEVEL

DEMAND OF TREE FRUIT

Abstract

An implicit cost system based on Lafrance and Pope demand model with an empirical application for tree fruit. The economic and econometric approach improves preciseness and accuracy of elasticities for policy analysis. The demand system is estimated using iterative seemingly unrelated regression (ITSUR) and generalized method of moments (GMM) with autocorrelation corrections. Elasticities are estimated for fresh and processed tree fruit. Findings indicate that implicit cost system outperformed the Translog system. Also, we conclude that increased U.S. exports drove up the farm level demand and grower prices for fresh tree fruit from 1980 to 2009.

Key words: implicit net put, fresh tree fruit, processed tree fruit, elasticity
Introduction

Researchers have long recognized that own-price and cross-price elasticities of demand among food commodities with similar tastes and uses are important for policy purposes. Accurate own and cross elasticity of tree fruit provide measures of price responsiveness and help estimating the benefits and costs of shocks for the fruit industry. Demand systems are applied to estimate elasticities to forecast, test structural change, and assess economic effects from shocks in the market.

Various studies have examined the demand for fresh fruit and vegetable and processed fruit. Price and Mittelhammer (1979) estimated farm level demand elasticities for 14 fresh fruits by mixed estimation technique incorporating available prior information. They provided a limited number of cross-elasticities due to not within framework of a complete demand system. You, Epperson, and Huang (1996) employed a composite demand system approach to estimate price and expenditure elasticities at the retail level for 11 fresh fruits and 10 fresh vegetables. They found that most fresh fruits and vegetables respond significantly to changes in their own prices but insignificantly to changes in total expenditures. Wohlgenant (1989) estimated reduced form specification in a complete system of demand equations to a set of eight disaggregated food commodities, which includes fresh fruit, processed fruit and vegetables and estimated price elasticities at both the farm level and the retail level. Durham and Eales (2010) estimated elasticities for 5 fresh fruit at the retail level using a weekly store-level data set in a region. Double-log, linear approximate almost ideal, almost ideal and quadratic almost ideal systems are estimated and they found that own-price elasticity of apples, pears, bananas, oranges, and grapes are elastic. One common topic in the above papers is that the authors estimated the
elasticities in terms of either individual or aggregated fresh fruit and/or vegetable.

Various studies have explored interrelationship in the supply chain of the U.S. fruit industry. Gardner (1975) examined the consequences of competitive equilibrium in product and factor markets for the relationship between farm and retail food prices. He found that retail prices can be specified as a static markup rule from the farm price under the assumption of constant returns to scale and competitive behavior in the marketing sector. Heien (1980) and Freebairn (1984) analyzed the relationship at farm and retail level prices for the U.S. food industry and found that the retail price changed via markup-type pricing behavior by Sim’s causality test. However, Wohlgenant (1989) did not use the markup pricing rule arguing that it could not accurately depict the relationship between the farm and retail price. Price relationship between farm level and retail level is used in processed fruit market as well (French 1986; French 1987).

This article fills an important gap in the literature in following ways. First, no recent studies have provided empirical estimates of elasticities for fresh and processed tree fruit. This is important for understanding market distortions from supply shocks, such as pest and disease outbreak. To understand economic substitutability across for usages for tree fruit is an interesting topic. As there are more tree fruit allocated to fresh market while the growers prices increased at the same time over the last three decades. We category the fresh and processed fruit based on several individual fruits and investigate the relations within the categories. Second, novel economic and econometric approaches are adopted to estimate elasticities to improve the accuracy and preciousness of our economic predictions and forecasts. We set up the demand system following Lafrance and Pope (2011). We derived the demand system for fresh and processed tree fruit based on an
implicit cost system. Our article is one of the first empirical applications of this method. Third, our results accurately capture the interrelationship between farm level prices and consumption changes. Domestic fresh consumption of tree fruit has been decreasing while the grower’s price on fresh tree fruit rose over last thirty years.

The overall objectives of this article are threefold: 1) to develop a farm level demand analysis of selected tree fruit to help our understanding of the utilization, market responsiveness, and economic substitution between fresh and processed tree fruit over the period 1980-2009; 2) to contribute to the literature in terms of empirical application of demand system. We combine recently developed consumer theory with production theory through implicit cost system.

The paper will proceed in the following manner. First, we present background information about tree fruit. Second, we discuss the data and model specification for the demand system, and the model estimation and empirical results. The final section discusses the results and concludes the paper.

**Background**

The overall production of tree fruit has increased, with fresh market utilization increasing and processed market utilization decreasing. This trend can be seen in Figure 2.1. The tree fruit considered in this paper include apples, cherries, pears, peaches and nectarines. The farm level demand for fresh tree fruit increased around one-third over time. In 1980, farm level demand for fresh tree fruit was 7508.6 million pounds, which rose to 9625.4 million pounds in 2009. However, farm level demand for tree fruit used for processing declined in the last three decades. Tree fruit for processing are in the form of canned, dried, juice, frozen and other. The measurement unit of utilized production of
tree fruit for processed market is in fresh equivalent weight. The farm level demand for tree fruit used for processing was 6713.4 million pounds in 1980, which declined to 5901.6 million pounds by 2009. The allocation of tree fruit between fresh and processed market can also be illustrated by market share (see Figure 2.1). Of tree fruit produced in the U.S., 53% went to the fresh market in 1980 which rose to 62% by 2009; 47% has been for processing market in 1980 which declined to 38% for processed market by 2009.

The trend of utilized production and cost share for each fruit category under the fruit system framework can be seen from Figure 2.2 and Figure 2.3. We define the cost share as the proportion of value of each category fruit out of total value of fruit. The value of each category fruit is measured at the farm level market. Cost share of other fruit is largest of the three fruit category, averaging 73%, with fresh tree fruit second, averaging 20.64%, followed by processed tree fruit with an average of 6.39%. There have been changes in the pattern of the fruit utilized over the past 30 years. Over time, cost share for other fruit has remained stable around 73%, whereas cost share for processed tree fruit shows a decline trend. The cost shares for fresh tree fruit fluctuates and with an increasing trend. The trend for the tree fruit is strongest for the most recent two decades.

One notable phenomenon is that both the grower price and utilized production for fresh tree fruit increases at the same time. From Figure 2.4, grower price for each category fluctuates over time. Fresh tree fruit prices have the highest volatility and also with highest prices among the three fruit groups, with other fruit second and processed tree fruit has the lowest volatility.

**Model Specification**

The Farm level, as opposed to the consumer level, is the point of market interaction
between the growers and processors (Flaming, Marsh and Wahl 2007). Many U.S. produced fruit are marketed through farmers to packers/processors. Packers/processors play an important role in connecting growers and consumers.

Lafrance and Pope (2009) developed a generalized quadratic expenditure system which allows applied researchers to choose a small number of price indices and income data to specify any exactly aggregable demand system. The authors solved questions relating to the integrability of the demand equations and the implied form and structure of indirect preferences. Lafrance and Pope (2011) applied consumer theory to production theory to develop a new way to empirically model netput functions. This specification allowed for the flexibility and rationality of specifying netputs as a function of competitive prices, fixed inputs, and restricted profits. This is the so called implicit netput function because they depend on restricted profit. They considered standard static production theory (netputs) and use envelope results from unknown restricted profit functions (McFadden 1978). Given that firm’s behavior is modeled as first order partial differential equations in terms of all the data, they considered Gorman’s (1981) specification for exact aggregation adapted from consumer theory and derived six possible cases of netput equations.

Following Pope and LaFrance (2011) and Corne (1992), we specify an industry restricted cost function for the tree fruit industry and derive the farm level demand system. McFadden (1978)\(^1\) illustrated that cost function and profit function can be considered as special cases of a restricted profit function, defining maximum profits over a subset of inputs and outputs with competitive prices when quantities of the remaining

\(^1\) If \(z\) is an output bundle, and all the commodities in the netput bundle are inputs, then \(V(z)\) is an input requirement set (with a negative sign) and \(\pi = p \cdot x\) is the negative of cost. Under the appropriate interpretation of \(V(z)\), cost minimization can be treated in this model.
inputs and outputs are fixed. Our paper is a special case of the Lafrance and Pope, in that we derive the implicit netput functions through cost minimization problem.

The restricted cost function is defined as:

\[ C(p, y) = \min_x \{ p \cdot x : x \in V(y) \} \]

where \( p \in R^m \) is prices for the inputs \( x \), \( x \in R^n \) is the inputs, \( y \in R^m \) is the fixed netputs (outputs), and \( V(y) \) is the input requirement sets for \( y \).

Cost minimization can be applied to the implicit netput function for both fresh tree fruit and processed tree fruit. The specific cost system is based on available data and industry characteristics. Farm level demand for tree fruit is used to produce value added products, especially for fresh tree fruit. Meanwhile, available data for processed tree fruit output is measured in fresh equivalent weight. In this sense, the output can be taken as the quasi-fixed output once the demand for the fresh and processed tree fruit are determined. The cost function therefore has precisely the same properties as the consumer’s expenditure function (Cornes 1992). The cost function, \( C(p, y) \), is continuous, non-decreasing, homogenous of degree one in input prices, and concave.

The netput demand equations for applied research may be obtained by applying envelop theory or Shepard’s lemma to the cost function \( C(p, y) \).

\[ x = \frac{\partial C(p, y)}{\partial p} \]

(1)

where \( x \) represents a vector of netputs (inputs here).

Lafrance and Pope (2011) introduced netputs in implicit form from a partial differential equation approach based on all available data:
The implicit netput form in equation (2) is more parsimonious in parameters compared with explicit netput form. They systematically illustrated how to solve integrability of netput equations and endogeneity of restricted cost.

The properties of implicit netput functions, \( x = g(p, y, C) \), are derived from the properties of cost function. Homogeneity of degree one in prices of the cost function indicates that \( g_p^T p + g_c^T C = 0 \). The adding up condition implies that \( p^T x = C \). Concavity of the cost function indicates that \( g_{p^T}^T + g_c^T x^T \) is symmetric, negative semidefinite. These properties are identical to those found for consumer demand (with concavity of cost in netput prices replacing the concavity of consumer expenditure in goods prices). These properties secure that the available literature on integrability of consumer demand systems can be applied to implicit netputs.

The demand system for tree fruit in equation (3) is derived from Rank 2, and is price independent generalized log form. The derivation can be found in Appendix. Rank 2 is sufficient given the aggregate data that we examine.

One assumption is made to be consistent with the available data. We assume the cost function is weakly separable in inputs, allowing us to partition inputs into two subgroups of tree fruit and other inputs, such as capital, labor and energy. We adapt the tree fruit input cost as the total cost, which is reasonable from two perspectives. First, this article focuses on farm level demand for fresh and processed tree fruit through implicit cost function. Second, the cost of tree fruit as inputs into production for processors made up over 50 percent of their wholesale prices.
In our empirical application, we employ a parsimonious approach to nest the translog form (Rank 1). Define \( \beta = \tilde{A}P^\xi = \tilde{A}\prod_{i=1}^{n} p_i^\xi \) and \( \alpha_p = \Delta\{p_i^{-1}\}(B \ln P + D \ln Y) \). \( \beta \) is a Cobb-Douglas function of \( P \), after taking logarithm of \( \beta \),

\[
\ln \beta = \ln \tilde{A} + \xi^T \ln P.
\]

More details on how to derive the specific netput equation can be found in Appendix.

The stochastic specification of the netputs equations in share form is given by

\[
s_i \equiv C_i^{-1}\Delta\{p_{it}\}x_i = \zeta + \prod_{i=1}^{n} p_{it}^{\xi_i} \left( B \ln P_t + D \ln Y_t \right) C_i^{-\kappa} + v_i, t = 1980, ..., 2009
\]

(3)

\[
\zeta = \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \end{bmatrix}, B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}, D = \begin{bmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{bmatrix}, \ln P_t = \begin{bmatrix} \ln p_{1t} \\ \ln p_{2t} \\ \ln p_{3t} \end{bmatrix}, \ln Y_t = \begin{bmatrix} \ln y_{1t} \\ \ln y_{2t} \\ \ln y_{3t} \end{bmatrix}
\]

(4)

where \( i \) indexes ith netput, \( t \) indexes observations over time, \( s_i \) is a vector of cost share, \( P_t \) is a vector of netput prices, \( Y_t \) is a vector of quasi-fixed outputs, and \( v_t = [v_{1t}, ..., v_{3t}]^T \) are error terms. \( \kappa, b_{ij}s, d_{ij}s \) and \( \zeta_i(s) \) are parameters to be estimated. The demand equations derived from the implicit cost function are estimated to be consistent with economic theory subject to symmetric and adding up conditions. These restrictions were imposed using parameter constraints given by:

\[
\sum_{j=1}^{3} \zeta_j = 1, \sum_{j=1}^{3} b_{ij} = 0, \sum_{j=1}^{3} b_{ij} = 0, \sum_{j=1}^{3} d_{ij} = 0, b_{ij} = b_{ji}
\]

(5)

We assume error terms with a higher order vector autoregressive processes (Berndt and Savin 1975):

\[
v_j = R_1 v_{j-1} + R_2 v_{j-2} + ... + R_L v_{j-L} + \varepsilon_j
\]

(6)
\[
R_1 = \begin{bmatrix}
\rho_i & 0 & 0 \\
0 & \rho_j & 0 \\
0 & 0 & \rho_k
\end{bmatrix},
R_2 = \begin{bmatrix}
\rho_i & 0 & 0 \\
0 & \rho_j & 0 \\
0 & 0 & \rho_k
\end{bmatrix},
R_L = \begin{bmatrix}
\rho_i & 0 & 0 \\
0 & \rho_L & 0 \\
0 & 0 & \rho_L
\end{bmatrix},
\epsilon_j = \begin{bmatrix}
\epsilon_{ij} \\
\epsilon_{jy} \\
\epsilon_{jx}
\end{bmatrix}
\]

(7)

with \( E(\epsilon, \epsilon^T) = \Omega, E(\epsilon, \epsilon^T) = [0]_m, t \neq t' \). We assume that \( \epsilon_j \) is independently and identically distributed with mean vector zero and singular covariance matrix \( \Omega \), which implies that one factor share equation is redundant. Therefore, one equation has to be dropped from the model because only two equations are linearly independent due to the adding up property. The error terms sum to zero since the true factor shares and observed shares sum to zero under the construction. The demand relationship for the dropped commodity is recovered by exploiting the parameter restrictions.

Price elasticities can be calculated at the sample means as:

\[
\begin{align*}
\epsilon_{ij} &= \left\{ \begin{array}{ll}
-1 + \zeta_i + \left( \frac{\bar{s}_i - \zeta_i}{\bar{s}_i} \right) \left[ k \zeta_i + (1-k)\bar{s}_i + \left( \frac{b_{ij}}{\sum_{k=1}^{n} b_{ik} \ln p_k + \sum_{l=1}^{n} c_{il} \ln y_l} \right) \right], & j = i \\
\zeta_j + \left( \frac{\bar{s}_j - \zeta_j}{\bar{s}_j} \right) \left[ k \zeta_j + (1-k)\bar{s}_j + \left( \frac{b_{ij}}{\sum_{k=1}^{n} b_{jk} \ln p_k + \sum_{l=1}^{n} c_{jl} \ln y_l} \right) \right], & j \neq i
\end{array} \right.
\end{align*}
\]

(8)

The netput elasticities with respect to cost are calculated at the sample means, and are given by:

\[
\frac{C}{x_i} \frac{\partial x_i}{\partial C} = \zeta_i + (1-k) \left( \frac{\bar{s}_i - \zeta_i}{\bar{s}_i} \right), i = 1, \ldots, n
\]

(9)

Data

We collect annual data for quantities and grower prices at the national level for the U.S. from 1980 to 2009 from Noncitrus Fruits and Nuts Summary from the USDA Economics, Statistics and Market Information System (ESMIS). The fruit system includes three fruit category: fresh tree fruit, processed tree fruit, and other fruit. The fresh and processed tree
fruit under investigation include apples, cherries, pears, peaches and nectarines. Other fruit include all fruit except aforementioned tree fruit.2

Noncitrus Fruits and Nuts Summary from the USDA Economics, Statistics and Market Information System (ESMIS) is the primary data source. Utilized production and prices for apples, cherries, pears, peaches and nectarines were collected from this publication. Data for utilized production and prices for other fruit were collected from Fruit and Tree Nut Yearbook. The fresh tree fruit and processed tree fruit quantity variables are simple summation of each utilized production under investigation. Utilized production is used instead of total production because utilized production is used as aggregate input at the farm level. The price for each category of fruit was constructed by summing together each valuation of utilization production divided by quantity for each fruit category. The price for processed tree fruit was also weighted by fresh equivalent weight in order to be consistent with the available data and farm level demand model we developed. Prices are deflated by the Producer Price Index (PPI) based on the year 1982, which came from the U.S. Department of Labor, Bureau of Labor Statistics.

Descriptive statistics of variables used in the analysis are reported in Table 2.1. Fresh tree fruit demanded at the farm level is an average of 8341.23 million pounds, which are about four thirds of processed tree fruit quantity. Over time, fresh tree fruit grower price has the highest average among competing fruit at $177059.49 per million pounds. Processed tree fruit grower price has the lowest average at $70803.79 per million pounds. Cost share for fresh tree fruit averaged 20.64%, which is about three times that for processed tree fruit.

---

2 Other fruit includes Citrus and Noncitrus except for the tree fruit reported in Fruit and Tree Nut Yearbook, USDA.
Model Estimation and Discussion

The empirical estimation proceeds in several steps. First, the other fruit equation is dropped from the system equations, yielding the two remaining equations (fresh tree fruit and processed tree fruit). Empirical estimation is completed in SAS and initially follows the standard methods for estimation a system of iterative seemingly unrelated regression methods. Wu-Hausman test\(^3\) for the exogeneity of input prices were performed for the system equation using lagged own-prices, bearing acreages, fertilizer price index as instruments. The null hypothesis that prices were exogenous could not be rejected. For comparison purpose, we report both ITSUR and GMM estimation results. Second, the Vuong test is performed to select between two nonnested netput demand systems. One is derived from multiple outputs multiple inputs implicit netputs functions. The other is derived from one output multiple inputs implicit netputs functions. Likelihood Ratio statistic is used to test for model selection between the two systems using Vuong test\(^4\) (Vuong 1989). Third, test of regression residuals is done. A nonparametric test is used to check for identical, independent distribution of regression residuals. The likelihood ratio tests for the models are completed to determine the order of autocorrelation. Based on the results, the system derived from multiple outputs multiple inputs implicit netputs functions is favored.

Table 2.2 contains result of the Wald-Wolfowitz (WW) runs test for regression

\(^3\) The statistic calculated is 16.86 with P-value=.2059. We conclude that we do not reject the null hypotheses that the prices are exogenous.

\(^4\) The multiple outputs multiple inputs implicit netput function and one output multiple inputs implicit netput function are nonnested. The hypothesis is that both proposed models are equally close to true model. The alternative is that one of the proposed models is closer to true model. The calculated statistic is 15.22 with p-value=0, this provides strong statistical support for rejecting one output multiple inputs implicit netput function.
residuals. The WW runs test statistic is a nonparametric test (Mittelhammer 1996) in order to test the null hypothesis that the error terms of each regression model are independent and identical distributed (IID). The result indicates that non-autocorrelation is significant at the 0.05 level from first order to third order.

Table 2.3 includes output of the likelihood ratio (LR) test for model selection, and sequences of the LR tests are completed to determine the order of autocorrelation. The LR test statistic is calculated using the adjusted LR test statistic for systems estimation (Moschini and Moro 1994). The test result implies that there is not enough evidence to show that a specific autocorrelation model is better than the other order.

