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THE ECONOMICS OF CONSUMER RESPONSE TO HEALTH-RISK INFORMATION IN FOOD

By

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ABSTRACT

THE ECONOMICS OF CONSUMER RESPONSE TO HEALTH RISK INFORMATION IN FOOD

By

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This research extends previous research on the demand effects of health concerns regarding Alar residues in apples. Following this previous research, an econometric model for retail fresh apple demand is developed for the New York City (NYC) retail apple market. However, a longer time series is used to estimate apple demand and two improvements are made to the demand model. One of these improvements incorporates the possibility that the national retail price and thus the NYC retail price may be affected by health-risk information at the national level. Therefore, the NYC demand equation is tested for simultaneity bias. The second improvement is in the modeling of seasonality in per capita apple purchases and retail apple price variables.

The results indicate that simultaneity bias is not an issue in estimating the retail apple demand in the NYC market. Therefore, the NYC apple demand is estimated by a single equation. A multiplicative seasonal ARMA model appears to represent seasonality in per capita apple purchases and retail apple price variables.

As found in the previous research, apple demand was found to shift downward immediately following the initial announcement of health risk in July 1984. Demand recovered fully when Alar was withdrawn from the market in June 1989. This finding suggests that sales losses could have been avoided had the Government recalled Alar in 1984 since the majority of the drop in sales is due to the initial and sustained shift in demand.

Following previous research, consumer's willingness to pay to avoid Alar residues in apples was calculated using the estimated demand model. Consumer's marginal

willingness to pay for risk reduction was calculated by dividing the annual willingness to pay to avoid Alar by estimates of consumers' perceived amount of risk avoided per year. As found in previous research, the estimates of consumer willingness to pay to avoid health risks suggest that consumers reacted to the health risks associated with Alar as they have to other health risks.

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CHAPTER I

INTRODUCTION

Consumer concerns about the safety of the food supply, especially about the safety of pesticide residues in food, have been high during the past decade.[1] These concerns appear to be due to new information that consumers have received about the potential health risks of pesticide residues in food. These risks are conveyed by new information about the toxicity and presence of pesticide resides in food.

An example of this is the Alar incident. Alar is a growth regulator primarily used on apples. In 1984, the Environmental Protection Agency (EPA) announced that it would reevaluate its risk assessment for Alar because of the evidence that Alar and its derivative UDMH cause cancer in laboratory animals. The toxicity of Alar was debated for five years by the experts, the food industry, the government and the producer of Alar, Uniroyal. The news media widely reported this dispute and thus caused a large impact on consumer purchases of apples.[2] Alar was taken off the market by Uniroyal in June of 1984, and subsequently banned for use in apple production by the EPA.

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[1]Julie A. Caswell, ed., Economics of Food Safety (New York: Elseiver Science Publishing Co., 1991).

[2]Eileen van Ravenswaay and John P. Hoehn, "The Impact of Health Risk Information on Food Demand: A Case Study of Alar and Apples," in Economics of Food Safety, ed. Julie A. Caswell (New York: Elseiver Science Publishing Co., 1991), pp. 155-174; A. Desmond O'Rourke, "Anatomy of a Disaster," Agribusiness 6 (1990), pp. 417-424; Boyd M. Buxton, "Economic Impact of Consumer Health Concerns About Alar on Apples," Fruit and Tree Nuts Situation and Outlook Yearbook TFS-250 Economic Research Service, United States Department of Agriculture (August 1989), pp. 85-88.

van Ravenswaay and Hoehn (1991) found that the demand for apples in the New York-Newark (NYC) metropolitan area[1] declined after the disclosure of health-risk information associated with lifetime consumption of apples treated with Alar. They examined the effect of the Alar incident on apple purchases until July 1989, one month after Uniroyal removed the chemical from the market. They were therefore unable to detect whether the Alar controversy caused any long-term effects to the NYC apple market.

After the withdrawal of Alar from the market several alternative scenarios regarding apple demand in the NYC market could have followed. One is that the demand for apples may have recovered fully when consumers received information that Alar was no longer on the market. This would imply that consumers responded swiftly to the information available to them. Another alternative is that it may have taken several periods of demonstrated product safety until consumers believed the apples were safe to eat. The last alternative is that the demand for apples never shifted back to the pre-product warning levels such that there remains a permanent effect in the NYC region apple market. This would have occurred if consumers who have shifted away from apple consumption to apple substitutes during the Alar scare did not return to consuming apples because of their lack of confidence in the apple market or simply because they become accustomed to consuming apple substitutes. It is not possible to determine which scenario applies to the NYC apple market unless we include the months after the chemical was removed from the market. To find out the long-term effects of the Alar incident, this research extends the previous research by van Ravenswaay and Hoehn (1991) by increasing the observation period to the months after the withdrawal of Alar from the market. This research also examines some particular

[1]During the presentation of the research, the expressions "NYC region" and "NYC market" will be used to represent the region that covers the New York-Newark metropolitan area.

problems in econometric modeling, including seasonality and simultaneity bias, which are discussed in more detail below.

1.1 Background

The Alar controversy began in July of 1984 when the EPA announced that Alar, the trade name for the chemical Daminozide, and its derivative UDMH were potential carcinogens. The EPA's decision not to ban Alar from the market at that time stimulated a debate between Government officials, consumer groups, and industry about the health risks of Alar. The debate continued through June 1989, when the chemical was removed from the market by Uniroyal, the manufacturer of Alar. The public debate was most controversial between February 1989 through June 1989; the news coverage of the Alar controversy was also its heaviest then. In February 1989, EPA announced that it would ban Alar within the next 18 months, when the tests were complete. During the following days, consumer groups criticized EPA for not banning Alar promptly. Later that month, a CBS 60 Minutes program focused on the findings of the Natural Resources Defense Council (NRDC) on the cancer risks to children from Alar and other pesticides in food.[1] During this month, the NRDC announced its risk estimate from Alar, and the EPA released a revised risk estimate.[2]

Uniroyal stopped most of its overseas sales of Alar in October 1989. The company claims that it continues to believe in the safety of Alar, but the domestic market for Alar had deteriorated so much that it was uneconomical to continue

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[1]Bradford H. Sewell and Robin M. Whyatt, "Intolerable Risk: Pesticides in Our Children's Food" (Washington, D.C.: Natural Resources Defense Council, 1989).

[2]For the chronology of the Alar incident from July 1984 through June 1989 see Eileen van Ravenswaay and John Hoehn, 1991. This chronology is based on the review of articles on Alar in the New York Times during that period.

production for the overseas market alone.[1] In November 1990, almost two years after the NRDC's report, a group of apple growers filed a law suit against CBS for airing the program that reported the NRDC's findings in March 1989 and against NRDC for declaring misleading statements to the public. The industry's estimate of the sales losses to the growers after February 1989 was $100 million.[2]

As seen from the chronology, there are three major events that mark the Alar incident. The first is the EPA's initial announcement in July 1984 that Alar was a potential carcinogen. The second is the events surrounding the publicity of the NRDC's and EPA's findings and the 60 Minutes program in February 1989. The third is the voluntary ban on Alar use in June 1989 followed by the Government ban. To understand the long-term effects of the Alar controversy on apple purchases, it is necessary to look at apple demand patterns after 1989, the date when the chemical was removed from the market.

1.2 Problem Statement and Scope of Research

This research analyzed how health-risk information about food affects food purchases over time by systematically identifying measures of the presence or absence of risk information in the market and incorporating these variables into an econometric demand model. Using the econometric model, estimates of how consumers value improvements in the safety of the food supply were developed. More specifically, this research investigated the long-term effect of the Alar incident on fresh apple purchases in the NYC retail apple market, and examined what consumers were willing to pay to avoid health risks associated with the consumption of Alar treated apples.

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[1] Allan R. Gold, "Company Ends Use of Apple Chemical," New York Times, 18 October 1989, p. A18.

[2] "After Scare, Suit by Apple Farmers," New York Times, 29 November 1990, p. A22.

One of the major reasons that we chose the NYC metropolitan area is to be able to follow up on the findings of van Ravenswaay and Hoehn (1991) by extending their data set through July 1991 to examine the demand patterns after Alar was removed from the market. The NYC market was originally chosen by van Ravenswaay and Hoehn (1991) due to the availability of the most comprehensive price data.

1.3 Importance of Research

The findings from this study have significant implications for the government and the food industry. An understanding of how consumers have reacted to the Alar incident and how the demand patterns have changed after risk was eliminated from the market provides guidance to policy makers in responding to consumer fears in similar health-scare events. The food industry also benefits from such knowledge in developing strategies to prepare for similar incidents. An estimate of the economic consequences of the Alar event provides an important piece of evidence for the apple industry in quantifying the revenue losses associated with the controversy on Alar. Another finding from this study is an estimate of the consumer's willingness to pay to avoid Alar residues in apples. From that willingness to pay estimate, it is possible to assess consumer's valuation of risk-reduction benefits. This piece of information is valuable for policy makers in evaluating policy alternatives concerning food safety improvements.