Based on the above findings and considering a sufficient degree of freedom in estimating parameters, the final demand model specification will incorporate first order autocorrelation correction process. The demand system is estimated using iterative seemingly unrelated regression with an AR (1) process. The aforementioned symmetric and homogeneity conditions are imposed to make the models consistent with economic theory. Parameter estimates and test statistic for the demand system based on implicit cost functions using equation (3) with imposed restriction in equation (5) and autocorrelation corrections in equation (6) are presented.

The price, quasi-fixed output, non-linear and autocorrelation parameter estimates and regression statistics from estimation of the demand system are in share form and are reported in Table 2.4. The goodness of fit for ITSUR (GMM), measured by Adjusted R-Square, is 99.83% (99.84%) and 99.74% (99.68%) for fresh tree fruit and processed tree fruit, respectively. Durbin-Watson statistics are 1.806 (1.978) and 1.59 (1.43) for fresh tree fruit and other fruit, respectively. Durbin-Watson statistics around 2 indicates no

5 See Mittelhammer (1996) for details of the Wald-Wolfowitz runs test
autocorrelation. After correcting for autocorrelation, the AR (1) process is stable. Model specification parameter $\kappa$ is significant at the 0.01 level. The significance indicates that implicit cost system outperformed the Translog system ($\kappa = 0$).

The estimated parameters do not have direct interpretation. Generally, elasticities are used to obtain further insights into implications for demand relationships. Equation (8) shows the relationships between the estimated parameters from the demand system and price elasticities. Table 2.5 reports the estimated elasticities for both ITSUR and GMM estimation methods at the sample mean. The estimated own price elasticities for ITSUR are -0.0169, -0.0412, and -0.0048 for fresh tree fruit, processed tree fruit and other fruit, respectively. Take the fresh tree fruit own elasticity of -0.0169 for example, it indicates a 1% increase in fresh tree fruit price causes a 0.0169% decline in quantity of fresh tree fruit demanded. As is consistent with demand theory, each fruit category satisfies the law of demand. In addition, own price elasticities are inelastic (i.e., $<1$). The elasticities from GMM are close to those of ITSUR, except for the cross-price elasticities for fresh and processed tree fruit have different sign. It is caused by the insignificant parameter estimate used to calculate the cross price elasticities.

Own cross-price elasticities are consistent with previous literature in both the sign and inelastic properties. Wohlgenant (1989) reports that farm level price elasticity for fresh fruit is -0.124 and for processed fruits & vegetables is -0.141. Although the concept of fresh and processed tree fruit in our article is smaller than fresh fruit and processed fruits & vegetables, the own price elasticities show the same negative sign and inelastic. It is because of perennial property that makes tree fruit supply less flexible. Less flexibility in supply cause price elasticities are even more inelastic than combination of all fruit. The
estimated cross-price elasticities are all negative and inelastic. Pairs with negative elasticities are classified as substitute products, while pairs with positive elasticities are complements. Fresh tree fruit and processed tree fruit are substitutes. This implies that fresh tree fruit prices have a negative effect over own quantities demanded and a positive effect on processed tree fruit demanded. Take the fresh tree fruit cross-price elasticity of 0.0203 for example; it indicates a 1% increase in fresh tree fruit price causes a 0.0203% increase in quantity demanded of processed tree fruit. All cross-price elasticities are inelastic. The cross-price elasticity of largest magnitude is for processed tree fruit. The estimated cross-price elasticity of other fruit with respect to processed tree fruit is 0.0209. Hence, processed fruit demand is relatively most sensitive to prices change.

The adjusted R-square for the fresh tree fruit and processed tree fruit equation is very high. Lack of variations in the data set itself maybe is the main reason for the high adjusted R-square result as can be seen in Figure 2.3. It shows that there is no specific pattern and trend for change of each fruit category shares. Moreover, the other fruit demand function is recovered from the demand system and the predicted and actual shares are shown in Figure 2.5. The estimated other tree fruit captures the peaks and valleys of the data, which also explains the high adjusted R-squares are reasonable.

Prices and quasi-fixed output explain about 99% of farm level tree fruit demand, and sheds light on using price changes to explain why fresh tree fruit demand has increased. The price changes at the farm level must be translated from wholesale or retail markets through changes in consumer’s preference. Figure 2.6 shows the per capita consumption for fresh and processed tree fruit over time. For fresh tree fruit, annual per capita consumption in the United States peaked at 31.09 pounds in 1987. By 2009 annual
consumption had dropped to 25.49 pounds. For processed tree fruit, annual per capita consumption was 27.95 pounds at the lowest point in 1981. By 2007 annual consumption peaked at 41.33 pounds. The retail level demand for fresh and processed tree fruit has opposite trend compared to farm level demand. At farm level, allocation of tree fruit to fresh market accounts for 62% in 2009 compared to 53% in 1980. Based on above analysis, we conclude that domestic consumption is not the reason that drives up the prices for the fresh tree fruit.

The price changes at farm level must be translated from the wholesale market through changes in international consumer’s preference. Figure 2.7 shows the proportion of utilized production of tree fruit out of domestic consumption. A proportion greater than one implies that the United States is a net exporter and less than one implies that the United States is a net importer. Farm level demand for processed tree fruit decreased and consumption increased over time because the United States imports more processed tree fruit from international market. However, the United States has been a net exporter of fresh tree fruit since 1980. The United States also imports fresh tree fruit because of seasonality. The United States supply of fresh tree fruit to international market was about 11.54% of consumption in 1980, which increases over time and peaked at 66.24% of consumption in 2009. Hence, it is the international market that drives up the quantity and prices for U.S. fresh tree fruit at the farm level.

**Conclusions**

This study derives an implicit cost system based on Lafrance and Pope demand model. An empirical application for tree fruit is conducted to improve preciousness and accuracy of elasticities for policy analysis. The U.S. national aggregated annual data with farm-
level price and quantities are used from 1980 to 2009. The fruit are categorized into fresh
tree fruit, processed tree fruit and other fruit according to their usage and analysis
purpose. The tree fruit under investigation include apples, cherries, pears, peaches, and
nectarines; other fruit include all exclude tree fruit. Iterative seemingly unrelated
regression method is adopted with autocorrelation corrections. The estimated parameters
are statistical significant and provide some findings on farm level demand for tree fruit.

The LaFrance and Pope’s demand system outperformed the Translog system which
implies that the non-linear system is better than linear system for tree fruit. ITSUR and
GMM estimation results are reported. Both fresh and processed tree fruit satisfy the law
of demand. At the same time, fresh tree fruit and processed tree fruit are substitutes at
farm level. The magnitude of the cross-price elasticities are less than one, which implies
that fresh and processed tree fruit are price inelastic. Processed tree fruit at utilization
market is the most sensitive to price.

The international market explains the price changes at the U.S. farm level through the
wholesale market. International consumers prefer more U.S. fresh tree fruit, which drives
up the prices and quantity demanded at the farm level. U.S. consumers buy more
processed tree fruit imported from international market. This explains the farm level price
change and allocation of tree fruit between fresh and processed market.
References


Figure 2.1 Utilized production of tree fruit for fresh and processed usage, 1980-2009
Figure 2.2 Utilized production for U.S. fruit, 1980-2009
Figure 2.3 Cost shares for U.S. fruit, 1980-2009
Figure 2.4  U.S. fruit prices by category, 1980-2009
Figure 2.5 Predicted share versus actual share for other fruit, 1980-2009
Figure 2.6 Per capita consumption for tree fruit, 1980-2009
Figure 2.7 Proportion of utilized production out of U.S. consumption, 1980-2009
Table 2.1 Summary statistics of annual data, 1980-2009

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh tree fruit grower price ($/Mlbs)a</td>
<td>177,059.49</td>
<td>23073.85</td>
<td>135,406.42</td>
<td>229,983.20</td>
</tr>
<tr>
<td>Processed tree fruit grower price ($/Mlbs)a</td>
<td>70,803.79</td>
<td>8218.48</td>
<td>56,894.60</td>
<td>94,540.69</td>
</tr>
<tr>
<td>Other fruit grower price ($/Mlbs)a</td>
<td>115,186.88</td>
<td>13391.92</td>
<td>87,134.85</td>
<td>147,603.36</td>
</tr>
<tr>
<td>Fresh tree fruit quantity (Mlbs)</td>
<td>8,341.23</td>
<td>912.93</td>
<td>6,371.20</td>
<td>9,625.40</td>
</tr>
<tr>
<td>Processed tree fruit quantity (Mlbs)</td>
<td>6,306.27</td>
<td>641.85</td>
<td>5,255.90</td>
<td>7,639.40</td>
</tr>
<tr>
<td>Other fruit quantity (Mlbs)</td>
<td>45,470.11</td>
<td>5394.53</td>
<td>37,163.20</td>
<td>56,347.40</td>
</tr>
<tr>
<td>Fresh tree fruit cost share (%)b</td>
<td>20.64</td>
<td>1.96</td>
<td>17.42</td>
<td>24.7</td>
</tr>
<tr>
<td>Processed tree fruit cost share (%)b</td>
<td>6.39</td>
<td>1.39</td>
<td>4.12</td>
<td>8.67</td>
</tr>
<tr>
<td>Other fruit cost share (%)b</td>
<td>72.98</td>
<td>2.03</td>
<td>68.1</td>
<td>76.57</td>
</tr>
</tbody>
</table>

*aInflation-adjusted US dollars(deflated by PPI,1982=100). bShare of fresh, processed tree fruit and other fruit cost.
### Table 2.2 Nonparametric Test for IID

<table>
<thead>
<tr>
<th></th>
<th>AR(0)</th>
<th>AR(1)</th>
<th>AR(2)</th>
<th>AR(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh tree fruit residuals</td>
<td>0.00</td>
<td>0.74</td>
<td>2.23</td>
<td>2.23</td>
</tr>
<tr>
<td>Processed tree fruit residuals</td>
<td>-1.49</td>
<td>0.00</td>
<td>-0.74</td>
<td>-0.74</td>
</tr>
</tbody>
</table>

Note: Ho: residuals are IID, Ha: Not IID. Reject Ho if $z \in (-\infty, -1.96) \cup (1.96, \infty)$
Table 2.3 Likelihood Ratio Tests of Autoregressive Disturbances

<table>
<thead>
<tr>
<th>Hu vs Hr</th>
<th>LR</th>
<th>Adj-LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1) vs AR(0)</td>
<td>3.95</td>
<td>2.60</td>
</tr>
<tr>
<td>AR(2) vs AR(0)</td>
<td>4.73</td>
<td>3.07</td>
</tr>
<tr>
<td>AR(3) vs AR(0)</td>
<td>4.69</td>
<td>3.01</td>
</tr>
<tr>
<td>AR(2) vs AR(1)</td>
<td>0.96</td>
<td>0.62</td>
</tr>
<tr>
<td>AR(3) vs AR(1)</td>
<td>0.93</td>
<td>0.59</td>
</tr>
<tr>
<td>AR(3) vs AR(2)</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Note: critical values at 5% and 10% are 3.84 and 2.7 respectively
<table>
<thead>
<tr>
<th>Parameter Estimate</th>
<th>NLITSUR</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>k</strong></td>
<td>0.0677 ***</td>
<td>0.0762 ***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.005)</td>
</tr>
<tr>
<td><strong>ε1</strong></td>
<td>0.7914 ***</td>
<td>1.0459 ***</td>
</tr>
<tr>
<td></td>
<td>(0.187)</td>
<td>(0.195)</td>
</tr>
<tr>
<td><strong>b11</strong></td>
<td>0.3867 ***</td>
<td>0.5029 ***</td>
</tr>
<tr>
<td></td>
<td>(0.078)</td>
<td>(0.087)</td>
</tr>
<tr>
<td><strong>b12</strong></td>
<td>0.0245</td>
<td>0.1011</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.065)</td>
</tr>
<tr>
<td><strong>b13</strong></td>
<td>-0.4112 ***</td>
<td>-0.6040 ***</td>
</tr>
<tr>
<td></td>
<td>(0.115)</td>
<td>(0.150)</td>
</tr>
<tr>
<td><strong>d11</strong></td>
<td>0.3312 ***</td>
<td>0.3521 ***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.017)</td>
</tr>
<tr>
<td><strong>d12</strong></td>
<td>-0.0366 ***</td>
<td>-0.0402 ***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
</tr>
<tr>
<td><strong>d13</strong></td>
<td>-0.3783 ***</td>
<td>-0.4612 ***</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
<td>(0.053)</td>
</tr>
<tr>
<td><strong>ε2</strong></td>
<td>0.6580 ***</td>
<td>0.9708 ***</td>
</tr>
<tr>
<td></td>
<td>(0.174)</td>
<td>(0.198)</td>
</tr>
<tr>
<td><strong>b21</strong></td>
<td>0.0245</td>
<td>0.1011</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.065)</td>
</tr>
<tr>
<td><strong>b22</strong></td>
<td>0.1709 ***</td>
<td>0.2759 ***</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.084)</td>
</tr>
<tr>
<td><strong>b23</strong></td>
<td>-0.1954 ***</td>
<td>-0.3770 ***</td>
</tr>
<tr>
<td></td>
<td>(0.091)</td>
<td>(0.145)</td>
</tr>
<tr>
<td><strong>d21</strong></td>
<td>-0.0378 ***</td>
<td>-0.0625 ***</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.015)</td>
</tr>
<tr>
<td><strong>d22</strong></td>
<td>0.1081 ***</td>
<td>0.1135 ***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.008)</td>
</tr>
<tr>
<td><strong>d23</strong></td>
<td>-0.1665 ***</td>
<td>-0.2282 ***</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.042)</td>
</tr>
<tr>
<td><strong>ε3</strong></td>
<td>-0.4494</td>
<td>-1.0167</td>
</tr>
<tr>
<td><strong>b31</strong></td>
<td>-0.4112</td>
<td>-0.6040</td>
</tr>
<tr>
<td><strong>b32</strong></td>
<td>-0.1954</td>
<td>-0.3770</td>
</tr>
<tr>
<td><strong>b33</strong></td>
<td>0.6066</td>
<td>0.9810</td>
</tr>
<tr>
<td><strong>d31</strong></td>
<td>-0.2934</td>
<td>-0.2897</td>
</tr>
<tr>
<td><strong>d32</strong></td>
<td>-0.0715</td>
<td>-0.0733</td>
</tr>
<tr>
<td><strong>d33</strong></td>
<td>0.5448</td>
<td>0.6894</td>
</tr>
</tbody>
</table>

Note: standard errors are in parentheses. *** indicate statistical significance at the 0.01 level. Variable netputs are numbered 1-3, for fresh tree fruit, processed tree fruit, and other fruit. b indicates the estimates of input prices, and d indicates the estimates of the quasi-fixed outputs (Eq3 & 4). Autocorrelation coefficient with t-statistics in parentheses is 0.1411(2.05), 0.35(1.6) for ITSUR and GMM, respectively.
Table 2.5 Price Elasticities at Sample Means

<table>
<thead>
<tr>
<th></th>
<th>Fresh tree fruit</th>
<th>Processed tree fruit</th>
<th>Other fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NLSUR</td>
<td>GMM</td>
<td>NLSUR</td>
</tr>
<tr>
<td>Fresh tree fruit price</td>
<td>-0.0169</td>
<td>-0.0054</td>
<td>0.0203</td>
</tr>
<tr>
<td>Processed tree fruit price</td>
<td>0.0063</td>
<td>-0.0066</td>
<td>-0.0412</td>
</tr>
<tr>
<td>Other fruit price</td>
<td>0.0106</td>
<td>0.0120</td>
<td>0.0209</td>
</tr>
</tbody>
</table>
Appendix

Consider Gorman’s (1981; also see Lau 1982) specification for exact aggregation adapted from consumer theory (Lafrance and Pope 2009):

\[ x_i(p, y, C) = \sum_{k=1}^{K} \alpha_{ik}(p) f_k(C(p, y), y), \quad i = 1, \ldots, n \tag{10} \]

In matrix notation with obvious notation:

\[ X = A(p)f(C, y) \tag{11} \]

where \( X \) is \( n \times 1 \), \( A \) is \( n \times k \), and \( f \) is \( k \times 1 \). Restrictions on \( A \) are required for homogeneity and can be obtained once \( f_k, k = 1, 2, \ldots, K \) are specified. Assuming all \( f_k \) functions are linearly independent, the rank of \( A \) is the rank of a Gorman system. Gorman (1981) and Russel and Farris (1993, 1998) and Lafrance and Pope (2009) have shown that the rank of \( A \) cannot exceed three. Van Daal and Merkies (1989), Lewbel (1990), and Lafrance and Pope (2009) showed that there exist only six possible cases (representations given below) under symmetry, adding up, homogeneity, and full column rank of \( A \), when the vector-valued functions \( f \) in (4) are specified in terms of nominal \( C \).

\[
\begin{aligned}
i. \text{ Rank 1 (Homothetic)} & \quad \begin{cases} 
  x(p, y, C) = \frac{\partial \beta(p, y)}{\partial p} \frac{C}{\beta(p, y)} \\
  p^\top \frac{\partial \beta}{\partial p} = \beta 
\end{cases} \\
\text{Implicit Cost Function} & \quad H \left( \frac{C}{\beta(p, y)}, y \right) = 0, \frac{\partial H(z, y)}{\partial z} > 0
\end{aligned}
\]

38
ii. Rank 2 PIGL

\[
\begin{aligned}
x(p, y, C) &= \frac{\partial \beta(p, y)}{\partial p} C + \beta(p, y)^{\kappa} \frac{\partial \alpha(p, y)}{\partial p} C^{1-\kappa} \\
p^T \frac{\partial \alpha}{\partial p} = 0, p^T \frac{\partial \beta}{\partial p} = \beta, \kappa \neq 0
\end{aligned}
\]

Implicit Cost Function

\[
H \left( \frac{1}{\kappa} \left( \frac{C}{\beta(p, y)} \right)^{\kappa} - \alpha(p, y), y \right) = 0, \frac{\partial H(z, y)}{\partial z} > 0
\]

iii. Rank 2 PIGLOG

\[
\begin{aligned}
x(p, y, C) &= \frac{\partial \beta(p, y)}{\partial p} C + \frac{\partial \alpha(p, y)}{\partial p} C \ln \left( \frac{C}{\beta(p, y)} \right) \\
p^T \frac{\partial \alpha}{\partial p} = 0, p^T \frac{\partial \beta}{\partial p} = \beta
\end{aligned}
\]

Implicit Cost Function

\[
H \left( \ln \left( \frac{C}{\beta(p, y)} \right) \right) / \alpha(p, y), y \right) = 0, \frac{\partial H(z, y)}{\partial z} > 0
\]

Results for the rank 3 Extended PIGL and PIGLOG cases employ an implicit solution to a Riccati differential equation that arises in this problem (Lafrance and Pope2009, pp.97-98). In cases iv. and v. below, \( \chi : \mathbb{R}_+ \times \mathbb{R}^m \rightarrow \mathbb{R} \) is an arbitrary smooth function. For brevity, and because it is seldom used, the full rank 3 trigonometric is omitted.

iv. Rank 3 PIGL

\[
\begin{aligned}
x(p, y, C) &= \frac{C^{1-\kappa}}{\kappa} \left\{ \frac{\partial \alpha(p, y)}{\partial p} + \frac{\partial \beta(p, y)}{\partial p} \left( \frac{C^\kappa - \alpha(p, y)}{\beta(p, y)} \right) \right\} \\
+ \beta(p, y) \frac{\gamma(p, y)}{\partial p} \left[ \chi(\gamma(p, y), y) + \left( \frac{C^\kappa - \alpha(p, y)}{\beta(p, y)} \right)^2 \right] \\
p^T \frac{\partial \alpha}{\partial p} = \kappa \alpha, p^T \frac{\partial \beta}{\partial p} = \kappa \beta, p^T \frac{\partial \gamma}{\partial p} = 0, \kappa \neq 0
\end{aligned}
\]

Implicit Cost Function
\[
H \left( \frac{C^\kappa - \alpha(p, y)}{\beta(p, y)} \right) - \int_0^{(p, y)} \left[ \chi(z, y) + w(z, y)^2 \right] dz - h(y), y \right) = 0
\]
\[
\frac{\partial H(z, y)}{\partial z} > 0
\]

Where
\[
w(0, y) = h(y),
\]
\[
w(\gamma(p, y), y) = \frac{C(p, y)^\kappa - \alpha(p, y)}{\beta(p, y)}, \forall (p, y) \in \mathbb{R}_+^n \times \mathbb{R}_m,
\]
\[
\frac{\partial w(z, y)}{\partial z} = \chi(z, y) + w(z, y)^2, \forall (z, y) \in \mathbb{R}_+ \times \mathbb{R}_m.
\]

The ubiquitous translog is in the rank1 class, and moving down the class leads to greater flexibility in \( C \) and rank. Adding up (assuming the system is complete) restricts
one of the functions of \( C \) to be \( C \) itself. Homogeneity and adding up place restrictions on the functions of \( \alpha, \beta, \gamma \). Lau’s (1982) Fundamental Theorem of Exact Aggregation places additional restrictions on the functions of \( \alpha, \beta, \gamma \).