1.4 Existing Empirical Evidence on the Impact of the Alar Incident on Apple Purchases

Buxton (1989) examined the impact of the Alar incident on Washington State red delicious FOB prices. He compared the actual weekly FOB prices during the 1988-1989 marketing season with the expected prices that usually occur over a typical season. The typical season price pattern was calculated based on the FOB prices for Washington State red delicious apples at the Wenatchee shipping point. The seasonal index was estimated by removing trend, cyclical and irregular price changes from the actual price series for the period of January 1983-March 1989. The author found that the FOB prices of red delicious apples fell after February 1989, the time that the news coverage on Alar was the most intense. The findings suggest that over the period starting in late February through the second week in September, the total revenue loss for the growers of red delicious apples in Washington was $140 million in 1989 dollars. The author also reports that the retail prices did not reflect the full decline in the FOB prices which made it harder to market apples remaining in storage.

O'Rourke (1991) examined the impact of the Alar incident on Washington State FOB shipping point apple prices. Washington State is considered the major supplier of apples to the U.S. market. Therefore, the impact of the Alar incident on the Washington State apple industry may be a good proxy for its impact on the U.S wholesale apple market. The author used existing price forecasting models developed by the Washington Growers Clearing Association for Red Delicious, Golden Delicious and Granny Smith apples, and projected what the FOB shipping point apple prices would have been had the Alar incident not occurred. The method he used in calculating the revenue change to the apple growers is to subtract the observed values of the actual 1988-1989 average FOB shipping point prices from the apple prices that were projected from the price forecasting models. His findings suggest that the apple industry lost $130 million in the 1988-1989 marketing season (in 1989 dollars). Red delicious was the variety most affected by the Alar scare.

van Ravenswaay and Hoehn (1991) examined the effect of the Alar scare in the NYC retail fresh apple market. The authors used a single-equation demand model to estimate demand for apples in the NYC region using a time series model. Monthly data from January 1980 through July 1989 were used. They found that the effect of the Alar incident dated back to the time when EPA first announced in July 1984 that Alar was a potential carcinogen. The study reported that over July 1984-July 1989 period, 70% of the estimated total sales losses to NYC region's retailers was attributable to the initial and sustained demand shift in July of 1984. The sales loss estimate was calculated by subtracting estimated actual apple sales from a projection of what sales would have been had the Alar incident never occurred. The sales loss estimate for the period of June 1984 through July 1989 was $194.8 million (in 1983 dollars). The authors estimated consumer's willingness to pay to avoid Alar treated apples and use this estimate to calculate willingness to pay to avoid cancer risks. They found that the willingness to pay for reduced cancer risks were consistent with the existing estimates of willingness to pay for reduced risk in the literature.

The findings of the above studies provide empirical evidence that the Alar incident caused a reduction in apple purchases. It should be noted, however, that the three studies differ from each other in several important aspects. For example, van Ravenswaay and Hoehn (1991) showed that the change in apple sales associated with the Alar incident started in 1984 and much of the sales losses are attributable to that event while Buxton (1989) and O'Rourke (1991) examined the Alar incident only for the 1988-1989 marketing season. Another notable difference is associated with the methods used in the three studies in calculating the revenue losses due to the Alar scare. Buxton (1989) and O'Rourke (1991) subtract the projected apple prices from the observed values of actual apple prices and multiply the difference with the actual quantity sold. van Ravenswaay and Hoehn (1991) subtract the projected apple sales from the estimated values of actual apple sales. The reason why van Ravenswaay and Hoehn use this method is to minimize estimation errors.[1] Still another difference between these three

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[1]See, Mark E. Smith, Eileen O. van Ravenswaay, and Stanley R. Thompson, "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii," American Journal of Agricultural Economics 70 (August 1988), pp. 513-520.

studies is that Buxton (1989) and O'Rourke (1991) examine the impact of the Alar scare on the wholesale apple market while the study by van Ravenswaay and Hoehn covers the retail apple market. For these reasons, it is not possible to compare the quantitative findings from these three studies.

All three studies, however, indicate that there is a downward demand shift at the apple market. O'Rourke's findings indicate that the national wholesale prices dropped in 1988-1989 marketing season as a result of a downward demand shift at the wholesale market, given that the supply of apples at the wholesale market is perfectly elastic. Buxton also concludes that the Washington State red delicious apple FOB prices fell as a result of a downward shift in wholesale apple demand. van Ravenswaay and Hoehn model the retail apple market at the NYC region and found that the demand at the retail level also shifts down.

This research examined the long term effects of the Alar scare by extending the observation period of the study by van Ravenswaay and Hoehn (1991). This was the major objective of the research. Several other objectives were also sought as listed below.

1.5 Research Objectives

1. The long-term effects of the Alar incident are estimated by extending the observation period used in the van Ravenswaay and Hoehn (1991) study to the period after the withdrawal of Alar from the market.

2. The possibility that the Alar incident may have affected the retail price of fresh apples at the retail market is examined. If the retail price of apples at the national market is affected, then the retail price of apples in the NYC region should also be affected under the assumption of perfectly elastic supply to the regional markets. If information about risk at the national level affected the national demand and thus

national apple price, representing the NYC apple demand with a single equation would cause the equation estimates to be inconsistent and biased. The estimated demand model should therefore be tested for simultaneity bias.

This objective involves specifying an econometric model for apples that involves the national retail market and the regional retail markets for apples. This enables us to form testable hypotheses about the effect of health-risk information on apple purchases at the regional level when the event actually covers the whole nation.

3. Alternative measures of the health-risk information variable are explored.

4. Improved methods to account for seasonality in apple purchases are developed. Seasonality means there is a high degree of correlation between the values observed during the same season across the years.

5. The findings of this model, which explicitly accounts for the seasonal error structure, are compared to the findings obtained with a first order autoregressive error structure reported in van Ravenswaay and Hoehn (1991). The comparison will be made for the January 1980-July 1989 period to maintain consistency with the observation period covered in the van Ravenswaay and Hoehn (1991) study.

This study will then extend the observation period through July 1991 and compare the models with the seasonal error structure for the two observation periods (i.e. January 1980-July 1989 period and January 1980-July 1991 period). This comparison allows us to observe how extending the observation period changes the equation estimates.

6. The change in revenues associated with the Alar event to the NYC apple retailers are estimated.

7. The impact of the Alar event on consumer welfare is estimated. This objective involves calculating the change in consumer surplus associated with the health-risk information and deriving the consumer's willingness to pay to avoid Alar residues in apples.

8. From the estimate of the consumer's willingness to pay to avoid Alar residues in apples, the consumer's willingness to pay for health-risk reduction is derived.

As the objectives stated above show, this research differs from the study by van Ravenswaay and Hoehn (1991) in at least three aspects. One is the extension of the observation period to include the period after Alar was removed from the market. The second is the correction for seasonality in the demand model. This allows us to detect the impact of the exogenous variables on quantity demanded in isolation of the variations in apple sales associated with seasonality. The third difference is that this research models the effect on regional apple prices of potential price adjustments in national markets caused by the Alar controversy.

1.6 Research Procedures

The research methods consist of the procedures listed below.

1. An econometric model of national retail demand and supply for fresh apples, retail apple demand for all the regions in the nation except the NYC region, and retail apple demand for the NYC region is developed.

2. The reduced-form equations for per capita apple consumption and the retail price of apples in the NYC region is derived.

3. The reduced-form equations and the demand equation for apples in the NYC region is used to derive testable hypotheses about the impact of health-risk information on per capita apple purchases and the retail price of apples in that region. These hypotheses test whether risk information affects purchases at the regional level through a regional demand shift, or through a change in the national price induced by information at the national level, or through both effects.

4. Alternative measures of the presence or absence of the reported risk over time are developed. Testable hypotheses to specify the information effect on apple demand are developed.

5. A seasonal time-series model of per capita apple consumption and apple prices variables is specified.

6. Simultaneity bias in the demand equation is examined. This procedure involves derivation of the asymptotic covariance matrix for the demand equation where the price variable is replaced by the fitted values for the price variable and the error structure of the demand equation is seasonal.[1]

7. The demand equation and the reduced-form equations are estimated using a seasonal error structure.

8. The significance of the coefficients of the information variables in the demand equation for the January 1980 through July 1989 observation period are compared with two different specifications of the error structures. These are the first order autoregressive error structure and the seasonal error structure.

9. The significance of the coefficients for the information variables are compared with the seasonal error structure for the two different observation periods. These are the periods of January 1980 through July 1989, and January 1980 through July 1991.

10. Hypotheses on different specifications of the information effect in the demand equation are tested for the extended observation period, that is the January 1980 through July 1991 period.

11. Changes in apple sales associated with changes in health-risk information are estimated in the NYC region.

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[1]The reason that the estimate of the covariance matrix for the demand equation with instrument for the price variable is separately calculated is because we are not able to do the two-stage least squares estimation and get the coefficient estimates as well as the asymptotic covariance matrix with the "BOXJENK" command in the Regression Analysis Time Series (RATS) econometric package (version 3.1) for personal computers which is used in this study to compute multiplicative seasonal ARIMA model.

12. Changes in consumer welfare associated with changes in health-risk information are estimated by computing the change in consumer surplus.

13. The consumer's implicit willingness to pay to avoid a one in one million risk of cancer death is computed using the estimate of the change in consumer surplus.

1.7 Description of the Data

Since this research is an extension of the study by van Ravenswaay and Hoehn, the data for the period between January 1980 through July 1989 is largely identical with the data used in that study.[1] There are two major differences, however. One difference is that the monthly population estimates that are used in this research covers a smaller area. The other difference is the inclusion of an income variable and a variable that measures the national holdings of fresh apples. Appendix A presents the description of the data used in this study. Appendix B reports the extended data set.

1.8 Plan for the Presentation of the Research

Chapter II develops a conceptual framework to analyze consumer response to information on health-risk from food. This chapter defines the information variables and states the hypotheses related to the information effect on the quantity of food demanded. Methods to quantify the welfare effects associated with the changes in health-risk information is presented later in the chapter. Chapter III presents the econometric model for apples. This chapter discusses the estimation procedures for the regression equations. Chapter IV presents the econometric findings of the research and

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[1]For a detailed description of the data used in Eileen van Ravenswaay and John Hoehn, 1991, see William Preston Guyton, "Consumer Response to Risk Information: A Case Study of the Impact of Alar Scare on New York City Fresh Apple Demand" (M.S. Thesis, Michigan State University, 1990).

discussion of the results. Chapter V presents the research conclusions, policy issues and research needs.

CHAPTER II

CONCEPTUAL FRAMEWORK

This chapter develops a conceptual framework for the analysis of consumer response to information on health risk from food. Section One presents a model of consumption choice that establishes a relationship between health-risk information and the demand for risky food. Section Two explains how the information variable in the demand equation is defined. Section Three states the hypotheses concerning the effect of health-risk information on food purchases. Section Four describes the methods used to measure the welfare changes associated with the changes in information on health risk.

2.1 A Model of Consumption Choice

This section first defines the terms used in the conceptual framework. The section then presents the consumer's optimization problem and derives the demand functions for risky and non-risky foods.

2.1.1 Definition of the Terms: Health Problem, Health Risk and Health-Risk Perception

There are two concepts closely related to a consumer's perceived lifetime health risk from any source in his/her lifetime. The first one is the range of health problems that the consumer expects to experience during his/her lifetime. The second one is the probability that a health problem will occur during the consumer's lifetime. This second concept is the lifetime health risk of the consumer.

There is a range of health problems that the consumer can face. Each is characterized by the type of health problem, the severity of the health problem, the duration of the symptoms, and the timing of their occurrence in the lifetime of the consumer.[1] Some examples of the type of health problem that the consumer might expect to face during a lifetime are cancer, allergies, ulcer, heart diseases, etc. The severity refers to the seriousness of the health problem. Curable cancer, for example, is less severe than incurable cancer. The duration is the amount of time that the health problem persists. The timing in a lifetime relates to the age the consumer expects he/she will be when the health problem is realized.

For the purpose of this study, we assume that there is only one health problem in the lifetime of the consumer. The type of health problem, its severity, duration, and timing in the lifetime of the consumer are well defined. The lifetime health risk of the consumer is the probability that the health problem will occur during the consumer's lifetime. This is the actual health risk that is unknown to the consumer before he/she receives health-risk information. We assume lifetime health risk is a random variable since we assume there is a range of heath-risk levels for the consumer at a given point in his/her lifetime. The probabilities associated with the likelihood of the occurrences of a range of lifetime health-risk levels are unknown until the consumer receives exogenous information on the riskiness of practicing a specific activity or consuming a particular food. The acquisition of the information can be considered a random experiment and the probabilities associated with the likelihood of the occurrences of a range of lifetime health-risk levels cannot be predicted with certainty prior to the experiment. These

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[1]Nicholas Rescher, Risk: A Philosophical Introduction to the Theory of Risk Evaluation and Management (New York: University Press of America, 1983).

probabilities constitute a probability distribution. This probability distribution is the consumer's lifetime health-risk perception function.

The concept of the lifetime health-risk perception function suggests that each level of health risk is associated with the consumer's perception of the likelihood of its occurrence during a lifetime. Since the perceived lifetime health risk is defined as a distribution function, it can be characterized by measures of center, such as mean, median or mode. In this study, for convenience, the consumer's health risk perception function will be characterized by the health-risk level that has the highest perceived probability of occurrence for the consumer (i.e., mode of the lifetime health-risk perception function). Therefore, the consumer's perceived lifetime health risk is the health risk level that the consumer considers most likely to happen.

In summary, the consumer's perceived lifetime health risk can be defined with the help of two concepts. One is the set of health problems that may result from all causes. Each health problem is characterized by the type, severity, duration, and timing in the consumer's lifetime. Note that the set is assumed to have only one element. The characteristics of the health problem are well defined. The second concept is the probability of the occurrence of the health problem in a lifetime. This is the lifetime health risk. With the aid of exogenous information, the consumer forms a probability distribution where each probability is the likelihood of the occurrence of the lifetime health risk. This is the consumer's health risk perception function. The consumer's perceived lifetime health risk is the health risk level that the consumer believes to have the highest probability of occurrence in the health risk perception function.

There are two types of health risks that the consumer faces in his/her lifetime. One is the baseline health risk associated with all the activities in the consumer's lifetime except the lifetime consumption of Alar-treated apples. These include dietary habits, smoking, alcohol consumption and nonconsumption activities such as driving a car, being exposed to radioactive substances, etc. The other one is the additional health risk associated only with the lifetime consumption of Alar-treated apples.

We assume that the lifetime health risk is additive. That is, it consists of the baseline health risk plus the additional health risk from consuming Alar-treated apples. Perceived lifetime health risk is also assumed to be additive. The consumer has a perceived baseline health risk and a perceived additional health risk that add up to the perceived lifetime health risk.

Assume that the consumer lives for three periods. The first period is all the time that has elapsed until the present time; it is denoted by the subscript o. Since the consumption decisions from this period have already been made, the health consequences due to consumption in the past are taken as given. The second period is the present period; it is denoted by the subscript t. The third period is the future; it is denoted by the subscript f.

The perception of the chances that the consumer will experience the health problem in the future period is $\pi_f = \delta_o v_o + \delta_t v_t + \rho_o q_o + \rho_t q_t$, where v_o and v_t are the quantities of the activities other than the consumption of Alar-treated apples in the past and present periods, respectively. q_o and q_t are apple consumption in the past and present periods, respectively. δ_o and δ_t are the consumer's past and present perception of the marginal probability of the occurrence of the future health problem associated with an additional unit of all other activities except the consumption of Alar-treated apples, respectively. δ_o and δ_t are the consumer's perceived baseline marginal health risk. ρ_o and ρ_t are the consumer's past and present perception of the marginal probability of the occurrence of the health problem associated with consumption of an additional unit of Alar-treated apples, respectively. ρ_o and ρ_t constitute the consumer's perceived additional marginal health risk. We also assume that v consists of two types of activities, v^1 and v^2, both at time o and time t. Here, v^1 includes consumer's preventive actions (i.e., investment in health care, exercise) and v^2 includes all other activities. The consumer reduces his/her chances that he/she will experience the health problem in the future, π_f, by making changes in the consumption of v and q at times o and t. For simplicity, we assume that the consumer finds it less costly to reduce marginal risk from consuming Alar treated apples by reducing his/her consumption of q rather than increasing his/her consumption of v^2.

δ_o and ρ_o are functions of the consumer's knowledge about the marginal risk associated with the consumer's choice of v and q in the past period. Since this period is already past, the risk consequences ($\delta_o v_o + \rho_o q_o$) associated with the past choice of these goods and activities are taken as given.

δ_t and ρ_t are functions of the consumer's knowledge about the marginal risk associated with the consumer's choice of v and q in the present period. We assume that the consumer receives information in the present period on the lifetime health risk associated with an average lifetime consumption of Alar-treated apples. The consumer receives information through signals from a given information source. The signals differ by their informational contents. The informational content of a signal indicates the presence or absence of risk in apples.

The presence or absence of risk can be determined by the information on residue and toxicity. The toxicity of a substance and how much residue there is in the food supply are essential aspects of the food safety question.[1] Toxicity information is information about how toxic or hazardous a particular substance is. It is the information about the dose-response relationship for a given exposure level. The dose-response information defines the health risk concerning the consumer's exposure to the risky food. For example the lifetime health risk given the lifetime exposure to the risky food may be 1 in 10,000 cancer deaths. Residue information is information on the amount of

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[1]Eileen van Ravenswaay, "Consumer Perceptions of Health Risks in Food," in Increasing Understanding of Public Problems and Policies - 1990 (Oakbrook: Farm Foundation, 1990).

substance in the food supply. A consumer's exposure to the substance over a lifetime is a function of the per-unit amount of residue as well as the total consumption of the risky food. The lifetime health risk is a function of both the toxicity and the lifetime exposure.