To complete the model specification, the factor demand equations in Equation (3) are derived from the Rank 2, which appears to be sufficient given the aggregate data that we examine. One such form is the PIGL (case ii. above) model of Muellbauer (Muellbauer 1975):

\[
x(p, y, C) = \frac{\partial \beta(p, y)}{\partial \beta(p, y)} C + \beta(p, y) \frac{\partial \alpha(p, y)}{\partial p} C^{1-\kappa}
\]  

where \( p^T \frac{\partial \alpha}{\partial \beta} = 0, p^T \frac{\partial \beta}{\partial \beta} = \beta, \kappa \neq 0 \)

Note that

\[
x_{p^T} = g_{p^T} + g_{C} g^T \\
= \beta^{-1} \beta_{pp^T} C + \left[ \beta^{\kappa} \alpha_{pp^T} + \beta^{\kappa-1} \left( \alpha_{p^T} \beta_{p^T} + \beta_{p^T} \alpha_{p^T} \right) \right] C^{1-\kappa} + (1-k) \beta^{2\kappa} \alpha_{p} \alpha_{p} C^{1-2\kappa} \]  

This is a clearly symmetric matrix. Homogeneity of cost function requires that \( \beta \) is homogeneous of degree one in prices and \( \alpha \) is homogeneous of degree zero in prices.

Hence, 1) \( \beta_{p^T} p = \beta, \beta_{pp^T} p = 0 \); 2) \( \alpha_{p^T} p = 0, \alpha_{pp^T} p = -\alpha_{p} \). And therefore,

\[
x_{p^T} p = \left( g_{p^T} + g_{C} g^T \right) p = 0 \text{ and the netputs add up in a complete system, } p^T x = C.
\]

In our empirical application, we employ a parsimonious approach to nest the translog form (Rank 1). Define \( \ln \beta = \ln \tilde{A} + \zeta^T \ln P \), \( \beta \) is a Cobb-Douglas function of \( P \), and to define \( \alpha_{p} = \Delta \{ p^{-1} \} \left( B \ln P + D \ln Y \right) \).

---

6 For notation convenience, we suppress the arguments of the functions \( \alpha, \beta \), and \( g \).
where:

\[ \beta = \tilde{A} \tilde{P}^T = \tilde{A} \prod_{i=1}^{n} p_i^{\xi_i} \]

1) \[ \beta^{-1} = \frac{1}{\tilde{A} \prod_{i=1}^{n} p_i^{\xi_i}} \]

2) \[ \beta_p = \left[ \frac{\xi_1}{p_1} \tilde{A} \prod_{i=1}^{n} p_i^{\xi_i} ... \frac{\xi_i}{p_i} \tilde{A} \prod_{i=1}^{n} p_i^{\xi_i} ... \frac{\xi_n}{p_n} \tilde{A} \prod_{i=1}^{n} p_i^{\xi_i} \right]^T \]

3) \[ \beta^k = \tilde{A}^k \prod_{i=1}^{n} p_i^{\xi_i} \]

4) \[ \beta^{-1}_p = \left[ \frac{\xi_1}{p_1} ... \frac{\xi_i}{p_i} ... \frac{\xi_n}{p_n} \right]^T \]

We can get

\[
x(p, y, C) = \frac{\partial \beta(p, y)}{\partial p} C + \beta(p, y) \frac{\partial \alpha(p, y)}{\partial p} C^{-1} - x \]

\[ = \beta^{-1}_p C + \beta^k \alpha_p C^{-1} \]

\[
= \left[ \frac{\xi_1}{p_1} ... \frac{\xi_i}{p_i} ... \frac{\xi_n}{p_n} \right]^T C^+ \tilde{A}^k \prod_{i=1}^{n} p_i^{\xi_i} \Delta \{ p_i^{-1} \} \left( B \ln P + D \ln Y \right) C^{-1} - x \]

\[ = \Delta \{ p_i^{-1} \} \left[ \xi C + \tilde{A}^k \prod_{i=1}^{n} p_i^{\xi_i} \left( B \ln P + D \ln Y \right) C^{-1} \right] \quad (14) \]

Then, the estimating equations of the PIGL form are:

\[
x = \Delta \{ p_i^{-1} \} \left[ \xi C + \prod_{i=1}^{n} p_i^{\xi_i} \left( B \ln P + D \ln Y \right) C^{-1} \right] \]

(15)

Where C is the total cost, \( \Delta \{ p_i^{-1} \} \) is a diagonal matrix with \( p_i^{-1} \) as the ith main diagonal element. B is a \( n \times n \) matrix. D is also a \( n \times n \) matrix. \( \alpha \) is HOM(0) in p so that \[ \sum_{i=1}^{n} b_y = 0, \sum_{j=1}^{m} d_y = 0; \beta \) is HOM(1) in p so that \[ \sum_{i=1}^{n} \xi_i = 1. \]
CHAPTER 3 ECONOMICS OF PEST AND DISEASE OUTBREAKS IN TREE FRUIT

Abstract
We set up a conceptual intertemporal economic model for a single tree fruit and illustrate a hypothetical fire blight outbreak in the U.S. pear industry. Our approach is to use dynamic simulation under scenarios with and without fire blight outbreaks to compare the stream of simulated outcomes and the measures of economic welfare of producers and consumers. We find that more severe the fire blight outbreak, the worse the consequences are for the pear industry. At the same outbreak level, scenarios with shocks from both international market and domestic consumers have the highest magnitude of impacts, followed by scenarios with shocks from international market, and then scenarios with only supply shocks. Positive benefits may arise from shocks in the short run, but in the long run, both domestic and foreign agents are worse off from the outbreaks.

Key words: tree fruit, perennial crop, pest and disease outbreak, simulation model
Introduction

In recent decades, international trade in tree fruit has expanded, and with that growth has come increased concern about pest and disease outbreaks. Once pest and disease outbreaks occur, the impacts are felt both domestic and international. Pest and disease events cause direct losses for fruit producers in the form of reduced quantity and/or quality, decreased acres of orchards, plus the costs of control and mitigation, which can be amplified by quarantines or other technical (phytosanitary) trade barriers. In 1998, fire blight outbreak in Washington State affected 36,000 acres of apples and 10,000 acres of pears, with an estimated industry cost of $68 million for Washington and Oregon in that year (Group 2005).

Increasing trade liberalization and international transportation of people and commodities have increased the potential for disease incursion. The Sanitary and Phytosanitary Measures Agreement and the Technical Barriers to Trade (TBT) Agreement allow countries to set standards to protect plant and human health (Newhouse and Hamilton 2010). Varying perceptions about the risks of pest and disease events may lead to sanction ban between countries when pest and disease outbreak. Importers are likely to overestimate the risk of pest and disease transmission and impose high standards in their technical barriers. International shipments are accepted only under specific SPS requirements written into SPS agreements between importing and exporting countries. If importing countries impose tighter phytosanitary restrictions, fruit trade will be disrupted.

Pest and disease events are public good problems complete with externalities. The impact can spread from supply chains to consumption in domestic market and international market as well. As in any epidemic, pest and disease control efforts produce
external benefits for neighboring and even global orchards, as well as private benefits. Thus we can expect private control efforts at lower than efficient levels. Recognition of this problem can be seen when public organizations as well as private growers invest to mitigate pest and disease events. Understanding the distribution of these benefits and costs is essential for guiding resource allocations.

Economic surplus analysis is used to estimate cost of pest and disease outbreaks in both plants and animals (Cembali et al. 2003; Paarlberg, Lee and Seitzinger 2003; Paarlberg, Seitzinger and Lee 2007; Zhao, Wahl and Marsh 2007). This approach is used to not only quantify production and consumption but also provide measures of welfare changes. As tree fruit are perennial crops, dynamic analysis of outbreaks are necessary. Unlike previous literature on pest and disease outbreak in tree fruit that focuses on specific protocol with another importer, such as, U.S. apple exports to Japan for fire blight issue (Calvin and Krissoff 1998), U.S. apple exports to Japan retain codling moth protocol (Calvin, Krissoff and Foster 2008), U.S. import avocados from Mexico for pest infestation (Disdier, Fontagné and Mimouni 2008), Australia on potential imports of New Zealand apples (Yue and Beghin 2009), maximum residue levels (MRL) of pesticides on trade of apples and pears (Drogué and DeMaria 2012), this study analyzes the dynamic economic impact of a hypothetical outbreak on domestic production, domestic consumption, and international trade considering potential effects from supply and demand.

Our interest is to help policy makers and the fruit industry understand the heterogeneous impacts (consumption, production, value added, and trade) from market distortions due to pest and disease outbreaks. First, regional economic assessments can
provide better information for policy formulation. Second, properly quantified outcomes can help to prioritize and plan for, respond to, mitigate, and clean up after such events. Third, our analysis can provide an economic assessment of trade distortions from such outbreaks, and provide valuable knowledge for resolving trade disputes.

The objectives of this study are twofold: 1) to develop a partial equilibrium model of tree fruit demand and supply with international trade to estimate the economic consequences of a disease or pest introduction or outbreak (henceforth termed outbreak) in tree fruit; 2) to construct an empirical model that calculates the economic consequences of a disease and/or pest outbreak in selected tree fruit (apples, pears, cherries, or peaches and nectarines) and that measures consumer and producer welfare effects from such outbreaks. And estimate the changes in welfare measures from mitigation by comparing with and without outbreaks.

The study will proceed in the following manner. First we provide background information on tree fruit for both fresh and processing use. Second, we present a model specification for selected tree fruit demand and supply at the farm level and the retail level, with an international trade component. Third, we report data and simulation methods as well as scenarios and results. Finally, we discuss conclusions from the model and data, followed by policy implications.

**Background**

The United States ranks as the world’s second largest pear producer behind China. According to the 2011 National Agricultural Statistics Service, the largest pear producing states in the U.S. are, in descending order, Washington (48%), Californian (26%), and Oregon (24%). The top three states essentially comprise the entire U.S. pear supply.
Yield per acre and bearing acreage together determine total production. Yield per acre has an upward trend and alternating for some years regarding to orchard management and technology change, weather, and pest and disease outbreaks. Bearing acreages fluctuate but have declined over last 80 years. The total production of pears has been quite stable during the past three decades, with an approximate balance between declining total bearing acreages along with increasing yield per acre. Once fruit are produced, they are allocated to the fresh and processed markets. Production composition of U.S. pears has averaged 54 percent for fresh use and 46 percent for processed use, with more and more pears allocated to fresh market. Fresh allocation reached 65 percent in 2010 (See Figure 3.1). Pears satisfying quality standards often go to the fresh market with a higher price, and the remaining fruit goes to the processed market with a lower price (See Figure 3.2).

The domestic market for fresh and processed pears is important, although per capita consumption of fresh and processed pears shows a declining trend, especially for processed pears. Per capita U.S. consumption in 2010 for fresh and processed pears was 2.9 pounds and 1.96 pounds (fresh equivalent weight), compared to 2001 with 3.25 pounds and 3 pounds, respectively (USDA-ERS, 2012).

Rising export prices coupled with more pears allocated to fresh use along with decreasing domestic consumption have led to speculation that U.S. growers may be relying more on foreign exports to move their fresh pears. The United States is a net exporter of fresh pears, and exported 188,346 tons in 2011, a 12 percent increase compared to 2010. According to USDA-FAS, U.S. fresh pears reach almost 100 countries and the largest markets for U.S. fresh pears are Canada, Mexico, Brazil, and Russia, in descending order. While the United States is a major supplier of pears in the domestic
market, pears from Argentina, Chile, South Korea, and other nations also enter the market. Previous research shows that the majority of imported pears enter the U.S. market during the contra-season of domestic production (Cook 2002; Zhang, Marsh and Schotzko 2007).

The United States had been a net exporter of processed pears and it becomes a net importer after 2000 (See Figure 3.3). Canada and Mexico, as the two of the largest foreign importers for processed pears, accounting for approximately 80 percent of U.S. total exports since 2007. Meanwhile, the United States imported more processed pears than exported them. In 2011, the United States imported processed pears from 23 countries. Approximated 94 percent of those were from China, who is the largest world producer. All importers except Canada impose either tariff barriers or non-tariff barriers on U.S. pears. Importers set a tariff or equivalent tariff rate between 5% and 60.3% for U.S. pears. Non-tariff barriers are in the form of SPS and other restrictions. Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures of the World Trade Organization (WTO, 1995) is one of the most important protocols in international trade. It recognizes the right of WTO members to protect themselves from risks posed by exotic pests and diseases. A country may impose bans, quarantine measures, or other trade restrictions on products from a trading partner that bear potential risks to human, animal, and plant life or health. Many importers impose SPS measures on pears imported from the United States, such as Argentina, Australia, China, Indonesia, Japan, South Africa, South Korea, Taiwan, and Vietnam.
A Conceptual Model of the Pear Industry

An intertemporal economic model for a single tree fruit is conceptualized. The model allows us to examine economic impacts of different levels of outbreak and of trade policy for fresh and processed pears in terms of consumption, production, value added, and trade; and to measure consumer and producer welfare effects from such outbreaks.

Overview of the Model

In our model of domestic and international supply and demand for fruit, we differentiate fresh and processed fruit. Fruit from growers to consumers passes through four market levels: the farm level, a packing or processing level, a wholesale level and a retail level. Fresh and processed fruit allocation is determined by producer prices and total production. Fresh fruit markets exhibit higher prices and therefore the remaining fruit goes to the processed market at lower prices. At the wholesale level, fruit is allocated to domestic or international markets. Supply and demand are linked through market clearing conditions. Farm-level and retail-level prices are identified through marketing margins.

The model is comprised of three fundamental parts, supply, demand, and international trade. A dynamic supply response model is necessary to capture the perennial nature of tree fruit. After planting, fruit tree takes several years to mature and then is commercially productive for several decades. Thus, decision regarding plantings and removals is expressed as a linear function of bearing acreages. Due to data limitation, perennial tree fruit supply response is estimated by an econometric model based on historical data. Bearing acreages along with yield per acre comprise the total supply. On the demand side, demand is aggregated by population from the individual demand model. Aggregate per capita demand models provide parameters that can be used to estimate gross and net
benefits to the industry from shocks. Imports and exports are linked to U.S. market prices through trade policy.

A hypothetical fire blight outbreak can be decomposed into three separate potential effects. Supply shocks result from reducing bearing acreages and decreasing yields, trade sanction shocks result from total loss of fruit exports either a United States trade embargo or importers decrease or even refuse to import fruit from the United States, and consumer shocks result from potential adverse consumer reaction to consumption of tree fruit. The most important is the effects of those exogenous shocks on the prices of domestic farm level outputs determined endogenously within model. The estimated dynamic supply response along with markets clear each year allows us to compare the simulation results with and without outbreak events, and different levels of public resources input to clean up the events among outbreak events.

To empirically estimate the model we construct an equilibrium displacement model for pears from the theoretical model. The logarithmic differential version is advantageous because the differential version is driven by elasticities. The logarithmic differential version can also be applied to observed historical data, and base data can be updated as new values are available.

**Supply, Demand and International Trade**

**Primary Farm Level Supply**

Pest and disease events affect regional supply in the short term and the long term because trees are durable goods (Zhao et al 2007). Pest and disease outbreaks cause damage by reducing yield and bearing acreage. Bearing acreages of a single fruit, the state variable, reflect the dynamic process. The long life cycle of perennially producing trees tend to
make suppliers less responsive to market prices in the short term. However, sudden
shocks to the production system can cause wide fluctuations in fruit market in a long term.

The production of perennial fruit involves planting, removal, yield, and time
dimensions. A model needs to provide a structural base for estimating response
relationships that encompass these dimensions (French and Matthews 1971). Several
studies have considered age distribution effects in providing separate estimates of new
planting and removal equations. See French and Matthews (1971) for asparagus, French,
Gordon and Minami (1985) for peaches, Akiyama and Trivedi (1987) for tea, Elnagheeb
Compared with annual crops, perennial crops involve not only planting, removal, and
replacement of plants. A perennial model must also consider lags between input and
output, and effects of populations of bearing plants on production. Error correction
models or adjustment models are used to capture the nature of relationships between
actual and desired values of new plantings. The acreage in individual age categories
evolves depending upon existing acreage, new planting, and removals. The producer
plants new trees and removes existing acreage to maximize profits over an infinite
horizon. By the dynamic nature of a perennial crop, the change in acreage is a linear
function of new plantings and removals (see equation 3). However, due to data
limitations on age distributions, and a lack of new plantings and removal data, we use
econometric methods to estimate changes in bearing acreages so that with yield per acre
we can predict total fruit production.

The dynamic process for the bearing acreage of fruit trees is given by

\[ K_{t+1} = K_t - RM_t, K_t = NP_t \]  

(1)
The total acreage of trees for year \( t \) is \( \sum_{j=0}^{\mu} K_j^i \), where \( K_j^i \) is the acreages of age \( j \) trees at year \( t \). Bearing acreage, \( B_i \), which is summation of different age of trees that bear significant quantity of commercial crop at period \( t \). \( NP_i \) denotes new plantings at year \( t \).

Assuming pear trees start to bear fruit at age 3, and maximum life time of trees is \( \mu \), then

\[
B_i = \sum_{j=3}^{\mu} K_j^i
\]  

(2)

And we find the change in bearing acreage as

\[
\Delta B_i = B_{i+1} - B_i = NP_i^0 + \sum_{j=3}^{\mu} RM_i^j
\]  

(3)

Yield per acre is an important factor that will affect the precision of the policy analysis result. Yield per acre of mature fruit trees reflects the influence of management and technological changes. With pears for example, the rootstock structure changes. Growers prefer to plant dwarf and semi-dwarf pear trees instead of standard trees. The rootstock structure changes the yield per acre of pear trees in the long run. Yields also reflect random seasonal variations in weather and pests. The effects of technological changes may be measured by a trend variable (a function of time or as a dummy variable). To capture these characteristics, we assume the expected yield of mature fruit can be written as a trend model of the following form: \( yp_{r,t+n} = \left(1 + g\right)^n yp_r \), where \( yp_r \) is the projected yield per mature bearing acre in year \( t + n \), which is equal to the value in the base year \( yp_{r,t} \) scaled by a growth rate \( g \). The trend growth rate implies that yield values are calibrated based on empirical analysis of historical data. To average out weather effects, we use a three-year moving average to estimate the growth rate.
The primary farm level supply for pears can be obtained by multiplying bearing acreage and yield.

\[ FS_{r,t+1} = B_{r,t+1}yp_{r,t+1} = (\Delta B_{r,t} + S_{r,t+1} + B_{r,t})yp_{r,t}(1 + g_r) \quad (4) \]

Based on primary farm level supply, we find change in supply:

\[
d\ln FS_{r,t} = \frac{\Delta FS_{r,t}}{FS_{r,t}} = \frac{FS_{r,t+1} - 1 - B_{r,t+1}yp_{r,t+1} - 1}{B_{r,t+1}yp_{r,t+1}} = \frac{(\Delta B_{r,t} + S_{r,t+1} + B_{r,t})yp_{r,t}(1 + g_r)}{B_{r,t}yp_{r,t}} - 1 \\
= (1 + g_r)(1 + \frac{\Delta B_{r,t} + S_{r,t+1}}{B_{r,t}}) - 1 = \frac{\Delta B_{r,t} + S_{r,t+1}}{B_{r,t}}(1 + g_r) + g_r \quad (5) \]

where \( FS_{r,t} \) is the total supply at region \( r \) at time \( t \), \( B_{r,t} \) is bearing acreages at region \( r \) at time \( t \), \( yp_{r,t} \) is yield per acre at region \( r \) at time \( t \), \( \Delta B_{r,t} \) is the change in bearing acreages at region \( r \), \( S_{r,t+1} \) is exogenous shock due to pest or disease outbreak on bearing acreages.