Note that the reported risk in the present period is the lifetime health risk associated with an average lifetime consumption of Alar treated apples. With the aid of this information, the consumer forms ρ_t, his/her perception of the marginal health risk, that is the marginal probability of the occurrence of the health problem associated with the consumption of an additional unit of Alar treated apple at time t. The reason why the consumer can make this inference is because the reported lifetime health risk is assumed to be proportional to the marginal health risk as explained in the paragraph below.

Let the reported risk be $\bar{R}$, where $\bar{R}$ is the lifetime health risk associated with lifetime consumption of Alar treated apples. The lifetime health risk is assumed to increase linearly with the consumption of the risky food. This is a result of the assumption of the linear dose-response model.[1] Therefore, the lifetime health risk can be annualized if we divide it by the consumer's life expectancy (i.e., 70 years): $\bar{S} = (\bar{R}/70)$, where $\bar{S}$ is the annual health risk associated with an average annual consumption of Alar treated apples. This implies that $\bar{S} = \bar{r} * \bar{q}$, where $\bar{q}$ is the average annual consumption of Alar treated apples and $\bar{r}$ is the marginal health risk associated with the consumption of one unit of Alar treated apple. Therefore, $\bar{r} = \bar{S}/\bar{q}$.

In summary, the reported risk (i.e., $\bar{R}$) is the lifetime health risk associated with the lifetime consumption of Alar treated apples. By the assumption of the linear dose-response model, the annual health risk associated with an average annual consumption of apples (i.e., $\bar{S}$) is proportional to $\bar{R}$. Since the marginal health risk associated with the

[1]Eileen van Ravenswaay and John Hoehn, 1991.

consumption of one unit of Alar treated apple (i.e., $\bar{r}$) is proportional to $\bar{S}$, we can say that the reported risk $\bar{R}$ is proportional to $\bar{r}$ as well.

The perception of the marginal probability of the occurrence of the health problem associated with consumption of an additional unit of Alar-treated apple in the present period (ρ_t) is a function of the currently available information on the presence or absence of risk. Note that the ρ_o, δ_o and δ_t are taken as given. The currently available information can be measured in several ways. The following two ways are used. One is by the timing of government announcements about new lifetime risks. The other is by counting repetitions of these announcements by the media per time period. The repetitions of the government's announcements about risk are important because the consumer's assessment of the magnitude of the health problem may be subject to learning. That is, the magnitude of a consumer's perception of risk may increase as he/she hears more often about the presence of risk. Therefore, ρ_t is characterized as a function of two variables. One variable measures the presence or absence of the risk by the timing of its initial announcement (d_t). The other variable measures the presence or absence of the risk by the number of times the same message is repeated at a given point of time (g_t).

(2.1) $$\rho_t = \rho_t(d_t, g_t)$$

To summarize, the consumer is assumed to live for three periods: the past, the present and the future. The consumer's perceived risk of experiencing the health problem in the future period is the sum of the perceived health risk associated with all activities except the consumption of Alar-treated apples and the perceived health risk associated with the consumption of Alar-treated apples in the past and in the present periods. In the present period, the consumer receives new information on the presence or the absence of health risk associated with the consumption of apples treated with

Alar. With the aid of this information, the consumer updates the perception of the probability of experiencing the health problem in the future period.

The next section discusses the consumer's optimization problem and derives the demand function for apples.

2.1.2 The Model of Consumption Choice

The model of consumption choice in this study is based on the expected utility model. This framework is useful in the food-safety context since consumption decisions are made in the presence of uncertainty.[1]

Assume that the consumer's preferences are separable. That is, preferences can be partitioned into groups such that the preferences within each group can be described independently of the quantities in other groups.[2] Following this assumption, food will be defined as a separate group.

Assume that the representative consumer consumes q (apples) and y (all other foods) during a lifetime. Among all food items, assume that only apples contain residues of a particular toxic substance (Alar).

The lifetime expected utility of the consumer is,

$$EU = U_t(q_t,y_t) + \pi_f * U_{fa}(q_f,y_f) + (1-\pi_f) * U_{fb}(q_f,y_f) \tag{2.2}$$

where, $\pi_f = \delta_o v_o + \delta_t v_t + \rho_o q_o + \rho_t q_t$ and $\rho_t = \rho_t(d_t, g_t)$. Here, $U_t(q_t,y_t)$ is the utility of the consumer in the current period and $U_{fa}(q_f,y_f)$ is the utility associated with poor health

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[1]Kwan E. Choi and Helen H. Jensen, "Modelling the Effect of Risk on Food Demand," in Economics of Food Safety, ed. Julie A.Caswell (New York: Elseiver Science Publishing Company, 1991), pp. 28-44; Young Sook Eom, "Pesticide Residues and Averting Behavior" (Raleigh: North Carolina State University, Division of Economics and Business, February, 1991), photocopy.

[2]Angus Deaton and John Muellbauer, Economics and Consumer Behavior (Cambridge: Cambridge University Press, 1980), pp. 122-125.

and $U_{fb}(q_f, y_f)$ is the utility associated with good health in the future. q_t and y_t are consumption of apples and all other foods in the present period, respectively. q_f and y_f are consumption of apples and all other foods in the future period, respectively. π_f is the consumer's perceived probability of the occurrence of the future health problem, after consuming q_o and v_o in the past period and q_t and v_t in the present period. Note that we assume that the past and present consumption is irrelevant to the current period's utility, i.e., the health effects are always delayed to the future period. We also assume that there are no marginal health risks associated with the future consumption.

The optimization problem of the consumer is to maximize (2.2) subject to the lifetime budget constraint. The lifetime budget constraint is,

$$m = p_q q + p_y y \tag{2.3}$$

where m is the consumer's lifetime disposable real income, p_q is the deflated retail price of apples, p_y is the deflated retail price of all other foods, q is the quantity of apple consumption in a lifetime and y is the quantity of all other foods in a lifetime. Note that m, p_q and p_y are assumed to be constant over a lifetime. Therefore the per-period budget constraint (i.e., the budget constraint at time t) is proportional to the lifetime budget constraint.

The lagrangian expression for the utility maximization is,

$$\begin{aligned} L = {} & U_t(q_t, y_t) + \pi_f * U_{fa}(q_f, y_f) \\ & + (1-\pi_f) * U_{fb}(q_f, y_f) + \lambda(m_t - p_{qt} q_t - p_{yt} y_t) \end{aligned} \tag{2.4}$$

where, λ is the Lagrange multiplier. Here, m_t, p_{qt} and p_{yt} be the consumer's disposable real income, the deflated retail price of apples and the deflated retail price of all other foods at time t, respectively .The first order conditions for this problem are shown in equation (2.5). If the consumer maximizes utility, equation (2.6) will express his/her demand for q and y in the present period.

$$\frac{\partial L}{\partial q_t} = \frac{\partial U_t}{\partial q_t} + \rho_t U_{fa} - \rho_t U_{fb} - \lambda P_{qt} = 0$$

(2.5)
$$\frac{\partial L}{\partial y_t} = \frac{\partial U_t}{\partial y_t} - \lambda P_{yt} = 0$$

$$\frac{\partial L}{\partial \lambda} = m_t - p_{qt} q_t - p_{yt} y_t = 0$$

(2.6)
$$q_t = q_t(p_{qt}, p_{yt}, m_t, \rho_t)$$
$$y_t = y_t(p_{qt}, p_{yt}, m_t, \rho_t)$$

Since ρ_t is defined as a function of d_t and g_t, the demand functions for q and y in the current period are as shown in equation (2.7).

(2.7)
$$q_t = q_t(p_{qt}, p_{yt}, m_t, d_t, g_t)$$
$$y_t = y_t(p_{qt}, p_{yt}, m_t, d_t, g_t)$$

To summarize, the demand for q (apples) is a function of its own price, the price of its substitutes, income and health-risk information available at time t. The health-risk information is measured by two variables. One represents government announcements about risk and the other represents the repetitions of the announcements.

The following section discusses alternative ways in which the information variable can be measured and incorporated in the demand function.

2.2 Specifying the Information Variables

Following van Ravenswaay and Hoehn (1991), the information variables (d_t and g_t) in this study are measured by news media reports about Alar's health risks. The announcements of new risks are identified by dummy variables. The variables S_{1t} and S_{2t} represent the two occasions when different estimates of health risk were announced. S_{1t} represents the July 1984 to June 1989 period. It begins with EPA's initial announcement in July 1984 that Alar was a potential carcinogen which EPA subsequently estimated as posing a lifetime cancer risk to food consumers of $1.0*10^{-4}$.[1] The period ends in June 1989 with the removal of Alar from the market. Consequently, S_{1t} takes the value of 1 between July 1984 through June 1989 and zero in all other months. S_{2t} marks the beginning of the period during which the NRDC announced a greater lifetime risk estimate of $2.4*10^{-4}$ and the EPA simultaneously released a revised risk estimate of $3.5*10^{-5}$. This is the period after February 1989 that lasted until Alar was removed from the market. Consequently, S_{2t} has the value of 1 between February 1989 through June 1989 and zero elsewhere.

The underlying hypothesis for this type of measurement of information is that the initial announcements of the health risk matters for the consumer. S_{1t} is hypothesized to cause a sustained downward shift in demand associated with the initial announcement by the EPA as found by van Ravenswaay and Hoehn (1991). However, the effect of this announcement is assumed to disappear upon the withdrawal of Alar from the market.

Following van Ravenswaay and Hoehn (1991), S_{2t} is hypothesized to cause an additional downward shift in demand associated with the simultaneously reported revised risk estimates of the EPA and the NRDC. This shift was also sustained through June 1989. The announcements of the revised risk estimates suggest the existence of a new event that increased the consumer's perceived risk level, thus causing apple purchases to decline even further.

There is a third variable that is measured with the nominal scale. This variable (S_{3t}) measures the effect of the withdrawal of Alar from the market. If the sales returned to the pre-announcement levels, S_{1t} and S_{2t} should be sufficient to represent the variations in sales during the Alar controversy given the way that these variables are defined. S_{3t} should then not bring any additional explanatory power to the model and

[1]For the reported lifetime cancer risk estimates associated with consumption of Alar from all food sources, see, Eileen van Ravenswaay and John Hoehn (1991).

should not be statistically different than zero, while S_{1t} and S_{2t} should be negative and significant.

It is possible that the intensity of news reporting on risk announcements is important in explaining the variations in apple purchases. This may be true if the risk perceptions involve learning such that the magnitude of the consumer's perceived risk increases with subsequent repetitions of announcements. Therefore, a measure of the intensity of the reporting over time should be considered.

An information variable can be constructed such that the risk information is identified by the number of media reports per time period (NYT_t). Using the intensity variable, we can test the hypothesis that the intensity of the coverage of the health risk is important for the consumers in making their consumption decisions. Lagged values of the NYT_t variable can also be incorporated in the model to test whether the intensity of coverage affects future consumption or only current consumption.

The intensity of information can also be measured by the cumulative amount of reporting at a given point in time. The information variable that is measured by the cumulative number of articles over time can be incorporated in the demand model to test the hypothesis that consumers update their risk perceptions with the receipt of new information. This variable is not stationary, however, since it involves a time trend. In econometric models that use time-series data, the dependent variable and the independent variables should both be stationary. To eliminate the nonstationarity problem, one can difference the variable. For example in a time-series model that involves a highly seasonal dependent variable, such as apple purchases, both the dependent variable and the independent variables may be seasonally differenced to eliminate nonstationarity in the variables. After seasonally differencing, however, the cumulative variable will no longer measure the cumulative number of articles, but will measure the total number of articles in a given year. This makes it difficult to interpret the coefficient estimate. For these reasons, the information variable that measures the presence or absence of risk with the cumulative number of articles will not be incorporated into the econometric model.

In summary, the information variables in this study are measured using both a nominal scale and an interval scale. The nominal scale uses the beginning of the two events during which the different risk estimates were announced to account for the one time demand shift associated with each event. Another information variable using the nominal scale is the variable that measures the presence or absence of the suspected chemical in the market. The interval scale measures the intensity of the reported risk by the amount of media reporting on risk each time period.

2.3 Hypotheses on Modelling the Information Effect

The hypotheses outlined in this section will be tested for the models that use monthly observations from January 1980-July 1989 as well as for the models estimated using the extended observation period through July 1991. This will allow us to compare the models with seasonal error structure for two different observation periods. We will then be able to understand if the extension of the observation period affects the model estimates. We will also be able to explore the long-term effects of the Alar controversy. We can also compare the models under two different error structures for the observation period of January 1980 to July 1989. This allows us to see how a seasonal error structure changes the model estimates when compared to a first-order autoregressive error structure.

The first hypothesis is that information about Alar's risk does not affect fresh apple purchases. If we reject the first hypothesis, then the following four hypotheses about the impact of risk information on apple purchases will follow.

Hypothesis two is that consumers do not forget the information that health risk is present until they receive an announcement that it is no longer present. In other words, consumers do not forget information that is still relevant to their well being. We use S_{1t}, the dummy variable that measures the presence or absence of the health risk to test this hypothesis.

Hypothesis three is that the intensity of the reporting of risk intensifies consumer risk perceptions and causes apple sales to drop. If this hypothesis is true, then the coefficient on the NYT_t variable and/or the lagged values of the NYT_t variable should be negative and significant. However, the period during which there was intense media coverage involves the month in which the EPA announced a revised risk estimate and the NRDC released its risk estimate (February 1989). Therefore, a different hypothesis could be that announcements on the presence of risk is important to consumers in determining their risk perceptions and thus their apple purchases. The presence or absence of these levels of health risk is measured by S_{2t}. It is not possible to test the two hypotheses separately since either or both explanations may be true. Since S_{2t} is likely to be correlated with the current and lagged values of the intensity variable, including these variables as separate regressors would cause a problem of multicollinearity. We can estimate two separate models, i.e., one model with the current and lagged values of the NYT_t and another model with S_{2t}. However, we would not be able to know which specification represents hypothesis three. In other words, we cannot separate out the effect of the variable that measures the intensity of the media coverage from the variable that measures the presence or absence of the risk estimates made in February 1989. There is not sufficient information to differentiate what the real cause of the drop in apple sales between February 1989 through June 1989 was. It could have been the announcement of the risk estimate made by the NRDC and a subsequent one made by the EPA in February 1989, or it could have been the intense media coverage stirred by the public controversy over what the correct risk assessment was which also was during that period. We would only be able to distinguish the effect of the NYT_t variable on per capita apple purchases had the two events (i.e., the announcement of revised risk estimates and the intense media coverage) occurred in separate time periods.

Hypothesis four is that consumers do not forget the initial risk information and they continuously revise and update their risk perceptions as they receive new information about risk. This hypothesis is likely to be true if there is a downward shift in apple demand associated with the initial announcement of risk coupled with an additional downward shift in demand when additional risks are reported. Similar to hypothesis three, note that we are not able to distinguish what the real cause of this additional drop in sales was since the period of the intense media coverage on the presence of risk involves February 1989, the month in which the revised risk estimates were released. Two different specifications of the demand equation are used to test this hypothesis. In one specification, the information variables would be S_{1t} and the current and/or the lagged values of the NYT_t variable. This represents the added effect of the intense media coverage. In another specification, the information variables would be S_{1t} and S_{2t}. This represents the added effect of higher risks reported by the NRDC and lower risks reported by the EPA. We do not reject hypothesis four if the coefficient on the S_{1t} variable and on the current and/or the lagged values of the NYT_t variable is significant. Similarly, we do not reject hypothesis four if the S_{1t} and S_{2t} are negative and significant. Note that S_{1t} represents the initial shift in demand associated with the initial information on health risk. The current and lagged values of the NYT_t variable and the S_{2t} variable represent the additional shift in demand. However, we do not know the real reason for the additional drop in sales. One reason may be that the consumer may react to the intense media coverage such that his/her perception of health risk may increase. The increased risk perception causes an additional downward shift in demand. Another reason may be that the announcement of the revised risk estimate of the EPA and the estimate made by the NRDC may intensify consumer's risk perceptions and this may cause an additional downward shift in demand. Similar to hypothesis three, both specifications must be true and we cannot differentiate between the models. We would be able to differentiate the reason why this additional downward shift in apple demand occurs had the two events (different risk estimates and the intense media coverage) happened in non-overlapping time periods.

The fifth hypothesis is that sales return to the pre-announcement levels once the reported risk is declared to be eliminated from the market. This implies that consumers regain confidence in the safety of the supply of apples once they receive a signal that indicates the risk is no longer present. This hypothesis is likely to be correct if consumers who switched to the apple substitutes during the Alar scare went back to their old purchasing habits after the heath risk is eliminated. S_{3t}, which measures the presence or absence of the chemical in the market, is used to test this hypothesis. If the fifth hypothesis is true, this variable should not provide any additional explanatory power to the equation estimates when the variables that represent the presence or absence of the risk are negative and significant, given the way S_{1t} and S_{2t} are defined.

2.4 Methods for Valuing the Welfare Effects of the Health-Risk Information

After an appropriate specification of the information variable in the demand function, the welfare effects of the Alar controversy can be estimated. By observing the shifts in demand function associated with the changes in health-risk information, it is possible to derive the marginal willingness to pay to avoid Alar residues in apples and to use this estimate to derive an estimate of the willingness to pay for a unit change in risk. This approach has been used in other studies that look at the welfare effects of the health-risk information[1]

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[1]Pauline M. Ippolitto and Richard A. Ippolitto, "Measuring the Value of Life Saving From Consumer Reaction to New Information," Journal of Public Economics 25 (1984), pp. 53-81; Eileen van Ravenswaay and John P. Hoehn, 1991.