Note that the supply change depends on the existing bearing acreage, change in bearing acreage the next year, yield per acre growth rate, and exogenous shocks.

Price expectation is an important factor for a grower’s decision-making process, and it would affect the accuracy of policy analysis. It would affect the supply response through a changing age distribution structure every year and therefore the production of fruit. Our model will solve for the equilibrium price in each period sequentially. Growers update their price expectation each year instead of making a fixed assumption on the expected price. They make an investment decision each year with new information. This will help to obtain more robust analysis results. See Appendix A for more details on the econometric model for supply response.

Once fruit are produced, they are allocated to either the fresh or processed markets. This allocation is determined by producer prices, with an observed fresh market prices higher than the processed market prices. Only those pears that fail to meet fresh market...
grade are processed. Gao and O'Rourke (1992) analyzed demand for Pacific Coast pears which separately identified Bartlett and winter pears in fresh and processed uses. They point out that production would affect pear price and the optimal allocation of pears to the fresh or processing markets. Farm level demand for $i$ at region $r$ is given as

$$FD_{i,r} = FP_{i,r}(p^F_{f,r}, p^F_{p,r}, FS)$$

where $i = f, p$ indicate fresh and processed use; $r = 1, \ldots, R$ denote the regions; $FD_{i,r}$ is the quantity demanded at the farm level for use $i$ at region $r$, $P^F_{i,r}$ is the farm level price for use $i$ at region $r$.

In the processing market, the price maybe set before the crop year. For example, the price for Bartlett processing pears grown in the Pacific Northwest has been set for the next three years (2012 to 2014) through negotiations between Washington Oregon Canning Pear Association and processors. So in practice, the allocation of fruit to fresh markets will be considered as a function of the total production and price for the fresh fruit. The allocation of fruit to the processed market will be the total production minus the quantity distributed to fresh markets.

$$FD_{f,r} = FP_{f,r}(p^F_{f,r}, FS)$$

$$FD_{p,r} = FS - FD_{f,r}$$

**Retail-level demand and supply**

**Individual demand model**

Let $q$ denote a $n$-vector of commodities consumed with a $n$-vector of corresponding prices $p$ and income $I$. We define $z$ to be other shift or conditioning variables. Then the consumer’s maximization problem is
\[
\max_x \{u(q; z) \mid p' x \leq I\}
\]

where \(u(q; z)\) reflects the individual’s utility function with appropriate properties\(^7\). Then the individual consumer’s demand for a vector of commodities can be represented by
\[
q = f(p, I; z)
\]

This implies that demand for fresh and processed fruit should be a function of the price of the fresh and processed fruit, their substitutes or complements, and other shift variables, such as a demand shift from consumer shocks due to a pest or disease outbreak.

Regional demand

Under the assumption that consumers have a homothetic utility function, the individual demand functions represented above can be linearly aggregated, \(Q = \sum_{k=1}^{\text{pop}} q\), by region in the United States to construct aggregate quantity demanded by region.

The per capita demand function for \(i\) at region \(r\) is given by
\[
q_{i,r}^D = f_{i,r}^D(p_{f,r}, p_{p,r}, p_{o,r}, I_r, z)
\]

(9)

where \(q_{i,r}^D\) is the per-capita consumption of the retail fruit \(i\) demanded at region \(r\);

\(p_{f,r}\) and \(p_{p,r}\) are retail-level prices for fresh and processed pears at region \(r\);

\(p_{o,r}\) is a vector of prices for all other substitutes or complement, if any, for the fresh and processed fruit;

\(I_r\) is the per-capita income at region \(r\);

\(z\) is a demand shift for consumer shock because of a pest or disease outbreak.

Possible alternative substitute or complement fruit varieties for pears include apples and oranges (Arnade and Pick 2000). In their empirical analysis, orange prices in their

\(^7\) See Deaton and Muellbauer (1990) for background details related to demand systems
demand model for pears showed statistical insignificance and apples prices were statistically significant. Hence, in our model analysis we choose apple as the complement or substitute for pears.

Consumers have concern about food safety. Fresh fruit has come under particularly close scrutiny because of the chemicals used to control pests or plant diseases. Health risks associated with pesticide residues on produce have been of concern for many years. A consumer’s willingness to pay for a health-risk reduction may serve as an indicator of demand for food safety. Consumer willingness to pay (WTP) for pesticide-free or low-pesticide fresh produce has been studied (Misra, Huang and Ott 1991; Eom 1994; Fu, Liu and Hammitt 1999; Boccaletti and Nardella 2000; Cranfield and Magnusson 2003). They found that consumers’ stated preferences for safer produce were primarily influenced by price differences and perceived risks and consumers who are concerned about health risks have greater WTP for pesticide-free or low-pesticide produce. This should be taken as evidence that consumers would like to buy less pesticide with their produce. Our study assumes that fewer consumers would purchase fruit if pest or disease occurs. We introduce parameters to capture the consumer shocks for fresh and processed fruit in the model structure.

Total consumption of fresh or processed fruit in each region of the United States depends on per-capita consumption multiplied by the scalar population, $p_{op_r}$, and a scalar $\alpha_{i,r}$, $0 \leq \alpha_{i,r} \leq 1$, of parameters that indicate the share of the population unafraid of a health risk associated with the fruit disease at region $r$.

National retail-level demand is given by
\[ QD_i = \sum_{r=1}^{g} QD_{i,r} = \sum_{r=1}^{g} \text{pop}_r \cdot q_{i,r}^D \cdot \alpha_{i,r} \] (10)

and regional retail-level demand is given by

\[ QD_{i,r} = \text{pop}_r \cdot q_{i,r}^D \cdot \alpha_{i,r} \] (11)

where \( QD_{i,r} \) denotes total consumption for \( i \) at region \( r \) and \( \text{pop}_r \) is the population at region \( r \).

The total production supplies are intended for both export and domestic markets. Retail level supply for domestic consumers includes domestic utilized production plus imported fruit and excludes those fruit demanded by international market (export).

**International Trade**

Trade is linked to U.S. market prices, trade policy, and disease outbreaks. We introduce two parameters to capture the specific trade intervention and severity of trade restrictions. Trade is determined by the U.S. domestic price along with the specific trade intervention. Exports depend on prices and trade interventions and, in some cases, on the disease outbreak. Of central interest are the effects of exogenous shocks in the international market on the prices of a country’s domestic farm outputs.

As pest and disease outbreaks can disrupt trade, parameter \( \gamma_e \), ranging from 0 to 1, is used to indicate the severity of trade restrictions imposed by foreign importers. Letting \( c_{i,r}^{SPS} \) be a vector of trade interventions, then

\[ E_{i,r} = \alpha_i (p_{i,r}^W - c_{i,r}^{SPS}) \cdot \gamma_e \] (12)

where \( E_{i,r} \) is the quantity demanded by international market from region \( r \), and \( c_{i,r}^{SPS} \) is the cost imposed by SPS. Peterson et al. investigate the trade impact of different pest-
mitigation measures using a product-line gravity equation for fresh fruit and vegetables and they find that phytosanitary treatments generally reduce trade (Peterson et al. 2013).

The import demand for foreign fruit products, if the imported fruit and domestically produced fruit are homogeneous, is also a function of the domestic price. As pest and disease outbreaks can disrupt trade, parameter \( \gamma m_i \), ranging from 0 to 1, is used to indicate the severity of trade restrictions. Letting \( tm_i \) be a vector of trade interventions, then

\[
M_{i,r} = md_i (p^W_{i,r} - tm_i) \cdot \gamma m_i
\]  

(13)

where \( M_i \) is the quantity of the imported fruit at region \( r \).

National retail-level supply is given by

\[
QS_i = \sum_{r=1}^{R} (FS_{i,r} + M_{i,r} - E_{i,r})
\]

(14)

And regional retail-level supply is given by

\[
QS_{i,r} = FS_{i,r} + M_{i,r} - E_{i,r}
\]

(15)

where \( QS_{i,r} \) is quantity of the retail-level supply for fruit at region \( r \), \( FS_{i,r} \) is the domestic produced fruit at region \( r \), \( M_{i,r} \) is the quantity imported by region \( r \) from the international market, and \( E_{i,r} \) is quantity demanded by the international market from region \( r \).

**Intermediaries**

For those pears going to fresh market, they go through packers/shippers to retailers and then to consumers. During harvest season, orchard bins full of pears are delivered to packing houses. The packers provide marketing services such as handling, washing, sorting and grading, packing, inspection, storage, and shipping. Packed pears are then
held in cold storage until they can be sold on the fresh domestic and international market. Pears are consumed by consumers through retailers and food services. For example, the U.S. Department of Agriculture buys almost a million cases of pears annually for school lunch programs. For those pears going to processed market, processors buy them and sell the processed product. Process means to can, concentrate, freeze, dehydrate, press, or puree pears.

Pears are value-added from growers to consumers through the packers and processors. Wholesalers play an important role in connecting farm-level and retail-level markets. It is reasonable to use a marketing margin to connect the vertical markets as long as evidence shows that no market power exists that will affect our analysis.

Wann and Sexton (1992) showed that producer prices in the US pear market are not significantly different from marginal costs. We assume that the market for selling producer fruit is competitive and that producer prices equal producer marginal costs. This assumption of competitive markets at the producer level is supported by the fact that there are 1,640 pear growers in Oregon and Washington and none of the pear growers are large (Carman et al. 2004; Winfree et al. 2004).

Carman et al. (2004) reported that there are approximately 70 handlers of winter pears in Oregon and Washington, none of which are large operations. Meanwhile, the largest individual shippers each handle 6 to 8 percent of all pears. Winfree et al. (2004) pointed out that more than 80 percent of the sales and marketing of pears is handled by fewer than ten sales desks or packers in the Northwest D’Anjou pear industry but oligopoly power is not an issue. This is because the packers do not actually buy the pears from the growers. Rather, they provide marketing services. They also found that the Northwest
D’Anjou pear industry has had some degree of oligopoly power when the new crop first enters the market and when flows of shipments from imports and/or other pear varieties are low. Arnade and Pick (2000) pointed out that estimating oligopoly power using annual data may generate results that suggest a competitive market when in fact seasonally varying oligopoly power may exist.

As discussed above, it is appropriate to use the marketing margin to connect the farm level and retail level markets in our model specification. We denote $p_{i,r}^W$ as the wholesale price for fruit $i$ at region $r$. The relationship between grower-received price and wholesale price is given by

$$p_{i,r}^F = p_{i,r}^W - MM_{i,r}^F$$

where $p_{i,r}^F$ is the growers’ price for $i$ at region $r$, and $MM_{i,r}^F$ is the markup price because of marketing services between the farm-level market and the wholesale-level market.

The relationship between retail received price and wholesale received price is given by

$$p_{i,r}^R = p_{i,r}^W + MM_{i,r}^R$$

where $p_{i,r}^R$ is the retail-level price for $i$ at region $r$, and $MM_{i,r}^R$ is the markup price because of marketing services from wholesaler to consumers.

**Market Closure**

In our empirical analysis, we assume the market clears at the national level. Equation (14) can be rewritten as

$$QD_i + E_i = \sum_{r=1}^{R} FS_{i,r} + M_i$$

(18)
where \( QD_i \) is the quantity demand at domestic retail market for \( i \). Using the markup price equation (16) and equation (17), the partial equilibrium wholesale price can be solved from the marketing clearing conditions. See Appendix B for differential transformation of the conceptual model.

**Results and Interpretation**

**Data**

Data for each individual state were collected from the Noncitrus Fruits and Nuts Summaries (USDA-NASS). State level bearing acreages, yield per acre, and grower prices received were collected from USDA-NASS. Quantity and price data for fresh and processed pears were taken from the Foreign Agricultural Service’s Global Agricultural Trade system (GATS). Per-capita consumption of fruit was collected from Food Availability Data System (USDA-ERS 2010). Wholesale price for fresh pears were downloaded from the Agricultural Marketing Service (USDA-AMS). Retail-level price for fresh pears was collected from the Bureau of Labor Statistics. Regional population data were from the Bureau of Economic Analysis, U.S. Department of Commerce. We deflated all the prices into 2010 dollar values and used the 4% discount rate to calculate net present values. Parameters such as elasticities are either from previous literature or calculated by authors.
Fire blight in Pears

Fire blight, caused by the bacterium Erwinia amylovora, is a common and devastating bacterial disease of apples and pears, as well as other species in the Rosaceae family.\(^8\) This disease can rapidly move internally in host plant tissues. Unlike many other plant diseases, fire blight is destructive to the current year’s crops, and it can cause permanent damage to an orchard.\(^{(}\text{Group 2005; Ellis 2008}\))

An epidemic outbreak of fire blight in a given geographic area has the potential to destroy the economic viability of apple and pear production in that region. The outbreak causes yield reductions, and it may indirectly put the processing industry at risk. An example is the processing pear industry in Ontario. A fire blight epidemic also has the potential of substantially increase a grower’s production cost. An infection requires diligent and regular dormant pruning, removal of diseased branches, and spraying with an EPA-labeled antibiotic during flowering, to reduce losses throughout the orchard. A blight prevention program results in higher cost on the spraying equipment, labor, and the applied chemicals. Labor already is the single largest expense to an orchard operation, averaging about 35-40% of total expenses. A significant fire blight outbreak, and the inability to access efficacious control tools, may result in a grower, or even a local industry, never being able to recover from the outbreak.

Prevention and control are the two basic ways of reducing costs of an invasive pest species\(^{(}\text{Dunley, Kupferman and Willett 2001}\)). Optimal resource allocation between prevention and control has been studied \(^{(}\text{Shogren 2000}\)). The only practical control strategy in case of an outbreak is eradication. The efforts made to eradicate pest or

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\(^8\) See Bonn and van der Zwet (2000) for more details about distribution and economic importance of fire blight.
disease depends on the characteristic of the pest, along with spatial factors, such as pest population size, rate of spread, and the capacity of a regulatory authority to reduce this rate of spread.

**Scenarios and Results**

We examine nine fireblight outbreak scenarios in the U.S. pear industry (See Table 3.1) and report their results compared with a baseline scenario. Three types of scenarios are considered: 1) supply shocks; 2) supply shocks and international trade distortion; 3) supply shocks, international trade distortion, and consumer shocks. For each case, we differentiate three levels of severity of outbreak for each case: High, Median, and Low. The high (low) level represents a worst (best) case outbreak event with more (less) severe trade distortion and adverse consumer reaction. The median level outbreak comes in between the high and the low levels.

The baseline scenario is simulated without pest and disease outbreak initially in 2002. The long run equilibrium is defined by pear trees planting and removal decision (change in bearing acreages), wholesale prices, consumption, import and export for fresh and processed pears. To compare with the baseline scenario, we quantify the economic impacts of outbreak scenarios.

**Scenarios 2-4: Outbreak Impact**

Figure 3.4 displays grower price fluctuation from a supply shock, where a hypothetical fireblight outbreak occurs in 2015 for three scenarios: High (Scenario 4); Median (Scenario 3); and Low (Scenario 2). Grower price is an average price of farm-level fresh and processed pear prices weighted by utilization. Grower price shows a pattern that it is alternatively higher and lower than the baseline every other 10-15 years and it converges to a long run equilibrium level. Bearing acreages has similar pattern but with opposite
direction. Bearing acreage simulation result in baseline displays a decline trend and this is consistent with the history of the pear industry in the United States. The figure also shows that High scenario has the largest impact in terms of the price fluctuation, followed by Median scenario, and then Low scenario. This is associated with higher change in production driven by higher change in bearing acreages results in lower grower price. In the long run, the grower price reverts to the baseline. Farm-level fresh and processed pear prices have the same pattern as the grower price. Farm-level fresh pear price is higher than processed pear price, which is consistent with historical data. The upward trend of grower prices are driven by demand increase that we assume a population growth rate.

As the grower prices grow over time, import demand for fresh and processed pears are also increasing and demand by foreign importing countries (export) decreases. Imports and exports fluctuate above and below the baseline over time. The higher the outbreak level, the farther the outbreak scenario deviates from the baseline.

Domestic consumer benefits associated with the outbreak are calculated as changes in consumer surplus (the area below the domestic demand curve) relative to the baseline, reflecting the effects of both price changes and shifts in the demand. Figure 3.5 and Figure 3.6 show time path of change in consumer surplus for fresh and processed pears. Consumer surplus follows a pattern. Consumers are worse off owing to higher pears prices for some time, and are better off when supply is higher than baseline for the others. Consumer loses more when higher shocks occur.

Producer benefits and/or losses associated with the outbreak are computed as well. There are the differences between the outbreak scenario and the basline, for each scenario and for each year of the simulation as the change in producer surplus. Figure 3.7 shows
change in revenue per acre for the three scenarios. The change in revenue per acre fluctuates within a range of -1000 and 2000 dollars per acre in discounted value. Severe shock results in larger loses. The positive change in revenue per acre eventually causes an increase in the time path of bearing acreages. Because of lag between investment decision and the realization of that decision in the pear industry, the effect on bearing acreages is not observed until the pear trees reach reproductive maturity. The increase in bearing acres results in increased production, driving down prices and revenue per acre and dissipating the benefits for producers.

**Scenarios 5-7: Outbreak and Trade Sanction**

Compared to scenarios 2-4, grower price in scenarios 5-7 are smaller on average. This may be associated with the decreased export due to trade sanction flow to domestic market drive the price down. High scenario has the biggest impact in terms of the price fluctuation. Higher bearing acreages lead to higher output, which results in lower grower price. Farm-level fresh and processed pear prices have the same pattern as grower price.

As the grower prices increase over time, imports for fresh and processed pears increase while exports decrease. But imports and exports deviate above and below the baseline. The higher the outbreak level, the wider the deviation from the baseline. At the same outbreak level, exports in scenario 5-7 (with trade sanction) is smaller than those in scenario 2-4 (without trade sanction).

Compared to scenario 2-4, domestic consumer benefits in scenario 5-7 are higher on average over time. Consumers benefit from decreasing exports but at the same time they consume less imports pears. Decline in exports and imports compared to baseline make the consumers benefits have similar pattern as scenario 2-4. Producer benefits and/or
losses measured by change in revenue per acre fluctuate within a range of -1200 and 2000 dollars per acre in discounted value, which is close to those without trade sanction (scenario 2-4).

**Scenarios 8-10: Outbreak, Trade Sanction plus Consumer Shock**

Overall, grower prices have an upward trend over time. Grower prices in scenario 8-10 are slightly higher than that of baseline only several years after outbreak and they are lower than that of baseline after 2022, which is different from scenarios 2-7. This may be associated with domestic consumer shocks shift down domestic demand and trade sanction increase domestic supply by decreasing export. These two factors together drive down grower prices. Farm-level fresh and processed pear prices have the same pattern as grower price.