The Hicksian compensating and equivalent measures are considered to be the correct theoretical measures of welfare. The compensating variation is the amount of income, paid or received under the prospective policy change, that would leave an individual at the initial level of utility. The equivalent variation is the amount of income, paid or received, that would leave an individual at the post-change level of utility when faced with the initial policy situation.[1] Willig demonstrates that the consumer surplus is a close approximation to the Hicksian measures of welfare when the budget share of a commodity is small.[2]

The welfare measure used in this study is the change in consumer's surplus due to a shift in an individual's apple demand associated with health-risk information. The share of apple expenditures in an individual's budget can be considered small. Following Willig, the Marshallian demand should approximate the Hicksian welfare measures. Therefore, observing the change in consumer surplus with and without the risk information will give the individual's willingness to pay to avoid Alar residues in apples. This willingness to pay estimate reflects the individual's total welfare change associated with the Alar incident.

The underlying assumption in the econometric model in this study is that the supply of apples to the NYC region is perfectly elastic at the national price plus a fixed transportation cost. Therefore, the quantity demanded is hypothesized to vary with changes in health-risk information at a given price. This implies that change in health-risk information causes a shift in the individual demand curve

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[1]John P. Hoehn and Douglas Kreiger, Methods for Valuing Environmental Change, Staff Paper no. 88-30 (East Lansing: Michigan Sate University, Department of Agricultural Economics, 1988).

[2]Robert D. Willig, "Consumer Surplus Without Apology," The American Economic Review 66(4) (September 1976), pp. 589-597.

and thus reduces the quantity of apples the individual consumes. The change in individual welfare comes from consuming less apples to avoid health risks associated with the consumption of Alar-treated apples.

The individual willingness to pay for avoiding Alar residues in apples at a given level of price at time t is,

(2.8)
$$WTP = \int_{p^*}^{\infty} q(p_{qt}, p_{yt}, f_t^0, m_t)dp - \int_{p^*}^{\infty} q(p_{qt}, p_{yt}, f_t^1, m_t)dp$$

where q(.) is the apple demand function, p_{qt} is the retail price of apples, p_{yt} is the retail price of apple substitutes, m_t is disposable income, f^0 is the absence of the reported risk and f^1 is the presence of the reported risk at time t.[1] p^* denotes the given level of price at time. The annual total willingness to pay can be obtained by summing the total willingness to pay at each time t over a year.

Dividing the estimate of the individual's annual total willingness to pay to avoid health risks from consuming Alar-treated apples by the individual's perception of the annual health risks due to Alar residues in apples gives the individual's annual marginal willingness to pay to avoid health risks associated with Alar incident.[2] However, the consumer's perceptions of health risks associated with the consumption of apples with Alar residues are not known. Following van Ravenswaay and Hoehn, the next best approach is to assume that the consumer's perception of health risks are similar to the health risks reported in the media.

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[1]Note that the presence or the absence of the reported risk is measured in various ways as discussed in section 2.2. For convenience, the symbol f_t will account for the risk information in general.

[2]Eileen van Ravenswaay and John P. Hoehn, 1991.

CHAPTER III

THE ECONOMETRIC MODEL

Chapter III describes the econometric model used to estimate the retail demand for apples and to examine the impact of health-risk information on apple purchases. Section One presents the econometric model for apples. The econometric model consists of the retail apple demand equation for the NYC region, the retail apple demand equation for all other regions, and the retail apple demand and supply equations for the nation. The model assumes that the national price and the quantity consumed of apples are determined simultaneously by the national apple supply and demand. We also assume that the supply of apples at the regional level is perfectly elastic at the national price plus a fixed transportation cost to the region. Section Two specifies the reduced-form equations for per capita quantity purchased and for the price of apples in the NYC region. The section then explores the relationships between the coefficient estimates for the information variables in the quantity and price reduced-form equations and in the demand equation for the NYC region. The hypotheses on the effect of information on price and quantity in the reduced-form equations and on quantity on the demand equation are stated later in the section. Section Three discusses the methods used to detect seasonality and to construct a stochastic model for the error structure associated with the price and the quantity variables. It then explains the estimation procedure for the demand equation.

3.1 An Econometric Model for Apples

In developing an econometric model for apples in a regional market such as the NYC market, the supply and demand relationships at the national market and at the regional markets should be jointly examined using a system of equations. This is justified by the assumption that price and quantity are determined simultaneously in the national market and that the supply of apples to the regional markets is perfectly elastic.

We assume that there are two regions in the national retail fresh apple market: the NYC region and the aggregate of all other regions.

The national price of apples is determined by national supply and demand. The supply of apples to the NYC region and all other regions is assumed to be perfectly elastic at the national price plus a fixed transportation cost. For convenience, we assume that the transportation cost to the NYC region is greater than zero and the transportation cost to all other regions is equal to zero. This implies that the retail price of apples in the NYC region is greater than the national retail price by a fixed proportion and the retail price of apples in all other regions is equal to the national retail price.

The econometric model for apples can be expressed in the following four equations.

The retail apple demand equation for the NYC region is:

$$q_t^r = \beta_1^r p_{qt}^r + \beta_2^r p_{yt}^r + \beta_3^r m_t^r + \beta_4^r f_t^r + e_t \tag{3.1}$$

$$p_{qt}^r = (1 + g)\, p_{qt}^n = c * p_{qt}^n$$

such that $0 < g \leq 1$ and $c = 1 + g$; where,

q_t^r : Per capita apple purchases in the NYC region at time t,

p_{qt}^r : Deflated retail price of apples in the NYC region at time t,

p_{yt}^{r} : Deflated retail price of the most common apple substitute (e.g., bananas) in the NYC region at time t,

p_{qt}^{n} : Deflated national retail price of apples at time t,

m_t^r : Deflated per capita disposable income in the NYC region at time t,

f_t^r : Health-risk information in the NYC region at time t,

e_t : Stochastic error term at time t, where $e_t \sim N(0,\sigma^2)$.

g : Proportionality factor between the national retail apple price and the retail apple price in the NYC region,

$\beta_1^r \ldots \beta_4^r$: The regression parameters.

The retail apple demand equation for the other regions is:

$$q_t^o = \beta_1^o p_{qt}^o + \beta_2^o p_{yt}^o + \beta_3^o m_t^o + \beta_4^o f_t^o + u_t \qquad (3.2)$$

$$p_{qt}^o = p_{qt}^n$$

where,

q_t^o : Per capita apple purchases in all other regions at time t,

p_{qt}^o : Deflated retail price of apples in all other regions at time t,

p_{yt}^o : Deflated retail price of the most common apple substitute (e.g., bananas) in all other regions at time t,

m_t^o : Deflated per capita disposable income in all other regions at time t,

f_t^o : Health-risk information in all other regions at time t,

p_{qt}^n : Deflated national retail price of apples at time t,

u_t : Stochastic error term at time t, where $u_t \sim N(0,\sigma^2)$.

$\beta_1^o \ldots \beta_4^o$: The regression parameters.

The retail apple demand equation for the nation is:

where,

w_t : Stochastic error term at time t, where $w_t \sim N(0,\sigma^2)$.

$$(3.3)\qquad q_t^n = \beta_1^r p_{qt}^r + \beta_2^r p_{yt}^r + \beta_3^r m_t^r + \beta_4^r f_t^r + \beta_1^o p_{qt}^o + \beta_2^o p_{yt}^o + \beta_3^o m_t^o + \beta_4^o f_t^o + w_t$$

and all other variables are identical to the ones in equations (3.1) and (3.2). Note that the demand equation for the nation (equation (3.3)) is the sum of the demand equations for the NYC region (equation (3.1)) and all other regions (equation (3.2)).

The retail apple supply equation for the nation is:

$$(3.4)\qquad p_{qt}^n = \beta_5^n q_t^n + \beta_6^n h_t^n + \beta_7^n f_t^n + z_t$$

where,

p_{qt}^n : Deflated national retail price of apples at time t,

q_t^n : Per capita national apple purchases at time t,

h_t^n : National apple holdings at time t,

f_t^n : Health-risk information in the nation at time t,

z_t : Stochastic error term at time t, where $z_t \sim N(0,\sigma^2)$.

$\beta_5^n \ldots \beta_7^n$: The regression parameters.

Equations (3.1) and (3.2) indicate that the demand for apples at the NYC region and all other regions could be affected by the health-risk information. We hypothesize that there is a downward demand shift at the NYC region and/or all other regions associated with the health-risk information in these regions. Since the national demand curve for apples is assumed to be the horizontal sum of the demand curves at the regional level, the demand shift at the national level associated with the health-risk information should be the result of the sum of the demand shifts at the NYC region and/or all other regions (equation (3.3)).

The downward shift in demand at the national level causes the national retail price of apples to drop. If we assume that there is no shift in national retail apple supply associated with the health-risk information at the national level such that estimate of β_7^n is statistically equal to zero, and since the NYC region's retail apple price is assumed to be proportional to the national retail apple price, the price at the NYC region should also drop.

It is possible, however, that the retail price at the NYC region does not change as a result of the health-risk information at the national level. One possible explanation for this may be that while the national wholesale apple prices decline as a result of a downward shift in demand associated with the health-risk information at the national level, the retailers at the NYC region and all other regions do not change the regional retail apple prices. This implies that the national retail apple prices and thus the regional prices are not affected by health-risk information. A possible reason that the retailers do not change retail price of apples may be because that may not anticipate a drop in demand such that they do not adjust prices. Still another reason may be that the retailers may not want to signal lower quality by dropping apple prices in order to avoid fueling consumers' fears. Buxton (1989) reports that the wholesale price of the Washington State red delicious apples dropped after February 1989 while the retail price did not fully reflect the decline in the wholesale prices. This finding is one empirical evidence that the price at the wholesale level drops as a result of a downward shift in wholesale demand while the price at the retail market does not change.

Alternatively, the national wholesale price may drop as a result of the health risk information at the national level and the retailers in all other regions change the retail apple prices while the retailers in the NYC region do not change the retail apple prices. In this research, however, we will only be able to explore the impact of the health risk information on retail prices at the NYC region. We will not be able to know what the effect of the health-risk information was on the national wholesale or retail price and to the retail price in the aggregate of all other regions.

Another reason why the national retail price and thus the retail price at the NYC region may not change as a result of the information on health risk is a possible downward retail supply shift associated with the controversy on Alar. As seen from equation (3.4), the health-risk information at the national retail level which is measured by f_t^n could cause a downward shift in the national supply of apples at the retail market commensurate with the downward shift in retail apple demand. One reason for this may be that the retailers may have removed apples from their shelves and they discontinued marketing apples until the controversy on Alar comes to an end because of liability concerns.[1] Another explanation for a downward shift in the retail apple supply curve may be the purchases of the unsold apples at the wholesale market made by the Federal Government in order to stabilize apple prices. It is reported that the United States Department of Agriculture purchased $15 million worth of apples in an effort to reduce the surplus at the wholesale market.[2] Therefore, the impact of the health-risk information on the market clearing price for apples at the national retail market and thus at the regional retail markets may be determined by both a supply and a demand shift at the national retail market.

Note that we cannot form testable hypotheses on the reasons why the health-risk information on the NYC retail apple price does or does not change with the health-risk information. Several alternative interpretations outlined in this section might be true. In this research, the only hypothesis regarding the retail price of apples at the NYC retail market is related to the question of whether or not the price at the NYC retail market was affected by the health-risk information. We do not know the reason why the NYC retail apple price was or was not affected by information on risk. According to one of the interpretations described above, the price change may be explained by a possible demand and supply shift at the national retail market associated with health-risk information. The discussion in Section 3.2.3 adopts this interpretation. The hypotheses

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[1]Richard Gibson, "Apples with Alar Frightened Grocers More than Buyers," The Wall Street Journal, 7 August 1989, p. B3.

[2] "U.S to Bail Out Apple Growers," The Chicago Tribune, 9 July 1989, p. C22.

related to the effect of health risk information on price and quantity at the NYC region outlined in Section 3.2.4 are also based on this interpretation.

In summary, the econometric model for apples at the retail market suggests that the health-risk information can cause a downward shift in apple demand at the NYC region and/or all other regions. Since national apple demand is the sum of the regional demands, the health-risk information should also cause a downward demand shift at the national level. Since the national price and quantity are assumed to be determined simultaneously, the national price, and thus the regional prices, will be affected by the risk information at the national level. Regional prices will be affected by a change in price at the national level since they are assumed to be proportional to the national price. Estimating the consumer demand for apples in the NYC region by a single equation may introduce simultaneity bias if p_{qt}^r in the NYC region's demand equation is correlated with the error term in this equation. Simultaneity bias at the NYC region's demand equation will therefore be tested.

The next section derives the reduced-form equations for q_t^r and p_{qt}^r at the regional level. These reduced-form equations can then be used to construct hypotheses on the effect of information on the equilibrium quantity of per capita apple purchases and on apple prices at the NYC region.

3.2 The Reduced-Form Equations and the Demand Equation

As we see from the econometric model outlined in Section 3.1, we no longer can assume that the price of apples at the NYC retail market is exogenous in equation (3.1). Using the econometric model, we can derive the reduced-form equations for q_t^r and p_{qt}^r expressed as functions of all the exogenous variables in the system of equations. By observing the coefficient estimates on the reduced-form equations, we can understand whether a particular variable had a significant impact on the equilibrium price and quantity. For example, we can form testable hypotheses on the impact of the health-risk information on retail apple prices and per capita quantity purchases at the NYC retail apple market. We will then be able to understand whether the information on health risk has affected the equilibrium price and quantity through a shift in demand at the NYC market or through a price change induced by the health-risk information at the national market or through both effects. Section 3.2.4 summarizes the related hypotheses.

The reduced-form equations for q_t^r and p_{yt}^r are expressed as functions of all the exogenous variables in the system of equations. The derivation of the reduced-form equations is presented in Appendix D.

3.2.1 <u>The Reduced-Form Equation for Per Capita Apple Purchases in NYC Region</u>

The reduced-form equation for q_t^r is:

$$q_t^r = \gamma_1 h_t^n + \gamma_2 f_t^n + \gamma_3 p_{yt}^o + \gamma_4 m_t^o + \gamma_5 f_t^o + \gamma_6 p_{yt}^r + \gamma_7 m_t^r + \gamma_8 f_t^r + \xi_t \tag{3.5}$$

where, ξ_t is the random error, γ_1-γ_8 are the regression parameters and the variables are as defined in equations (3.1) through (3.4) in Section 3.1.[1]

Note that in equation (3.5) the observed variables are h_t^n, p_{yt}^r, m_t^r and f_t^r. We do not have the data for the remaining four variables. Therefore equation (3.5) will be estimated by using only the observed variables. This means that we are going to omit f_t^n, p_{ty}^o, m_t^o and f_t^o.

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[1]Note that equation (D.7) in Appendix D is identical to equation (3.5). Therefore, the γ_1-γ_8 coefficients consist of the parameters of the structural equations as explicitly seen in equation (D.7) in Appendix D.

The omission of some of the independent variables in the equation causes the estimates of the coefficients in the remaining variables to be biased unless these variables are orthogonal to the included variables. The estimate of the covariance matrix is also biased upwards regardless of whether or not the omitted variables are orthogonal to the included variables.[1]

If for example we estimate equation (3.5) using only the observed variables, the coefficient on the information variable in the reduced-form equation is γ^r and the expected value of the estimator is:

$$E(\gamma^r) = \hat{\gamma}^r = a*\gamma_2 + b*\gamma_5 + \gamma_8 \tag{3.6}$$

where a is the slope of the least squares estimate from the regression of the information variable at the NYC region on the information variable at the national level (f_t^n) and b is the slope of the least squares estimate from the regression of the information variable at the NYC region on the information variables for all other regions (f_t^o).[2] If a and b are statistically different than zero, then the coefficient estimate of the information variable in the reduced-form equation is biased.

For simplicity, assume that a and b are both equal to one. Following this assumption, the expected value of the coefficient on f_t^r at the regional level is:[3]

$$\hat{\gamma}^r = \gamma_2 + \gamma_5 + \gamma_8 \tag{3.7}$$

Note that the estimate of the covariance matrix of the reduced-form equation is still biased upwards because of the omitted variables in the equation. This means that the statistics that are used to test the significance of the coefficient estimates are likely

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[1]Peter Kennedy, A Guide to Econometrics, 2d ed., (Cambridge: MIT Press, 1985), p. 69.

[2]William H. Greene, Econometric Analysis (New York: Macmillan Publishing Company, 1990), p. 259.

[3]See equations (D.16) and (D.17) in Appendix D.

to be lower than they actually are. This increases the likelihood that we do not reject the null hypothesis that the coefficient estimates are equal to zero when the alternative hypothesis is true. To overcome this problem we can increase the significance level of the hypothesis test such that the percentage of the area in the rejection region increases. For example, instead of using a 1% significance level we can use a 5% or a 10% significance level.

3.2.2 The Reduced-Form Equation for Deflated Retail Apple Price in the NYC Region

The reduced-form equation for price is:

$$\text{(3.8)} \quad \begin{aligned} p^r_{qt} = {} & \alpha_1 h^n_t + \alpha_2 f^n_t + \alpha_3 p^o_{yt} + \alpha_4 m^o_t \\ & + \alpha_5 f^o_t + \alpha_6 p^r_{yt} + \alpha_7 m^r_t + \alpha_8 f^r_t + \varsigma_t \end{aligned}$$

where ς_t is the random error, α_1-α_8 are the regression parameters and the variables are as defined in equations (3.1) through (3.4) in Section 3.1[1].

As in the case for the reduced-form equation for quantity equation note that in (3.8) the observed variables are h^n_t, p^r_{yt}, m^r_t and f^r_t. Since we do not have the data for the rest of the variables, we have to estimate (3.8) by using only the observed variables. The coefficient estimates of the included variables may be biased because of their possible correlation with the excluded variables.

If we estimate (3.8) using only the observed variables, the coefficient on the information variable in the reduced-form equation is α^r and the expected value of the estimator is:

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[1]Note that equation (D.6) in Appendix D is identical to equation (3.8). Therefore, the α_1-α_8 coefficients consist of the parameters of the structural equations as explicitly seen in equation (D.6) in Appendix D.

$$E(\alpha^r) = \hat{\alpha}^r = a*\alpha_2 + b*\alpha_5 + \alpha_8 \quad (3.9)$$

where a is the slope of the least squares estimate from the regression of the information variable in the NYC region on the information variable at the national level (f_t^n) and b is the slope of the least squares estimate from the regression of the information variable at the NYC region on the information variables for all other regions (f_t^o).