Different from scenario 2-7, imports for fresh and processed pears increase over time but they are less than those in baseline (Recall that in scenarios 2-7 imports fluctuate above and below baseline). Export for fresh and processed pears has a downward trend but higher from 2022 to 2040 compared to scenario 2-7. More pears are exported is associated with domestic consumer shock after outbreak dominate the effect from trade sanction imposed.

Domestic consumer benefits associated with the outbreak, measured by change in consumer surplus with baseline, reflects the effects of both price changes and demand shifts. Change in consumer surplus with baseline is negative over time for fresh pears, which indicates that consumer surplus for fresh pears is worse off than baseline, different with pattern of scenario 2-7 (recall that in scenario 2-7 consumer surplus fluctuated above and below baseline over time). Consumer surplus for processed pears is worse off
followed by several years better off after outbreak. Consumers lose more when shocks are severe. Producer benefits and/or losses measured by change in revenue per acre fluctuate within a range of -1500 and 1000 dollars per acre in discounted value. The change in revenue per acre fluctuates and is higher than baseline for the first several years and then is negative for the rest of the time, which is different with scenarios 2-7 (recall that revenue per acre fluctuates with a range). Severe shock results in larger loses. This may imply that it takes much longer for the pear industry to recover from multiple effects by fire blight shock.

**Comparisons between Baseline and Outbreak Scenarios**

To summarize the effects of the pest and disease outbreak over the 60-year simulation, we report average effects over 60 years for some variables and for other variables we report net present value in 2010 of the effects over the 20 years and 10 years after hypothetical outbreak in 2015 and 60 years since initial year in 2002. The average effects illustrate the overall impact of the fire blight outbreak over 10, 20 and 60 years. The values at the end of 60 year compared to baseline show us how the pear industry performance in order to recover from outbreak in the long run. Through comparing the simulation results with baseline, impact of different scenarios from fire blight outbreak are quantified (See Table 3.2).

Compared to the baseline, fire blight outbreaks in scenario 2-4 decrease the average number of bearing acreage and production over the 60 years. These decreases in production are associated generally with decrease in domestic consumption and decreases in exports and imports for both fresh and processed pears. And the more severe the fire blight outbreak, the higher the impacts are on production, consumption, export, and
Scenario 4 has the largest impact from the fire blight outbreak, followed by scenario 3, and then scenario 2. These means show average effects and they average out the negative impacts in some years and positive impacts in others over 60 years. For instance, average imports of fresh pears and processed pears in scenario 2 are higher than those in baseline over time, while imports in scenario 2 is much less than those in baseline in 2062. In 2062, the bearing acreages are higher than those in baseline. The increase in production causes the grower price is smaller than the grower price in baseline and wholesale prices in outbreak scenarios are smaller than the wholesale price in the baseline, which results in decreases in the export and import and consumption as well compared to the baseline.

Compared to baseline, the outbreaks and sanction ban in scenario 5-7 decrease the bearing acreages and production over the 60 years. These decreases in production and sanction ban imposed by foreign importers are associated with decrease in exports, imports, and processed pear consumption and increase in domestic fresh pear consumption. Scenarios with sanction ban export less than scenarios without sanction ban under the same outbreak level. For instance, scenario 5 and scenario 2 has the same outbreak level but scenario 5 with sanction ban export less than (4.4 million pounds) those in scenario 2 without sanction ban. Because of sanction ban, more fresh and processed pears go to domestic market and therefore results in less import. And hence decline in exports drives up the total consumption of fresh and processed pears. In the 2062, although bearing acreages and production are higher than those of baseline, the impact of sanction ban imposed by importing countries decrease exports affects the price in a long time such that the wholesale prices are still below baseline’s. Because of much less
export in the scenarios 6-7 than in baseline balanced with even more less import for fresh pears, the consumption for fresh pears are still slightly lower than those in baseline. While consumption for processed pears are higher than those in the baseline.

Scenarios 8-10 are three levels of shocks on: bearing acreages, sanction ban, and consumer adverse reaction (See Table 3.1). Compared to baseline, the outbreaks, sanction ban, and consumer shock in scenarios 8-10 decrease the bearing acreages and production over the 60 years. The impacts in scenarios 8-10 are higher than scenarios 5-7 and 2-4 at the same level of fire blight outbreak. These decreases in production and trade sanction imposed by foreign importers and domestic consumers adverse reaction are associated with decrease in exports, imports and domestic consumption over the 60 years. The average exports are lower than those in baseline but higher than those in scenario 2-7. The average prices in scenarios 8-10 are lower than that in scenario 2-7 mainly due to consumer shock. And with lower price, exports of fresh and processed pears increase. In 2062, bearing acreages and production are lower than those in baseline. Scenarios 8-10 have the biggest gap with baseline compared to scenarios 2-7 in terms of imports and consumption, while exports are closest to the baseline compared to other scenarios. The impact of the consumer adverse reaction, even if there was trade sanction, results in lower prices of fresh and processed pears than those in baseline. The lower price causes more pears are exported and less pears are imported.

The net benefits/loss from the fire blight outbreak, reflecting the consequences of both effects of demand and supply responses, are expressed as average present values (in 2010 dollar value) of changes in the economic surplus accruing to different groups. Take scenario 3 as an example, over 60 years horizon, these net losses include $1.26 million to
domestic producers and $4.65 million for domestic fresh pears consumers and $4.04 million for domestic processed pears consumers, yielding a total national net loss of $9.96 million each year. The change in national benefit is higher over 20 years than 60 years. Over 20 years horizon, the change in national loss is $20.52 million compared to the baseline, include total loss of $12.05 million for domestic fresh pears consumers and $10.7 million for domestic processed pears consumers, while producer benefit $2.24 million each year after outbreak. The change in national benefit is higher over 10 years after outbreak than 20 years. Over 10 years horizon, the change in national loss is $61.86 million compared to the baseline, include total loss of $43.32 million for domestic fresh pears consumers and $38.86 million for domestic processed pears consumers, while producer benefit $20.32 million each year after outbreak.

From a global perspective, we calculated the foreign consumer surplus (the “foreign consumer surplus” measured off the demand for U.S. exports) and foreign producer surplus (the “foreign producer surplus” measured off the supply to the United States from worldwide). Over 60 year horizon, changes in foreign consumer surplus for fresh and processed pears are negative, reflecting that foreign consumers are worse off due to U.S. fire blight outbreak in the long run. While, foreign producers are better off in scenario 2-4 within 10 to 20 years after outbreak. Overall, the net changes in foreign benefits are worse off than in baseline. The welfare change over 20 year horizon is similar to over 60 years except that net change in foreign losses is higher than those over 60 years.

**Discussion and Conclusions**

This study presents an intertemporal economic model to estimate economic impacts of a single tree fruit pest and disease outbreak. The model is designed to examine the
economic consequences of pest and disease outbreak on demand and supply with international trade. Our approach used a dynamic simulation of the single tree fruit industry under scenarios with and without outbreak to compare the stream of simulated outcomes and the consequences for measures of economic welfare of producers in the industry, consumers, the nation as a whole, and the rest of world.

A hypothetical fire blight outbreak in the U.S. pear industry is used to illustrate the utility of the model. The model considers three effects for the hypothetical fire blight outbreak for the pear industry and looking forward more than 40 years after the events. The three effects include supply shock, trade sanction, and consumer shock with 9 scenarios. The more severe the fire blight outbreak, the worse the consequences are for the pear industry. At the same outbreak level, scenarios with consumer shocks and sanction ban imposed have the highest magnitude impacts, followed by the scenarios with sanction ban imposed, and then scenarios with supply shocks. The national may benefits from the shocks in the short run, but in the long run, both the domestic and foreign parts are worse off from the outbreaks.

This study revealed a number of issues that may be important in analyses of other polices in the context of perennial tree fruit and in analyses of international trade policy and food safety in a more general setting. First, analyses of pest and disease outbreak deal with events that are not predictable that is difficult to estimate with any precision and that, when they do occur, can have disastrous consequences for demand. The modeling of consumer shock is added into the model to capture the uncertainty. Second, in the case of perennial crops, analysis become particularly complicated because of the initial impacts on supply response will last for a long time and with limited data for pear trees age
distribution, we use econometric model to estimate the change in bearing acreages to capture the dynamic supply response.

In summary, the study reveals consequences of fire blight outbreak in the pear industry through compare with non-outbreak scenario. The study also reports the changes in the benefits for different shocks, includes supply shock, international market shock, and consumer shock. These findings quantify the benefits and/or losses for different groups both in the short run and in the long run. It would be interesting to apply some policy implications in the future work.
References


Figure 3.1 Production and Allocations of Pears for Fresh and Processed Usage, 1980-2010
Figure 3.2 Grower Price for Pears Dollars per Pound, 1980-2010
Figure 3.3 Exports and Imports of Fresh and Processed Pears, 1989-2011
Figure 3.4 Economic Impact of Fire Blight Outbreak on Grower Prices, 2002-2062
Figure 3.5 Economic Impact of Fire Blight Outbreak on Change in Consumer Surplus for Fresh Pear, 2002-2062
Figure 3.6 Economic Impact of Fire Blight Outbreak on Change in Consumer Surplus for Processed Pear, 2002-2062
Figure 3.7 Economic Impact of Fire Blight Outbreak on Change in Producer Surplus per Acre (Change in Revenue) of Pears, 2002-2062
Table 3.1 Hypothetical Fire Blight Outbreak Scenarios in U.S. Pear Industry, 2015

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Bearing Acreage Shock</th>
<th>Export Shocks</th>
<th>Consumer Shock</th>
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<td></td>
<td></td>
<td>Specific Intervention</td>
<td>Mutiple Shock</td>
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<td>(2)</td>
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<tr>
<td>(3)</td>
<td>-4000</td>
<td>-0.03</td>
<td>-0.07</td>
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<td>(4)</td>
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<td>-0.03</td>
</tr>
<tr>
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</tr>
<tr>
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<td>(8)</td>
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<tr>
<td>(10)</td>
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Table 3.2 Simulation Results for Fire Blight Outbreak Scenarios, 2002-2062

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<td>-7.59</td>
<td>-17.82</td>
<td>-33.56</td>
</tr>
<tr>
<td>Imports -Processed Pears (million lbs)</td>
<td>129</td>
<td>-0.6</td>
<td>-1.94</td>
<td>-4.02</td>
<td>-1.25</td>
<td>-2.95</td>
<td>-5.35</td>
<td>-3.41</td>
<td>-8.18</td>
<td>-15.48</td>
</tr>
<tr>
<td><strong>Consequences over 60-Year Horizon (million dollars)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in U.S. Consumer Surplus (CS)-Fresh pears</td>
<td>-2.77</td>
<td>-4.65</td>
<td>-5.55</td>
<td>-0.28</td>
<td>-0.20</td>
<td>0.87</td>
<td>-1.14</td>
<td>0.09</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td>Change in U.S. Consumer Surplus (CS)-Processed pears</td>
<td>-2.45</td>
<td>-4.04</td>
<td>-4.70</td>
<td>-0.79</td>
<td>-1.08</td>
<td>-0.40</td>
<td>-1.31</td>
<td>-0.38</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>Changes in Producer Surplus (PS)</td>
<td>0.58</td>
<td>-1.26</td>
<td>-5.33</td>
<td>-2.78</td>
<td>-6.64</td>
<td>-12.42</td>
<td>-7.50</td>
<td>-17.49</td>
<td>-32.23</td>
<td></td>
</tr>
<tr>
<td>Changes in Producer Surplus per Acre</td>
<td>31.70</td>
<td>14.93</td>
<td>-46.19</td>
<td>-44.32</td>
<td>-106.43</td>
<td>-206.43</td>
<td>-153.05</td>
<td>-358.40</td>
<td>-670.67</td>
<td></td>
</tr>
<tr>
<td>Changes in Foreign Consumer Surplus-Fresh pears</td>
<td>-0.26</td>
<td>-1.08</td>
<td>-2.45</td>
<td>-1.54</td>
<td>-3.32</td>
<td>-5.61</td>
<td>-1.45</td>
<td>-2.87</td>
<td>-4.35</td>
<td></td>
</tr>
<tr>
<td>Changes in Foreign Consumer Surplus-Processed pears</td>
<td>-0.01</td>
<td>-0.03</td>
<td>-0.08</td>
<td>-0.09</td>
<td>-0.17</td>
<td>-0.27</td>
<td>-0.09</td>
<td>-0.16</td>
<td>-0.24</td>
<td></td>
</tr>
<tr>
<td>Changes in Foreign Producer Surplus-Fresh pears</td>
<td>0.07</td>
<td>0.09</td>
<td>0.06</td>
<td>-0.02</td>
<td>-0.07</td>
<td>-0.15</td>
<td>-0.22</td>
<td>-0.52</td>
<td>-0.99</td>
<td></td>
</tr>
<tr>
<td>Changes in Foreign Producer Surplus-Processed pears</td>
<td>0.07</td>
<td>0.09</td>
<td>0.06</td>
<td>-0.02</td>
<td>-0.07</td>
<td>-0.15</td>
<td>-0.22</td>
<td>-0.52</td>
<td>-0.99</td>
<td></td>
</tr>
<tr>
<td>Net Changes in Foreign Benefits</td>
<td>-0.13</td>
<td>-0.93</td>
<td>-2.40</td>
<td>-1.68</td>
<td>-3.63</td>
<td>-6.19</td>
<td>-1.98</td>
<td>-4.07</td>
<td>-6.56</td>
<td></td>
</tr>
</tbody>
</table>

### Consequences over 20-Year Horizon (million dollars)

| Change in U.S. Consumer Surplus (CS)-Fresh pears | -6.68 | -12.05 | -15.97 | -2.72 | -4.73 | -5.25 | -9.38 | -15.22 | -26.70 |
| Change in U.S. Consumer Surplus (CS)-Processed pears | -5.98 | -10.70 | -14.05 | -3.34 | -5.80 | -6.86 | -8.54 | -13.72 | -23.17 |
| Changes in Producer Surplus (PS)                  | 2.54  | 2.24  | -0.72 | -2.15 | -5.63 | -11.34 | -7.81 | -18.57 | -34.83 |
| National Benefits(CS+FS)                          | -10.12 | -20.52 | -30.75 | -8.21 | -16.16 | -23.44 | -25.72 | -47.52 | -84.70 |
| Changes in Producer Surplus per Acre              | 100.15 | 161.10 | 186.35 | 7.10  | 3.49  | -28.78 | -105.94 | -257.70 | -509.30 |
| Changes in Foreign Consumer Surplus-Fresh pears   | -0.39 | -1.64  | -3.76 | -2.34 | -5.16 | -8.78 | -2.19 | -4.43  | -6.71  |
| Changes in Foreign Consumer Surplus-Processed pears | -0.01 | -0.05  | -0.12 | -0.14 | -0.27 | -0.43 | -0.14 | -0.25  | -0.37  |
| Changes in Foreign Producer Surplus-Fresh pears   | 0.90  | 1.72  | 2.45  | 0.27  | 0.58  | 0.83  | -0.60 | -1.49  | -3.08  |
| Changes in Foreign Producer Surplus-Processed pears | 0.20  | 0.37  | 0.53  | 0.08  | 0.17  | 0.25  | -0.11 | -0.29  | -0.62  |
| Net Changes in Foreign Benefits                   | 0.70  | 0.40  | -0.89 | -2.12 | -4.67 | -8.13 | -3.04 | -6.46  | -10.77 |

### Consequences over 10-Year Horizon (million dollars)

| Change in U.S. Consumer Surplus (CS)-Fresh pears | -22.31 | -43.32 | -63.04 | -18.37 | -35.85 | -52.25 | -37.30 | -70.74 | -122.63 |
| Change in U.S. Consumer Surplus (CS)-Processed pears | -20.08 | -38.86 | -56.39 | -17.48 | -33.96 | -49.34 | -32.85 | -62.11 | -106.27 |
| Changes in Producer Surplus (PS)                  | 11.62  | 20.32  | 26.18  | 6.85  | 11.88  | 14.58  | 0.69  | -2.61  | -12.61  |
| National Benefits(CS+FS)                          | -30.77 | -61.86 | -93.25 | -29.00 | -57.93 | -87.01 | -69.46 | -135.46 | -241.51 |
| Changes in Foreign Consumer Surplus-Fresh pears   | -0.50  | -1.98  | -4.44  | -2.50 | -5.89  | -10.18 | -2.33 | -5.00  | -7.66  |
| Changes in Foreign Consumer Surplus-Processed pears | -0.02 | -0.06  | -0.14 | -0.14 | -0.30 | -0.49 | -0.14 | -0.28  | -0.41  |
| Changes in Foreign Producer Surplus-Fresh pears   | 3.26  | 6.53  | 9.81  | 2.62  | 5.28  | 7.93  | 1.67  | 2.87  | 3.09   |
| Changes in Foreign Producer Surplus-Processed pears | 0.74  | 1.48  | 2.22  | 0.63  | 1.26  | 1.90  | 0.41  | 0.72  | 0.80   |
| Net Changes in Foreign Benefits                   | 3.47  | 5.97  | 7.46  | 0.60  | 0.36  | -0.84 | -0.39 | -1.69  | -4.18  |
Appendix A: Econometric Model for the Primary Farm Level Supply

We use a reduced form of change in bearing acreage to estimate the supply response for pear production, with an econometric model for change in bearing acreage:

\[
\Delta B_t = \beta_0 + \beta_1 \Delta B_{t-1} + \beta_2 \Delta \bar{p} + \beta_3 \bar{B}_{t-2} + \beta_4 \bar{Y}_{t-2} + \beta_5 t + u_t,
\]

Where \( \Delta B_t = B_t - B_{t-1} \), which is the change of pear-bearing acreage from year \( t-1 \) to year \( t \); \( \Delta \bar{p} = \left( \frac{\sum_{i=0}^{2} p_{t-i} + \sum_{i=0}^{2} p_{t-1-i}}{3} \right) \), which is the change of a three-year moving average of real producer pear price; \( \bar{B}_{t-2} = \frac{\sum_{i=0}^{5} B_{t-2-i}}{5} \), which is average bearing acreage during the previous five years at year \( t-2 \); \( \bar{Y}_{t-2} = \frac{\sum_{i=0}^{5} Y_{t-2-i}}{5} \), which is average yield per acre during the previous five years at year \( t-2 \), \( t \) is time trend starting from 1 at year 1920. \( u_t \) is the error term.

Table B.1 Parameter Estimates for Supply Response Model

| Variable   | Parameter Estimate | Standard Error | t Value | Pr > |t|  |
|------------|--------------------|----------------|--------|------|---|
| Intercept  | 14937              | 2429.63372     | 6.15   | <.0001 |
| \( \Delta B_{t-1} \) | 0.32289         | 0.08853        | 3.65   | 0.0005 |
| \( \Delta \bar{p} \) | 6.38583        | 3.12902        | 2.04   | 0.0445 |
| \( \bar{B}_{t-2} \) | -0.15549       | 0.02494        | -6.23  | <.0001 |
| \( \bar{Y}_{t-2} \) | -243.322       | 117.09314      | -2.08  | 0.0409 |
| \( t \)   | -28.5886          | 16.69686       | -1.71  | 0.0907 |

The estimation result shows that the adjusted R-square is 72.22%, which indicates that the model explains 72.22% of total variation. The DW statistic is 2.062 (approximately 2), implying that there is no autocorrelation in error terms.
Change in bearing acreage at year $t$ explains the summation of new plantings at year $t-2$, and removals at year $t$. Average yield per acre during the previous five years at year $t-2$ has a statistically significant negative effect on the change in bearing acreage. A stable increase in yield per acre reduces growers’ incentive to expand orchards or it accelerates the growers’ incentive to remove old trees and replant. Average bearing acreage during the previous five years at year $t-2$ ($\bar{B}_{t-2}$) also has a statistically significant impact on the change in bearing acreage. It is a good indicator for old trees that need to be removed in the next few years. If the proportion of old trees is higher, then the change in bearing acreage would decrease, caused by removal. Change in bearing acreage at a previous period has positive effect on the change in bearing at the present period.

A change in the three-year moving average of real producer pear price ($\Delta p^r$) is statistically significant and positively related to the change in bearing acreage. This can be explained as the growers’ expectation for the future pear market. If growers expect the price to go up, then they would expect more output through additional plantings and delayed removals.

A time trend as a proxy for orchards’ operation and management culture has a negative effect on bearing acreage. The removal of old trees may be postponed for better operation and management skills, therefore decreasing the change in bearing acreage.

The degree of the damage caused by pest and disease will depend on different factors, such as varieties and the orchard’s pest and disease control ability. A hypothetical outbreak of pest or disease in the fruit industry is used to illustrate the economic impact of these outcomes. Different scenarios of potential economic losses due to pest or disease
outbreaks can be applied to test the impact. The results allow us to estimate the effects of pest and disease shocks on bearing acreages along with yield, allowing us to predict total production.
Appendix B: Differential Transformation of the Conceptual Model

A numerical solution of the partial equilibrium model is facilitated by a total logarithmic differential version of the equations presented in the preceding part. The logarithmic differential version is advantageous because the differential version is driven by elasticities, which are easier to obtain than specific functional forms. The logarithmic differential version can also be applied to observed historical data and base data can be updated as new values are available.

The farm-level demand for fresh fruit is given by equation (7). Total logarithmic differentiate equation (7) gives:

\[ d \ln FD_{f,r} = \epsilon_{f,r}^F d \ln p_{f,r}^F + \frac{\partial FP_{f,r}}{\partial FS} d \ln FS \]  

(19)

where \( \epsilon_{f,r}^F = \frac{d \ln FD_{f,r}}{d \ln p_{f,r}^F} \) is the own-price elasticity of farm-level demand for fresh fruit, \( \frac{\partial FP_{f,r}}{\partial FS} \) is to measure the proportion of the total production change that will cause a proportional change in allocation to the fresh market.

Using a total logarithmic differentiatial equation \( FD_{p,r} = FS - FD_{f,r} \) (8), we get

\[ d \ln FD_{p,r} = \frac{FS}{FD_{p,r}} d \ln FS - \frac{FD_{f,r}}{FD_{p,r}} d \ln FD_{f,r} \]  

(20)

Total logarithmic differentiation of market margin equations (16) (17) gives:

\[ d \ln p_i^W = \frac{p_{i,r}^W}{p_i^W} d \ln p_{i,r}^F + \frac{MM_i^F}{p_i^W} d \ln MM_{i,r}^F \]  

(21)

\[ d \ln p_i^R = \frac{p_{i,r}^W}{p_i^R} d \ln p_{i,r}^W + \frac{MM_i^R}{p_i^R} d \ln MM_{i,r}^R \]  

(22)
The final demand in conceptual functional form is given by equation (11), which is per-capita consumption of fruit (equation (9)) multiplied by population. Logarithmically differentiating equation (11) regional consumption gives:

\[
d \ln Q_{i,r}^D = d \ln pop_r + \varepsilon_{f,i}d \ln p_{f,r} + \varepsilon_{p,i}d \ln p_{p,r} + \varepsilon_{o,r}d \ln p_{o,r} + \varepsilon_{i,r}d \ln I_r + d \ln \alpha_{i,r}
\]

(23)

where \(\varepsilon_{f,i} = \frac{d \ln Q_{i,r}^D}{d \ln p_{f,r}}\) is the elasticity of retail demand for fruit \(i\) with respect to retail fresh fruit price, \(\varepsilon_{p,i} = \frac{d \ln Q_{i,r}^D}{d \ln p_{p,r}}\) is the elasticity of retail demand for fruit \(i\) with respect to retail processed fruit price, \(\varepsilon_{o,r} = \frac{d \ln Q_{i,r}^D}{d \ln p_{o,r}}\) is the elasticity of retail demand for fruit \(i\) with respect to retail other fruit price, \(\varepsilon_{i,r} = \frac{d \ln Q_{i,r}^D}{d \ln I_r}\) is the income elasticity.

National demand in logarithmic differential form is given as:

\[
d \ln QD_i = \sum_{r=1}^{R} \frac{Q_{i,r}^D}{QD_i} \left( d \ln pop_r + \varepsilon_{f,i}d \ln p_{f,r} + \varepsilon_{p,i}d \ln p_{p,r} + \varepsilon_{o,r}d \ln p_{o,r} + \varepsilon_{i,r}d \ln I_r + d \ln \alpha_{i,r} \right)
\]

(24)

Taking total logarithmic differentiation of the exported fruit equation (12) gives:

\[
d \ln E_i = \varepsilon_{i}^{e}\left(p_{i}^{e}-c_{i}^{SPS}\right)^{-1}\left(p_{i}^{e}d \ln p_{i}^{e}-dc_{i}^{SPS}\right)+d \gamma e_i
\]

(25)

Fruit import demand is given by equation (13). Taking logarithmic differentiation of equation (13), we get

\[
d \ln M_i = \varepsilon_{i}^{md}\left(p_{i}-tm_{i}\right)^{-1}\left(p_{i}^{w}d \ln p_{i}^{w}-dtm_{i}\right)+d \ln \gamma m_i
\]

(26)

where \(\varepsilon_{i}^{md}\) is the own-price elasticity of imported fruit \(i\).

The conceptual retail-level supply functional form is given in equation (14). Total logarithmic differentiation of the function and substituting equation (25), (26) into it gives equation (27):
\[
\begin{align*}
 d \ln Q_{i} &= \sum_{r=1}^{R} \left( \frac{FS_{i,r}}{QS_{i}} \frac{d \ln FS_{i,r}}{QS_{i}} + \frac{M_{i,r}}{QS_{i}} \left( e_{i}^{\text{md}} \left( p_{i} - tm_{i} \right)^{-1} \left( p_{i}^{w} d \ln p_{i} - dtm_{i} \right) + d \ln \gamma m_{i} \right) - \frac{E_{i}}{QS_{i}} \left( p_{i}^{\varepsilon} \left( \gamma c_{i}^{\text{SPS}} \right)^{-1} \left( p_{i}^{\varepsilon} d \ln p_{i}^{\varepsilon} - dc_{i}^{\text{SPS}} \right) + d \gamma e_{i} \right) \right) \\
 \text{(27)}
\end{align*}
\]

In empirical analysis, the total logarithmic differential equation is given by equation (28):

\[
\begin{align*}
 d \ln Q_{i} &= \sum_{r=1}^{R} \frac{FS_{i,r}}{QS_{i}} d \ln FS_{i,r} + \frac{M_{i,r}}{QS_{i}} \left( e_{i}^{\text{md}} \left( p_{i} - tm_{i} \right)^{-1} \left( p_{i}^{w} d \ln p_{i} - dtm_{i} \right) + d \ln \gamma m_{i} \right) \\
&\quad - \frac{E_{i}}{QS_{i}} \left( p_{i}^{\varepsilon} \left( \gamma c_{i}^{\text{SPS}} \right)^{-1} \left( p_{i}^{\varepsilon} d \ln p_{i}^{\varepsilon} - dc_{i}^{\text{SPS}} \right) + d \gamma e_{i} \right) \\
\text{(28)}
\end{align*}
\]

Retail-level market clearing conditions are given by equation (18). Combining equation (25) and (28), we get the total logarithmic differentiation form:

\[
\begin{align*}
 \sum_{r=1}^{R} \frac{Q_{i,r}^{D}}{Q_{D}} \left( d \ln p_{o,r} + e_{f,r} d \ln p_{f,r} + e_{p,r} d \ln p_{p,r} \right) \\
= \sum_{r=1}^{R} \frac{FS_{i,r}}{QS_{i}} d \ln FS_{i,r} + \frac{M_{i,r}}{QS_{i}} \left[ e_{i}^{\text{md}} \left( p_{i} - tx \right)^{-1} \left( p_{i} d \ln p_{i} - dtx \right) + d \ln \gamma m \right] \\
- \frac{E_{i}}{QS_{i}} \left( p_{i}^{\varepsilon} \left( \gamma c_{i}^{\text{SPS}} \right)^{-1} \left( p_{i}^{\varepsilon} d \ln p_{i}^{\varepsilon} - dc_{i}^{\text{SPS}} \right) + d \gamma e \right) \\
\text{(29)}
\end{align*}
\]

We can solve the single fruit equilibrium to derive retail-level fresh and process price based on the retail-level market clearing conditions.
CHAPTER 4 EFFECTIVENESS OF PEAR PROMOTIONAL ACTIVITIES

Abstract

This study analyzes the effectiveness of advertising and promotional activities conducted by the Pear Bureau Northwest (PBN) on fresh pears during 2007/08 to 2011/12 crop marketing seasons by nonparametric estimation method. The main results of this study show a predominately positive and significant role of advertising expenditures in promoting all winter pears and D’Anjou pears demand and in gaining positive marginal net returns (MNRs) to pear growers. Overall, promotional activities yield MNRs in the range of $2 to $10 per dollar promotional expenditure. Promotional effectiveness shows interregional disparity and varies promotional types and pear varieties. This study also finds that domestic demand for all winter pears and D’Anjou pears is significantly related to a number of other factors.

*Key words:* Pear regional demand, advertising and promotion, investment returns
Introduction

Economic evaluations of the effectiveness of promotion program have become a standard procedure for commodity commissions in the United States and the produce sector. The Pear bureau Northwest (PBN) began funding evaluations of promotional impacts using econometric techniques since the late 1990s (Erickson et al. 1997; Zhang, Marsh and Schotzko 2007). More recently, econometric evaluations of promotional impact have been done for commissions promoting orange juice (Williams, Oral Capps and Bessler 2004), avocado (Carman and Craft 2005), strawberries (Carter, Chalfont and Goodhue 2005), almond(Crespi and Sexton 2005), walnuts (Kaiser 2005), honey (Ward 2008), and watermelon (Ward 2008), for example. Model is based on the economic theory of consumer demand.\(^9\) An economic hypothesis for evaluating commodity programs is that the advertising and promotion expenditure act as a positive shift effect on demand.

Investigating the relationship between various advertising and promotion activities and demand for pears has crucial implications. It not only provides information for assessing effectiveness of these efforts but also for planning future activities. Information on effectiveness of these efforts on different varieties provides valuable information for the marketers to plan specific future activities. Meanwhile, it quantifies investment returns to growers from expenditures spent on promotional and advertising activities. Direct (current month) and pass-on effect (12 months) net returns to growers are estimated for each regional market and pear varieties.

Fresh pears compete/complement with other fresh fruit in various regions. In particular, fresh fruit is one of the most profitable departments in a retail grocery store, so this

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\(^9\) See Piggott and Marsh (2011) for a more general review of consumer demand analysis.
knowledge is becoming critical as overall store margins. The promotional and advertising activities helps to develop markets and increase market shares and provide explanation for the rise or decline in their substitutes/ complementary consumption.

Differentiation regional markets when evaluating the effectiveness of promotion and advertising activities is demanding as marketing performance of promotion and advertising activities varies across regions. Pears produced in the Washington and Oregon State comprise the nation’s largest pear producing region, where produce approximately 84% of all fresh pears grown in the United States, while those pears are distributed to domestic market all over country and international market. Transportation costs and absorption of fluctuation in the FOB prices are diverse from region to region. Fresh pears from growers to consumers pass through four market levels: the farm level, a packer/shipper, a wholesale level and a retail level. Pears through those market levels differ in market power from firm concentration levels and efficiencies.

The objectives of this study are first to assess the significance and magnitude of the effect that advertising and promotional efforts have had on wholesale demand for fresh all winter pears and D’Anjou pears in major U.S. retail markets, then to estimate returns to investments in advertising and promotional activities undertaken by pear growers through the Pear Bureau, and third attempt to identify, contrast, and compare interregional differences in the impact of advertising and promotional efforts on wholesale demand and investment return for pears in major U.S. retail markets.

This study contributes in two ways. The study period is from 2007/08 to 2011/12, during the latest economic recession. We examine fresh pears marketing changes and compare with previous study. We find that the fresh pears market is more prices sensitive
than before economic recession. Based on the promotion expenditure data from the PBN, we are able to compare the different effects of promotional types on pears and investment returns to growers. Promotional types include full ad buys and layered ad buys, both of which are in the form of price discounts (but full ad buys last longer than layered ad buys). We find that promotional type that last longer has higher impact on demand and better investment returns.

The study will proceed in the following manner. First, we present background information about promotional activities. Second, we derive regional pear demand functions and estimation methods, followed by a briefly data description. Then, we present the estimated results and empirical analysis. The final part discusses results and concludes the paper.

**Background**

Marketing advertising and promotion are important to increase awareness and consumption of fresh Pears. The Pear Bureau Northwest (PBN) has the responsibility to promote, advertise and develop markets for fresh pears grown in Oregon and Washington. The Pear Bureau Northwest sign agreements regarding agreement types, promotion types, amount of expenditures, and how to distribute them to each variety of fresh pears with retail markets, such as food stores and supermarkets. The agreement types, either promotional or sampling, convey price information through offering discount and quality information through offering samples. We call Ad buys those expenditures spent on price discount and Demos those spent on giving away samples. Promotional and advertising activities are called full and layered. Compared to layered, full promotion last longer and with more advertising promotional expenditure. The duration of full promotion is
between 45 and 365 days within a crop marketing year. The duration of layered
promotion is between 1 and 255 days within a crop marketing year. Demos range
between 1 and 168 days within a crop marketing year. Varieties include all winter pears
and D’Anjou pears in this study. Advertising and promotion activities abroad (e.g.,
Canada) conducted by the Pear Bureau are excluded from this study.

The Pear Bureau data on expenditures for ad buys and demos were uniformly allocated
by month for each region based on the duration of advertising and promotion. The
observations relating to promotional expenditures were entered under three different
categories for each variety: ad buys-full promotion, ad buys-layered promotion and
demos.10 Figure 4.1 presents Ad Buy-Full, Ad Buy-Layered, and Demo expenditures for
all winter pears and D’Anjou pears by the Pear Bureau from marketing year 2007/08 to
2011/12. Full-Adbuys has the highest advertising and promotional expenditures, followed
by Layered-Adbuys, and then Demo expenditure.

Methodology

Regional Demand Function

Let \( q \) denote a \( n \)-vector of commodities consumed with a \( n \)-vector of corresponding
prices \( p \) and income \( m \). We define \( z \) to be a vector of advertising or promotional
expenditures (e.g., ad buys or demos), and \( y \) to be a vector of other shift or conditioning
variables. Then the economic agent’s maximization problem is

\[
\max \left\{ u(q; z, y) \mid m = \sum_{k=1}^{n} p_k x_k \right\} \tag{1}
\]

where \( u(q) \) reflects the individual’s utility function with appropriate properties.11 Then,

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10 We will use “Full ad buys”, “Layered ad buys”, and “Demo” refer to promotion and sampling types that
we defined.

11 See Deaton and Muellbauer (1990) for background details related to demand systems.
the individual agent’s demand for a vector of commodities can be represented by

$$q = f(p, m; z, y)$$  \hspace{1cm} (2)$$

This implies that demand for pears should be a function of the price of pears, its substitutes or complements, income, advertising and promotional expenditures, and other shift variables.

The individual demand functions represented in equation (2) can be linearly aggregated, $Q^* = \sum_{i=1}^{S} q_i$, by region in the United States to construct aggregate quantity demanded by region. Here $S$ indicates the regional population. Regional per capita demand can be derived as

$$Q = \frac{Q^*}{S} = \frac{1}{S} \sum_{i=1}^{S} q_i / f\left( \frac{p}{S}; z, y \right)$$  \hspace{1cm} (3)$$

where $M/S$ is per capita income in the region.

Regional per capita demand models were estimated for each of the four regions (west, east, central, and south) in the United States with monthly data. Empirically, the demand model for D’Anjou pears was specified as

$$Q_{anj,t} = F\left( P_{anj,t}, P_{alt,t}, CPI_{t}, M_{t}, FAB_{anj,t}, LAB_{anj,t}, DM_{anj,t,t}, Q_{other,t}, Q_{anj,t-1}, Q_{anj,t-12}, IMP_{t} \right) + \varepsilon_{t}$$  \hspace{1cm} (4)$$

where $F( )$ is the regression function and $\varepsilon_t$ are the unobserved errors. Additional discussion of the regression function and the unobserved errors is provided in more detail below. In (4), $Q_{anj,t}$ is the regional per capita pear shipments (boxes/person) in month $t$, $P_{anj,t}$ is region’s pear wholesale price ($/box) normalized by the region’s total consumer price index (or CPI-U) in month $t$, $P_{alt,t}$ is region’s apple, orange, and/or $\varepsilon$ is the unobserved error. Additional discussion of the regression function and the unobserved errors is provided in more detail below. In (4), $Q_{anj,t}$ is the regional per capita pear shipments (boxes/person) in month $t$, $P_{anj,t}$ is region’s pear wholesale price ($/box) normalized by the region’s total consumer price index (or CPI-U) in month $t$, $P_{alt,t}$ is region’s apple, orange, and/or

\[ \varepsilon_t \]

\[ \text{Regional per capita shipments are used to proxy per capita demand.} \]
banana wholesale price ($/lb) normalized by the region’s total consumer price index in month $t$, $CPI_{F_t}$ is the region’s consumer price index for food normalized by the region’s total consumer price index in month $t$, $M_t$ is the region’s income per capita ($) normalized by the region’s total consumer price index in month $t$, $FAB_{anj,t}$ and $LAB_{anj,t}$ is the region’s expenditure on full ad buys and layered ad buys for D’Anjou pears ($) normalized by the region’s total consumer price index in month $t$, $DM_{anj,t}$ is the region’s expenditure on demos for D’Anjou pears ($) normalized by the region’s total consumer price index in month $t$, $Q_{other,t}$ is the region’s per capita consumption of other pears (boxes/person) (including other winter pears and Bartlett pears) in month $t$, $Q_{anj,t-1}$ is the region’s per capita consumption of D’Anjou pears lagged one month, or $t-1$, and $Q_{anj,t-12}$ is the region’s per capita consumption of D’Anjou pears lagged twelve months, or $t-12$. $IMP_t$ is the quantity of pear imports to the United States in the $t^{th}$ period, scaled to the per capita level by regional population.

The demand model for all winter pears (which includes D’Anjou pears) is

$$ Q_{awp,t} = F\left( P_{awp,t}, P_{alt,t}, CPI_{F_t}, M_t, FAB_{awp,t}, LAB_{awp,t}, DM_{awp,t}, Q_{awp,t-1}, Q_{awp,t-12}, IMP_t \right) + \epsilon_t, \tag{5} $$

where the subscript $awp$ represents all winter pears. Bartlett pear wholesale price ($$/Box) is added into all winter pear demand model. Note that except for $Q_{other,t}$, which is not included in the all winter pears model, this is a similar specification to (4).

Several comments about the demand equations specified in (4) through (5) are in order. First, the demand functions are specified to exhibit the economic property of homogeneity of degree zero in prices and income. This is imposed mathematically by
normalizing all prices and income by region’s total consumer price index. It implies that if the level of all prices and the level of income rises (or falls) by precisely the same proportions, demand will remain unchanged.

Second, economic theory dictates a negative relationship between the quantity demanded of pears and pear price. The law of demand is not imposed in the demand model, but rather is an economic hypothesis to be empirically tested in the subsequent analysis. In contrast, there is no a priori economic justification to have a priori beliefs about the relationships among the remaining variables and quantity demanded for pears. These remain empirical questions to be determined by the regression analysis. A negative (positive) relationship between the price of another good (i.e., apple price) and the quantity demanded of pears would indicate pears and apples are complements (substitutes). A positive (negative) relationship between the quantity demanded of pears and income implies a normal (inferior) good.

Third, the quantity of other pears was included in the D’Anjou pear model instead of the price of other pears. A complete price series for other winter pears was not available. Including the quantity of other pears (as opposed to the price of other pears) results in what is known as a conditional demand model in which demand effects are analyzed given that a certain level of a specified good is consumed (Pollak 1969). Similarly, the total quantity of per capita pear imports, instead of the import price, was specified in the model.

Fourth, several lagged variables were included in the model yielding a dynamic specification of the demand model. The variable $Q_{anj,t-12}$ accounts for seasonal pear consumption evident in the data and found in previous studies. The variable $Q_{anj,t-1}$
accounts for short run habit formation in consumption patterns from month to month. It is anticipated that these parameters are positive (indicating increases in past quantity demanded tends to increase future quantity demanded) and less that one in magnitude (for stability). In this manner, persistent patterns of pear demand can be captured from month-to-month and year-to-year.

Fifth, economic theory does not necessarily dictate the sign of the relationship between advertising and promotion expenditures and quantity demanded for pears. It is anticipated the relationship would be positive given the past evidence, suggesting that advertising and promotion expenditures are associated with increases in the quantity of pears demanded. However, the sign and magnitude of these effects remain empirical questions that we address ahead.

**Nonparametric Estimation**

D’Anjou pears and all winter pears demand models in (4) and (5) were estimated for each of the four regions using nonparametric Nadaraya-Watson (NW) regression procedure in GAUSS. In nonparametric regression analysis neither the distribution of errors nor the functional forms of the regression function are prespecified, yielding very flexible specifications of the pear demand models. Preliminary analysis of pear demand models with parametric regression approaches (such as the linear model using least square method) yields results that were neither necessary consistent with economic theory nor satisfactory in explaining impacts of advertising and promotion expenditure on pear demand. A disadvantage of the parametric regression approach, which requires that the

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regression function be specified with an explicit functional representation, is that it can result in model misspecification. In turn, this can yield biased and inconsistent parameter estimates that lead to incorrect inference about how variables such as advertising and promotion relate to demand (Judge et al. 1988). Given the complex nature of pear demand and multifaceted nature of advertising and promotion activities, it is not surprising that parametric regression approaches proved inadequate for the analysis and that the nonparametric regression approach has proven more successful. Erickson et al (1997) and Zhang et al (2007), also found parametric approaches to be inadequate and resorted to nonparametric analysis to explain determinants of pear demand.

The basic framework of nonparametric approach is to assume that the demand models in (7) and (8) have a standard regression form as \( Y = g(X) + \varepsilon \), where \( X \) is \( k \) dimensional explanatory variables, \( g(\cdot) \) is a real-valued function, and \( \varepsilon \) is a vector of error terms. We are interested in the partial derivatives of the regression function with respect to explanatory variables, \( \frac{\partial g(\cdot)}{\partial x_j} = \beta_j \). The marginal effects are often referred to as response coefficients. The response coefficients can be estimated by using nonparametric estimator of expectation of \( Y \) conditional on \( X \), \( \hat{g}(\cdot) \), and then estimate the marginal effects with \( \frac{\partial \hat{g}(\cdot)}{\partial x_j} = \hat{\beta}_j \).

In principle, if the random vector \((Y, X)\) has a joint \((k+1)\) dimensional probability distribution \( f(Y, X) \), then the true regression function is by definition

\[
E(Y | X) = g(x) = \int_{-\infty}^{\infty} y \left[ \frac{f(y, x)}{f(x)} \right] dy. \]

Here we replace the joint PDF \( f(y, x) \) and marginal PDF \( f(x) \) based on Kernel density estimators to produce an estimate of the regression function of \( Y \) on \( X \). In empirical analysis, we use Nadaraya-Watson (NW) Kernel
Regression. Let \((y_i, x_i), i = 1, ..., n\) be an iid random sample outcome from the \((k+1)\) dimensional continuous PDF \(f(y, x)\), where the \((k+1)\) dimensional random vector \((Y, X)\) is used to denote the population random vector. Furthermore, let

\[
\tilde{f}(y_o, x_o; y, x) = \frac{1}{nh^{k+1}} \sum_{j=1}^{n} K_s \left( \frac{y_o - y_j}{h}, \frac{x_o - x_j}{h} \right)
\]

(6)

\[
\tilde{f}(x_o; x) = \int_{-\infty}^{\infty} \tilde{f}(y_o, x_o; y, x) dy_o = \frac{1}{nh^k} \sum_{j=1}^{n} K \left( \frac{x_o - x_j}{h} \right)
\]

(7)

\[
\tilde{E}(Y | X = x) = \tilde{g}(x_o; x) = \int_{-\infty}^{\infty} \frac{1}{nh^{k+1}} \sum_{j=1}^{n} K_s \left( \frac{y_o - y_j}{h}, \frac{x_o - x_j}{h} \right) dy_o
\]

(8)

Equation (6) is a kernel density estimate of \(f(y_o, x_o)\) conditional on observations \((y, x)\). Equation (7) is the marginal kernel density of \(\tilde{f}(y_o, x_o; y, x)\). Equation (8) is the nonparametric regression function.

With properties of kernel function, the marginal kernel function for the \(k\) dimensional \(x_o\) vector is given by \(\int_{-\infty}^{\infty} K_s(z, \frac{x_o - x_j}{h}) dy_o = K \left( \frac{x_o - x_j}{h} \right)\). The kernel density satisfies symmetric around zero in its first argument, and thus \(\int_{-\infty}^{\infty} zK_s(z, \frac{x_o - x_j}{h}) dz = 0\). where

\[
z = \frac{y_o - y_j}{h} \quad \text{and} \quad dy_o = h dz.
\]

Replace the above two properties into equation (11), we get
\[ \hat{E}(Y \mid X = x) = \hat{g}(x_o; x) = \frac{\sum_{j=1}^{n} y_j K\left(\frac{x_o - x_j}{h}\right)}{\sum_{j=1}^{n} K\left(\frac{x_o - x_j}{h}\right)} = \sum_{j=1}^{n} w_j(x_o) y_j \] (9)

where \( w_j(x_o) = \frac{K\left(\frac{x_o - x_j}{h}\right)}{\sum_{j=1}^{n} K\left(\frac{x_o - x_j}{h}\right)} \), and \( \sum_{j=1}^{n} w_j(x_o) = 1 \). This estimate is called the Nadaray-Watson (NW) Kernel regression estimator. The estimate is a weighted average of the observed \( y_j \) values, the weights being supplied by the kernel \( K(\cdot) \) normalized by the kernel sum.

The estimator of response coefficients are

\[ \hat{\beta}_j = \frac{\partial \hat{g}(\cdot)}{\partial x_j} = \frac{\partial}{\partial x_j} \sum_{j=1}^{n} w_j(x_o) y_j / \partial x_j \] (10)

Under general conditions, the estimator is consistent and asymptotically normal (Pagan and Ullah 1999).

\[ \left( n h^{2+k} \right)^{1/2} \left( \hat{\beta} - \beta \right) \sim N \left[ 0, \frac{\sigma^2}{f(x)} \int h^d \left[ \frac{\partial K(z)}{\partial z} \frac{\partial K(z)}{\partial z^t} \right] dz \right] \] (11)

where \( z = \left( \frac{X_{i1} - x_1}{h}, ..., \frac{X_{ik} - x_k}{h} \right) \), the variance of noise component of the model, \( \sigma^2 \), can be estimated by \( \hat{\sigma}^2 = n^{-1} \sum_{j=1}^{n} \left[ y_j - \hat{g}(x_j) \right]^2 \), and the marginal kernel density can be estimated.

From above, we see that the NW estimator is about to choose a kernel density (K), and bandwidth (h). In this study, we use the Gaussian kernel, which is
\[ K(\mu) = \frac{1}{\sqrt{2\pi}} \exp \left( -\frac{1}{2} \mu^2 \right) \] (12)

The nonparametric regression model is governed by the choice of a window-width, which was determined by minimizing the sum of squares with cross-validation (Hardle 1990; Mittelhammer, Judge and Miller 2000). The least square cross validation (LSCV) is to minimize the squared difference between \( y_j \) and \( \hat{g}_{-j} \) as

\[
h_{LSCV} = \arg \min_h \left[ \sum_{j=1}^{n} (y_j - \hat{g}_{-j})^2 \right] (13)
\]

Where \( \hat{g}_{-j} (\cdot) \) is the “leave one out” NW estimator of \( g(\cdot) \). That is,

\[
\hat{g}_{-j}(x_o; x) = \sum_{i=1,i\neq j}^{n} w_i(x_o) y_i (14)
\]

The test statistics for individual response coefficients were constructed using standard bootstrap Monte Carlo techniques. Response coefficients and elasticities reported were calculated from the bootstrapped distribution. The reported goodness of fit test is the R-square between the actual and predicted quantity demanded of pears. To test the null hypothesis that the error terms of each regression model were independent and identically distributed the Wald-Wolfowitz runs test statistic was calculated (Mittelhammer 1996).

**Data Source and Descriptive Statistics**

This study includes several categories of data from difference sources. Pear shipment quantities and promotion expenditure data were obtained from the Pear Bureau records and aggregated into monthly data. The units for the quantity of shipped pears were selected to be a 44lb box. Wholesale fruit prices were collected from USDA Agricultural Marketing Service (AMS) reports covering 15 major U.S. cities. Annual state population
data were collected from the U.S. Bureau of the Census. Quarterly personal income data in each state were obtained from the Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Monthly population and income data for each region were interpolated using trend regression. A Producer Price Index (PPI) and Food Consumption Price Index (CPI) were assembled from the U.S. Bureau of Labor Statistics (BLS). Pear imports were collected from FAS, USDA, covering total quantity of monthly pear imports from outside of the U.S.

Market and promotion data were aggregated into four different geographic regions that collectively represent the 48 contiguous states of the United States. Each region was composed of nine or more states. The specific regions and the representative wholesale competing fruit market information in selected cities for each of the regions.\footnote{West Region (11 states; 3 wholesale markets): California, Oregon, Washington, Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Major wholesale competing fruits markets in west region include Los Angeles, San Francisco, and Seattle.\newline Central Region (12 states; 3 wholesale markets): Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Illinois, Indiana, Michigan, Ohio, and Wisconsin. Major wholesale competing fruits markets in central region include Chicago, Detroit, and St. Louis.\newline South Region (16 states; 5 wholesale markets): Arkansas, Louisiana, Oklahoma, Texas, Alabama, Kentucky, Mississippi, Tennessee, Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia. Major wholesale competing fruits markets in south region include Baltimore, Atlanta, Dallas, Miami, and Columbia.\newline East Region (9 states; 4 wholesale markets): Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Pennsylvania, New Jersey, and New York. Major wholesale competing fruits markets in east region include Boston, New York, Philadelphia, and Pittsburgh.}

For each of the four regions, we constructed a data set includes: a) population weighted monthly prices of D’Anjou pears (including Red D’Anjou), all winter pears, apples, bananas, oranges, peaches, and grapes, b) monthly quantities of D’Anjou (including Red D’Anjou) and all winter pears shipped into the region, c) monthly CPI, PPI, income, and population for the region, and d) monthly pear imports. Monthly data descriptive statistics by region from September, 2007 to July, 2012 is presented in Table 4.1.
There is certain pattern for monthly shipments for all winter pears and D’Anjou pears by region over the study period. The west region had the highest number of shipments over all five marketing seasons for all pears. The second highest number of shipments was the southern, and then the eastern and central region altered for different month. Significant seasonality is evident for all pears across all regions consistent with availability of the crop. Specifically, for D’Anjou, shipments start in August or September and increase to a peak near the end of a calendar year or in the first quarter of the subsequent year. Then shipments decrease until June or July.

The pear imports followed a persistent seasonal pattern. The importing window ranged from February to May in every crop year. Large magnitudes of imports begin appearing in February, which is about one month behind the peak month of D’Anjou’s domestic shipments, implying a possibility for contra-seasonal demand-driven imports. Pear imports reach highest volumes in March, April, and May; and then they drop down below 230,000 boxes per month in following months (until the next February). It is interesting to note that both pear import and domestic shipments are lowest in July and August.

Regional wholesale prices and shipping point (i.e. FOB) prices from 2007 to 2012 for all winter pears and D’Anjou pears also show certain pattern. Predominately, the FOB prices form a lower envelope for the wholesale prices over this period. Each price series in the wholesale market exhibits characteristics consistent with seasonal availability of all winter pears and D’Anjou pears. However, the wholesale prices vary across the regions. For example, the price of D’Anjou pears in the west region was typically lower than that in other regions. The differences across the regions are likely due to a combination of differing marketing strategies relating to the passing through/absorption of fluctuations in
FOB prices, as well as transportation costs, differing market power from firm concentration levels, and efficiencies in the various regions.

**Empirical Results**

**Estimation Results for Demand Model**

Table 4.2 and Table 4.3 present the results of nonparametric regressions for D’Anjou and all winter pears demand across four regions. The adjusted R-square values of D’Anjou pears for the east, south, central, and west regions are 0.85, 0.84, 0.96, and 0.74, respectively, and the adjusted R-square values of all winter pears for the east, south, central, and west regions are 0.93, 0.88, 0.93, and 0.80, respectively, indicating a very high explanation of pear demand for each of the region. Outcomes of the Wald-Wolfowitz (WW) runs test statistic for each region indicated that the null hypothesis of independent and identical error terms could not be rejected. This provides strong evidence against problems such as autocorrelation and heteroskedasticity in the error terms of the regression models that can add another layer of complication to the empirical analysis.

The model results are consistent with economic theory in that the own-price elasticity was negative for each of the models (see Table 4.4). The own price response coefficients were negative and statistically significant for all regions. The price elasticity for D’Anjou pears of largest magnitude was in the south region (-2.06), followed by west (-1.76), east (-1.61), and central (-0.46) region. The price elasticity for all winter pears of largest magnitude was in the west region (-2.27), followed by central (-2.21), east (-1.62), and south (-1.16) region. For instance, this indicates that a 1% increase in the price of D’Anjou pears in the west region will yield a 1.76% decline in the quantity demanded.
Different from Zhang et al. 2007, who report that D’Anjou was nationwide “price inelastic” and all winter pears was “price inelastic” for all except in the south region, we found that D’Anjou is “price elastic” except in central region and all winter pears are nationwaide price elastic. It maybe implies that under economic recession, consumers are more price sensitive. Those regions with price elastic suggest that the likelihood of increasing total revenue is higher when increasing shipments to other regions relative to the central region. By comparing own-price elasticities between D’Anjou and all winter pears, price sensitivities of pear’s varieties and regional differences are illustrated. In the central, west, and east (but price elasticity are nearly equal in the east), the own-price elasticities for all winter pears are greater than their counterparts for D’Anjou Pears. This suggests that consumers are more price sensitive to other winter pears relative to D’Anjou pears. For the west region, the findings are consistent with Zhang et al 2007. They found that in the south and west region other winter pears are more price sensitive than D’Anjou pears. In the south region, the own-price elasticities for D’Anjou pears are greater than their counterparts for all winter pears, reflecting D’Anjou demand is more price sensitive than other winter pears.

Both full ad buys and layered ad buys are found to be positive and statistically significant related to shipment demand for D’Anjou pears and all winter pears for each region. This provides strong evidence that increases in promotional expenditure significant increased demand for D’Anjou pears and all winter pears. Demos play a limited role in increases of quantity demanded. Demo expenditure is positive and statistically significant only in the central for D’Anjou pears and in the central and west for all winter pears. Table 4.4 shows the promotion and advertising elasticities across
regions for full ad buys, layered ad buys, and demo expenditures. It is important to point out that the magnitude of the elasticities for full ad buys were larger than those of layered ad buys and demos for each region. Promotion elasticities for all winter pears were generally greater than those of D’Anjou pears. This is true for both ad buys full and layered promotional activities. Also, the ad buys promotion elasticities were greater than demo elasticities.

Substitutes or complements fruit were statistically tested in each model. Negative coefficients for prices of other fruit indicate gross complements; positive sign indicated gross substitutes. We find that consumer preferences have change during the economic recession compared with the results from Zhang et al (2007). They found that D’Anjou pears and apples were gross complements in each region and all winter pears and apples were gross complements except in the east region during 1998/99 and 2004/05. However, we find that apples are gross complements with D’Anjou pears only in the central and are gross complements with all winter pears in the east and west region. The orange price response coefficients were negative and statistically significant in all except west region, which implies that oranges take over apples as main complement for both D’Anjou pears and all winter pears. We also find that consumers in the central region have different preference with other regions. Bananas are substitutes for D’Anjou pears and Bartlett pears are gross complements with all winter pears in the central region.

The estimates for the food CPI were generally positive, and statistically significant in the east, south, and central region for both D’Anjou pears and all winter pears. The food CPI elasticities for D’Anjou pears quantity demanded are 11.42 (east), 8.31 (south) and 1.89 (central) in the central region. This result is different with Zhang et al 2007 that all
Food CPI were statistically insignificant for D’Anjou pears and was statistically significant for all winter pears in the south and west. And it suggests that when holding other variables constant, D’Anjou/ all winter pears demand increases when price index for food increases. Given the dramatic changes in food prices over the study period this interpretation makes good economic sense. The estimates for income were generally positive, but statistically insignificant. This indicates that measures of income used in the empirical analysis were not consistent determinants of regional pear demand over study period. However, the results need to be interpreted with caution. While it is important that these variables were not consistently statistically significant over the course of the study period, the economic significant of large changes in income on the consumer demand remain as potentially important determinants in the future. McCloskey (1985) argues that an insightful analysis should extend beyond statistically significance and include some discussion of the magnitude of the estimated economic effects.

Demand for D’Anjou pears and all winter pears in current month is illustrated to be consistently related to the previous period consumption in nationwide, indicating habit formation in the demand. Quantities lagged 12 months were also positively and significantly associated with current demand for pears, which accounts for seasonality in consumer demand. Demand for D’Anjou pears in current month is also illustrated to be consistently related to demand for other pears (other winter pears and Bartlett). As expected, the quantity of other pears (Bartlett, Bosc, Comice, Seckel, and other pears) was positive and statistically significant for each region. This suggests that increased demand for other pears was associated with increased demand for D’Anjou pears. The
response coefficients for the lagged variable were between 0 and 1 for each region, satisfying stability conditions for the estimated models over time.

The per capita import response coefficients were statistically insignificant in the D’Anjou pears model except in the central. Different with Zhang et al 2007, the result suggest that the pattern of the total pear imports in a current period are not associated with a positive increase in domestic pear demand within same period except in the central region. This is consistent with Cook (2002) who reports “the vast majority of imports (to the U.S.) are contra-seasonal, limiting the effect on the domestic industry.” Also, per capita pear imports were found to be insignificantly related to domestic demand for all winter pears. Our findings suggest that the pattern of the total pear imports in a current period tend not to be associated with a positive increase in domestic pear demand within same period.

**Promotion Effectiveness**

Marginal net return (MNR) is used to measure promotional effectiveness to growers. MNR is calculated as net price return to growers per box times the change in quantity demanded for one dollar change in promotional expenditures (see Appendix). The overall MNR is defined as the weighted average of individual MNR for full ad buys, layered ad buys, and demos (weighted by their respective expenditures). This provides a general perspective on the returns of advertising and promotion expenditures by the Pear Bureau over the study period (2007/08 to 2011/12 market seasons). First round and cumulative effects are calculated to specifically conduct the promotional effectiveness comparison across pear varieties and regions. The difference between the first round and cumulative effects is pass-on effects over time from promotional activities. Nationally, an additional
an additional $3.357 and $4.624 of grower net return in the immediate month (i.e. first round effect), and $6.335 and $10.937 in cumulative MNR over the entire 12 months, respectively\textsuperscript{16}. See Figure 4.2 and Figure 4.4.

Overall promotional effectiveness for D’Anjou and all winter pears varied significantly across regions and they have different regional patterns. For D’Anjou pears, the west region exhibited the largest net return to D’Anjou growers in the first round, being $5.001, followed by the east ($2.561), central ($2.383), and south ($2.039) regions. The west region showed the highest in magnitude of cumulative MNR ($10.035), followed by the central ($4.63), east ($4.008) and south ($3.556). It is interesting to notice that the immediate performance of investment and promotional efforts in the east was better than that in the central while their cumulative performances were opposite, reflecting different pass-on effects of promotion activities between regions. For all winter pears, the largest net returns to growers in the immediate month were in the west ($7.822), followed by the central ($4.303), east ($2.093), and south ($1.861) regions. Cumulative MNRs follow a different pattern as the immediate MNRs. The west region had the highest cumulative MNR ($19.489), followed by the central ($10.976), south ($3.627), and east ($3.114) regions. There is a different pass-on effect of promotion activities in the east and south region. For D’Anjou pears, the south region showed the smallest both immediate MNR and cumulative MNR, while for all winter pears the south region ranked 3rd for cumulative MNR and smallest for immediate MNR. All of immediate MNR and

\textsuperscript{16} Change in quantity demanded (boxes) for one dollar spend promotional expenditures is calculated by the MNR divides net return price to growers ($3.405/box). For example, nationally, an additional $1 for promotional expenditures on D’Anjou and all winter pears resulted in an additional 1 box and 1.36 boxes demanded in the immediate month, and 1.86 boxes and 3.21 boxes demanded over the entire 12 months, respectively.
cumulative MNR achieved more than a one dollar return for every dollar of expenditure by the Pear Bureau.

The most significant different with Zhang et al 2007 is that they found the south region had the highest magnitude in both first round and cumulative MNRs. While the current finding is that the south region has the third highest magnitude in cumulative MNR (only better than that of east region) and smallest first round MNR. Consistent with them, we find that the east region had the smallest magnitude in terms of cumulative MNR. They found the net returns in the east region are smaller in magnitude for both immediate first round and cumulative MNRs. However, we find that the net returns in the east region are bigger in magnitude for both immediate first round and cumulative MNRs (greater than $1). This is also true for the central region.

Although the promotional efforts by the Pear Bureau during the study period resulted in significant net returns to growers as shown above, the effectiveness of promotional activities varied among different promotional types and between pear varieties. We look closer at the marginal net returns to growers by delineating between ad buys and demos expenditures. For D’Anjou pears, we don’t provide the effectiveness of demo expenditure on D’Anjou pears for each region as we empirically did not find statistically significance demo expenditures in those regions. Nationally, the marginal net returns of full ad buys expenditures for D’Anjou pears were $4.188 for the immediate first round and $7.561 for the cumulative return. This was much larger than layered ad buys expenditures at $0.399 and $3.005, respectively (See Figure 4.3). This implies that an additional dollar spent on full and layered ad buys for D’Anjou pears produced an additional $4.188 and $0.399 in grower net return during the current month and $7.561 and $3.005 during the 12 months.
For all winter pears, the magnitude on ad buys and demo expenditures were varied significantly. The full ad buys had the highest MNR of $6.082, followed by layered ad buys of $0.846 and demos of $0.044. This implies that an additional dollar spent on full, layered ad buys or demos for all winter pears produced an additional $6.082, $0.846 or $0.044 in grower net return during the current month. The cumulative MNR over the following twelve months is $13.293, $9.241 and $0.109, respectively (See Figure 4.5).

We find that the effectiveness of same promotion type shows interregional difference for D’Anjou pears (See Figure 4.3). The largest net returns for full ad buys were in the west ($6.163 for the first round and $12.319 for the cumulative), followed by the east ($3.345 for the first round and $5.115 for the cumulative), and the central ($3.12 for the first round and $4.199 for the cumulative), and then the south ($2.291 for the first round and $3.823 for the cumulative). The largest net returns for Layered ad buys were in the central with $2.01 for the first round and $12.303 for the cumulative returns, followed by the south with $0.111 for the first round and $2.473 for the cumulative returns. The net returns due to layered ad buys in the rest of the regions were smaller and less effective in increasing total net returns. In the central region the return on Layered ad buys was greater than that of full ad buys over all regions except in the west. It is interesting to notice that the immediate performance of investment in full ad buys expenditure in the central ($3.12) was better than that in layered ad buys expenditure in the central ($2.01) while their cumulative performances were opposite ($4.199 for full ad buys and $12.303 for the layered ad buys), reflecting different pass-on effects between ad buy types in the central.
The outcomes of the same promotional activities for all winter pears vary across regions as well (See Figure 4.5). For example, layered ad buys expenditure in central region performed the best layered promotions (the cumulative MNR ($31.346) was even greater than full ad buys expenditure in the west region ($24.378)). The west region led all regions in returns of full ad buys expenditures, achieving $9.872 for the immediate first round and $24.378 for the cumulative MNR. It is interesting to notice that the immediate performance of investment in ad buys full expenditure in the south ($2.463) and central ($5.783) was better than that in layered ad buys expenditure in the south ($0.584) and central ($3.493) while their cumulative performances were opposite ($3.948 for full ad buys and $12.218 for the layered ad buys in the south, $10.172 for full ad buys and $31.346 for the layered ad buys in the central), reflecting different pass-on effects between ad buy types. As for demos, the immediate first and cumulative MNR are near zero for all regions. In the pear regional demand model, the response coefficients for the demo expenditure were significant in the central and west. Overall, Demos plays almost limited rules in increase the net returns for growers.

**Conclusions**

Pear Bureau promotion effectiveness was evaluated using nonparametric economic techniques to estimate demand equations for all winter pears and D’Anjou pears in four regions (west, east, south, and central) across 48 contiguous states in the United States. The models were analyzed over the marketing seasons from 2007/2008 to 2011/12. Major marketing promotional activities, full ad buys, layered ad buys, and demo, were investigated in the domestic market.
The most important result of this study we illustrated was that the Pear Bureau advertising and promotion expenditures had a predominately positive and statistically significant impact on increasing domestic demand for D’Anjou pears and all winter pears. The advertising and promotional activities resulted in generating positive returns to pear growers and the Pear Bureau. We find that under the economic recession, the consumers are more price sensitive than before the recession. Differences in marginal net returns were identified among all winter pears and D’Anjou pears. Findings also reveal important differences in the immediate and cumulative marginal net returns promotional types (full ad buys, layered ad buys, and demos) and across regions. The investment returns on all winter pears outperformed D’Anjou pears. Nationally, an additional $1 of expenditure for marketing promotion on all winter pears resulted in an additional $4.624 of grower net return in the immediate month (i.e. first round effect), and $10.937 in cumulative MNR over the entire 12 months. The returns for D’Anjou pears were $3.357 and $6.335 for immediate month and cumulative MNR. At the national level, a one dollar increase in full ad buys expenditure creates highest returns to growers, and followed by layered ad buys expenditure and then demo. Demo expenditures seemed play a very limited role in increasing returns to growers. However, full ad buys and layered performance shows interregional disparity. A one dollar increase in full ad buys expenditure was predominately larger for that in layered ad buys expenditures for all regions except the central for both all winter pears and D’Anjou pears. Overall promotional effectiveness varied notably across regions. The west region has the largest net returns to growers both in the immediate month and cumulative MNRs for both D’Anjou pears and all winter pears. All winter pears and D’Anjou pears show different region pattern that reflect
different pass-on effects of promotion activities. For instance, the immediate performance of investment and promotional efforts in the east ($2.561) was better than that in the central ($2.383) while their cumulative performances were opposite ($4.008 in the east and $4.63 in the central).

These findings suggest opportunities for ongoing and future advertising and marketing strategies by the Pear Bureau. They also suggest opportunities for future research on the optimal allocation of advertising and promotion expenditures within activities and among D’Anjou and other winter pears.

Domestic pear demand was also found to be significantly related to a lot of other factors. Pear demand was significantly impacted by the price of pears. Relative to the Zhang et al (2007), consumer preferences for some fruit have changed over time and across regions. Both oranges and apples are complementary goods but oranges took over apples as main complementary for both D’Anjou and all winter pears. Pear demand was also significantly impacted patterns of habit formation and seasonality. The total quantity of imported pears was positive but insignificantly associated with demand for all winter pears in each region and D’Anjou pears except in the central region. Food CPI was significantly and positively associated with demand for all winter pears and for D’Anjou pears except in the west region. Per capita income was not a consistent determinant of pear demand across regions. The significant effect from the food CPI and not income may be related to the economic recession with less disposable income consumers are becoming more price conscious and price sensitive.
References


Figure 4.1 Ad Buy and Demo Expenditure for D’Anjou and All Winter Pears, 2007-2012
Figure 4.2 Marginal Net Returns to Growers of D’Anjou Pears
Figure 4.3 MNRs by Region and Promotional Type for D’Anjou Pears
Figure 4.4 Marginal Net Returns to Growers of All Winter Pears

<table>
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Figure 4.5 MNRs by Region and Promotional Type for All Winter Pears
Table 4.1 Monthly Data Descriptive Statistics by Region, 2007.9-2012.7

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Numbers in parentheses represent standard deviation.
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Note: *** indicates 95% statistically significant, ** indicates 90% statistically significant.
Numbers in parentheses represent standard errors.
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Note: *** indicates 95% statistically significant, ** indicates 90% statistically significant. Numbers in parentheses represent standard errors.
Table 4.4 Estimated Own-price and Promotional Elasticities for D’Anjou Pears and All Winter Pears

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Appendix

Following Erickson et al (1997) and Zhang et al (2007), the price linkage equation between the wholesale price of pears and the FOB shipping point price of pears is specified as

\[ P_w = f(P_{FOB}, Q, C, T) \]  

(15)

where \( P_w \) is the wholesale price, \( Q \) is the volume of product, \( C \) is the cost of other inputs (such as labor, energy, and office expenses), \( P_{FOB} \) is the FOB price, and \( T \) represents trend of technology and other potential factors influencing marketing services.

Assuming the function is homogenous of degree one in prices, then the expression in (15) can be rewritten as

\[ P_w = P_{FOB} f(1, Q, C / P_{FOB}, T) = P_{FOB} g(Q, C / P_{FOB}, T) \]  

(16)

This equation indicates that the wholesale price can be expressed as a function of the FOB price multiplied by a function \( g( ) \) that represents the marketing services markup applied to the delivered per unit cost of the product. The empirical price linkage equation is given by

\[ P_w = a_1 P_{FOB} + a_2 Q * P_{FOB} + a_3 T * P_{FOB} + a_4 C \]  

(17)

which is linear in parameters and can be estimated with ordinary least squares. In the empirical estimation, the variable \( C \) was represented by an index of intermediate supplies, materials, and components prices used in wholesaling.

Price linkage models for D’Anjou and Bartlett pears were specified and estimated to build a relationship between FOB and wholesale prices. Intuitively, this linkage relationship is explained by the total volume of product, technology changes, and costs.
associated with supplying pears to wholesale markets (including labor, energy, and office expenses added in the marketing channel such as re-packaging, storing and transporting). Building this price linkage equation is designed to provide further insights into the marketing margin between FOB and wholesale prices, as well as provide information (i.e., price flexibilities) to estimate marginal net returns to growers.

Tables A.1 through A.2 present the results of the ordinary least squares regressions on the price linkage relationships for all winter pears and D’Anjou pears, respectively. The majority of variables in both models are statistically significant for each region, and the signs of the coefficients are predominately consistent across the regions. The R-square values range from 0.2239 to 0.6516.

Some key observations are that there is a positive and statistically significant relationship between the wholesale and FOB prices of all winter pears in each region. This is anticipated given the similar characteristics of the FOB and wholesale prices, as demonstrated in Figures 3.1-3.3. The product of the FOB price and volume (Q*P), or value, is negative for all regions. Holding all else constant, one interpretation is that price decreases as volumes of pear shipments increase. The interaction between FOB price and trend (T*P) is negative and significant, suggesting that marketing services may have become more efficient over time. Finally there is a positive and statistically significant relationship between wholesale prices and the price of intermediate supplies and materials (C). This suggests that increases in prices of these factors may be passed on to

17 The t-values reported in the tables provide measures of whether or not the variables in the models are statistically significant in determining wholesale price. A good rule of thumb is that the t-values above (below) 1.96 (-1.96) indicate that a variable is significant with at least 95 percent confidence, above (below) 1.645 (-1.645) indicate that a variable is significant with at least 90 percent confidence, and above (below) 1.0 (-1.0) indicate that a variable is significant with at least 68 percent confidence.
buyers of pears.

The price linkage results of the current study are consistent with those reported by Zhang et al (2007) in that the sign on the parameter coefficients predominately remain the same. The estimates for variables in the D’Anjou models are similar to those in the all winter pears models (except for (Q*P) in the central region that is not statistically significant for D’Anjou pears).

Table A.1 Regression Results for Price Linkage Equations of All Winter Pears

<table>
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<tr>
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<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>T-value</td>
<td>Estimate</td>
<td>T-value</td>
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<tr>
<td>P-FOB</td>
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<td>T*P-FOB</td>
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<td>-0.0037</td>
<td>-3.151</td>
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<td>C</td>
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<td>9.829</td>
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<td>R2</td>
<td>0.4856</td>
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Table A.2 Regression Results for Price Linkage Equations of D’Anjous Pears

<table>
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<th>Central</th>
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</thead>
<tbody>
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<td></td>
<td>Estimate</td>
<td>T-value</td>
<td>Estimate</td>
<td>T-value</td>
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<tr>
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<td>0.5053</td>
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Marginal Net Return

Given a promotion effort, \( Promo \), the marginal net returns of the promotion can be derived from previous equations as

\[
MNR = P^{NR} \frac{\partial Q}{\partial Promo}
\]

where the net return price to the grower, \( P^{NR} \), is calculated as the FOB price/box less
packing costs of $10.35/box and less the Pear Bureau assessment charge adjusted by a percentage net return for each varities, respectively. Assessment charge for D’Anjou pears and all winter pears is $0.49/box. Percentage net return for D’Anjou pears and all winter pears is 26.4%. More precisely the percentage of net returns is the ratio of (the net return price minus costs)/(total revenue). Annual cost of production estimates were obtained from Clark Seavert at Oregon State University.

Immediate MNR

The price linkage equation has the following expression:

\[ P_w = a_1P^* + a_2Q^* P^* + a_3T * P^* + a_4C \]

Focusing on D’Anjou pears the demand equation is:

\[ Q_{anj,t} = f\left(P_{anj,t}, P_{alt,t}, CPI_{ft}, M_{t}, AB_{anj,t}, DM_{anj,t}, Q_{other,t}, Q_{anj,t-1}, Q_{anj,t-12}, IMP_{t}\right) + \epsilon_t \]

Following Erickson et al (1997) the marginal change in quantity from a change in promotions \( \text{Promo} \) is

\[ \frac{\partial Q}{\partial \text{Promo}} = \frac{\left(\frac{\partial f}{\partial \text{Promo}}\right)}{\left(1 - \frac{\partial Q}{\partial P_w}\left(\frac{\partial f}{\partial P_w}\right)\right)} \]

with

\[ \frac{\partial f}{\partial \text{Promo}} = \frac{\partial Q}{\partial \text{Promo}}; \quad \frac{\partial f}{\partial P_w} = \frac{\partial Q}{\partial P_w} \]

where \( P_w \), wholesale price, and the function \( f(\cdot) \) are both defined in equation (1).

Consequently, the marginal change in quantity from a change in promotions \( A \) can be rewritten as
\[
\frac{\partial Q}{\partial \text{Promo}} = \frac{\partial Q}{\partial \text{Promo}} \frac{\text{Promo}}{Q} \left( 1 - \frac{\partial Q}{\partial \text{Promo}} \frac{P}{Q} \right) \frac{\text{Promo}}{1 - \text{Flexibility}_w \times \text{Elasticity}_{\text{Promo}}} \frac{Q}{\text{Promo}}
\]

Then for given observations \( Q, \text{Promo} \) the immediate MNR can be derived as: \( j=0 \)

\[
\text{MNR}_{j=0} = P^{NR} \times \frac{\text{Elasticity}_{\text{Promo}}} {1 - \text{Flexibility}_w \times \text{Elasticity}_{\text{Promo}}} \frac{Q}{\text{Promo}}
\]

**Cumulative MNR**

Let \( b_1 = \frac{dQ}{dP}, b_3 = \frac{dQ_{i-1}}{dQ_i}, a_2 = \frac{dP}{dQ} \)

From the demand equations we can derive the following:

\[
dQ_{i+1} = (b_1)dP_{a_{i+1}} + (b_3)dQ_i = (b_1)(a_2P'dQ_{i+1}) + (b_3)dQ_i
\]

The cumulative marginal change in quantity from a change in promotions can be expressed as

\[
\frac{dQ_{i+1}}{d\text{Promo}_i} = \frac{dQ_{i+1}}{dQ_i} \frac{dQ_i}{d\text{Promo}_i} = b_3 \frac{dQ_i}{1 - b_1(a_2P')} \frac{dQ_i}{d\text{Promo}_i}
\]

So we can derive the following expression in terms of elasticities and flexibilities for \( j=1 \) as

\[
\frac{dQ_{i+1}}{d\text{Promo}_i} = \frac{dQ_i}{dQ_{i-1}} \frac{dQ_{i-1}}{d\text{Promo}_i} \frac{dQ_i}{1 - \frac{dQ_i}{dP} \frac{dP}{dQ}} \frac{dQ_i}{d\text{Promo}_i} = \frac{dQ_{i+1}}{dQ_i} \frac{dQ_i}{dP} \frac{dQ_i}{d\text{Promo}_i} \frac{Q_{i+1}}{Q_i} \frac{Q_i}{\text{Promo}_i} \frac{Q_{i+1}}{Q_i} \frac{Q_i}{\text{Promo}_i} \frac{Q_i}{\text{Promo}_i}
\]

\[
= \frac{\text{Elasticity}_{\text{lag}}Q_{i+1}}{1 - \text{Elasticity}_P \times \text{Flexibility}_w \times \text{Elasticity}_{\text{Promo}}} \frac{Q_i}{\text{Promo}_i}
\]
\[ \text{Elasticity}_{\text{lag1}} \times \text{Elasticity}_{\text{prom}} \times \frac{Q_t}{\text{Promo}_t} \]

Similarly we can derive the expression for \( j=2 \)

\[ \frac{dQ_{t+2}}{d\text{Promo}_t} = \left\{ \frac{b_3}{1-b_1(a_2P^*)} \right\}^2 \frac{dQ_t}{d\text{Promo}_t} = \frac{b_3}{1-b_1(a_2P^*)} \left( \frac{b_3}{1-b_1(a_2P^*)} \frac{dQ_t}{d\text{Promo}_t} \right) \]

\[ = \frac{b_3}{1-b_1(a_2P^*)} \frac{dQ_{t+1}}{d\text{Promo}_t} \]

In general we have the following expression: \((j=1, 2, \ldots, 11)\)

\[ \frac{dQ_{t+j}}{d\text{Promo}_t} = \text{Elasticity}_{\text{lag1}} \times \frac{dQ_{t+j-1}}{d\text{Promo}_t} \]

Hence, the cumulative MNR through the jth months is

\[ \text{MNR}_{\text{cum}} = p^{NR} \times \sum_{j=0}^{k} \frac{dQ_{t+j}}{d\text{Promo}_t} \frac{dQ_{t+j}}{d\text{Promo}_t} \]

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