Following the assumption that a and b are both equal to one, the estimate of the coefficient on f_t^r is[1]:

$$\hat{\alpha}^r = \hat{\alpha}_2 + \hat{\alpha}_5 + \hat{\alpha}_8 \quad (3.10)$$

Similar to the reduced-form equation for quantity, the estimate of the covariance matrix of the reduced-form equation for price is biased upwards because of the omitted variables in the equation. Therefore, the same caveat as in the reduced-form equation for quantity applies here when making statistical inferences about the significance of the coefficients for the reduced-form equation for price.

By examining the coefficient estimates of $\hat{\alpha}_r$ and $\hat{\gamma}_r$, we can understand whether the change in apple purchases in the NYC region is due to the price change at the national level, the demand shift at the regional level, or both effects. This analysis is outlined in the following section.

3.2.3 Interpretation of the Estimates for the Coefficients on the Information Variables in the Reduced-Form Equations

It is possible to form hypotheses to test whether health-risk information affects per capita purchases at the regional level through a regional demand shift or through a change in the national price induced by the information at the national level, or through

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[1]See equations (D.11) and (D.12) in Appendix D.

both effects. The hypotheses can be tested by observing the estimates for the coefficients on the information variables in the reduced-form equations for quantity and price, and in the regional demand equation. The estimates for the information variables in the reduced-form equations include the coefficients for the information variables in the structural equations. The structural equations are the NYC region's demand equation, the other region's demand equation, the national demand equation and the national supply equation.

The estimate of the coefficient for the information variable in the reduced-form for quantity has two components.[1] One is the change in apple sales at the regional level associated with the change in the national price induced by the risk information at the national level (i.e, $\beta_1^r * \hat{\alpha}^r$). The other is the shift in the regional demand associated with the information on per capita apple consumption at the regional level (i.e, β_4^r). The net effect of information at the regional level is determined by these two components that are embodied in the coefficient estimate of the information variable in the reduced-form equation for quantity.

The change in regional price associated with the risk information at the national level is determined by the estimate of the coefficient on the information variable in the reduced-form equation for price, $\hat{\alpha}_r$.[2] In this formulation, note that the denominator of the $\hat{\alpha}_r$ is always positive because of the assumption that $\beta_5^n > 0$, $\beta_1^o < 0$ and $\beta_1^r < 0$. The sign of the numerator determines the sign of the coefficient estimate of the information variable in the reduced-form equation for price. The information coefficients in the numerator of the reduced-form equation for price are β_7^n which corresponds to the supply shift at the national level associated with the health-risk information and $\beta_4^o + \beta_4^r$, which corresponds to the demand shift at the national level. The relative effects of the

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[1] See equation D.18 in Appendix D.

[2] See equation D.12 in Appendix D.

demand and the supply shift at the national level determine the impact of information on retail apple price at the national level and thus at the regional level. If the effect of the supply shift at the national level is stronger (weaker) than the effect of the demand shift at the national level, then the price should go up (down). If the two effects are equal, there should be no change in the national price, and thus there should be no change associated with the risk information in the regional price.

The following section describes the hypotheses concerning the effect of health-risk information on quantity and price in the reduced-form equations and on quantity in the demand equation.

3.2.4 Hypotheses on the Information Effect on Reduced-Form Equations and Demand Equation

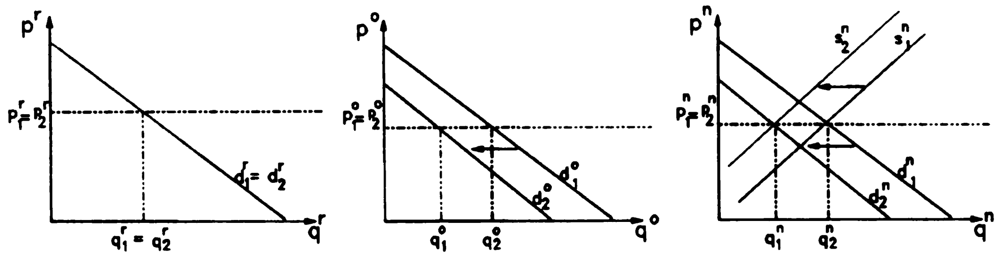
The following four hypotheses represent the effect of health-risk information on equilibrium level of retail apple price and per capita apple consumption at the NYC retail apple market. By observing the coefficient estimates on the information variables in the reduced-form equations and in the NYC demand equation, we can understand how the equilibrium price and quantity pair at the NYC region was affected by the Alar incident.

Note that we are not able to observe the national retail market and all other markets. Therefore, the following hypotheses are based on the estimates of the NYC demand equation (equation (3.1)), the reduced-form equation for per capita apple purchases in the NYC region (equation (3.5)) and the reduced-form equation for deflated retail price in the NYC region (equation (3.8)). The testable hypotheses are on the effect of information on the equilibrium price and quantity pairs at the NYC market from the reduced-form equations. We are also able to estimate the demand curve for apples in the NYC market such that we can observe shifts in the demand curve associated with the Alar incident. Therefore, the hypotheses outlined below are going to be tested by observing the significance of the coefficient estimates on the information variables in the reduced-form equation for quantity (γ^r), the reduced-form equation for price (α^r) and the NYC demand equation (β_4^r). The algebraic derivation of the estimates of the coefficients for the information variables in the reduced-form equations is presented in Appendix D. As stated in Section 3.2.3 and explicitly derived in Appendix D, the estimates of γ_r and α_r include coefficients for the information variables of the structural equations. The following hypotheses can be interpreted in terms of the expected signs of the coefficients on the information variables in the structural equations as outlined in Section 3.2.3.

The first hypothesis is that there is no effect of health-risk information on apple purchases in the NYC region. One explanation of this hypothesis is that the Alar incident had no impact on apple purchases across the nation at all. Another explanation of this hypothesis is represented in Figure 3.1. In Figure 3.1, the Alar incident shifts down the national retail apple demand curve from d_1^n to d_2^n. There is a commensurate supply shift at the national retail market such that the retail supply shifts down from s_1^n to s_2^n which causes the national retail apple price and thus the price at the regional level remain unchanged, i.e, $p_1^n = p_2^n$, $p_1^o = p_2^o$ and $p_1^r = p_2^r$.[1] Since there was no change in demand at the NYC region, the equilibrium per capita apple consumption also remains unchanged, i.e., $q_1^r = q_2^r$ in Figure 3.1. If the retail apple price at the NYC region remains unchanged, then $\hat{\alpha}^r = 0$ which implies the effect of the national supply shift on the equilibrium national retail apple price is equal to the effect of the national demand shift as outlined in Section 3.2.3. Since the NYC retail apple demand curve remains unchanged, then $\beta_4^r = 0$. As seen in equation D.18 in Appendix D, the net effect of

[1]Note that aside from the possibility of a supply shift at the retail level, there are other explanations of why the national retail apple price and thus the NYC retail apple price was not affected by the Alar incident (see, Section 3.1).

information at the NYC level is determined by two components. Therefore, $\hat{\gamma}^r$ should also be equal to 0.

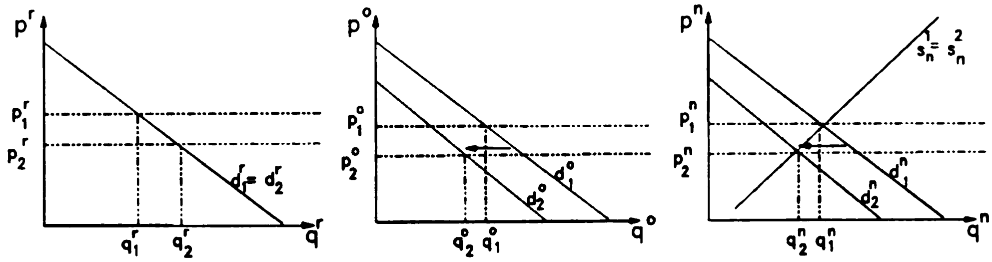


NYC Region Other Regions Nation

Figure 3.1 Hypothesis I

If the coefficient on the information variable in the reduced-form equation for price (α^r) is statistically different than zero, then hypotheses two and three follow.

Hypothesis two is that the change in apple sales in the NYC region is due <u>only</u> to a change in the national price induced by health-risk information at the national level. As represented in Figure 3.2, this hypothesis implies that apple demand at the national retail market shifts down from d_1^n to d_2^n which causes the national retail apple price to drop from p_1^n to p_2^n. Subsequently, the equilibrium price at the NYC region drops from p_1^r to p_2^r and the equilibrium per capita apple consumption increases from q_1^r to q_2^r as seen in Figure 3.2. According to this hypothesis, there was no downward shift in the demand curve at the NYC region such that $d_1^r = d_2^r$. If the retail apple price at the NYC region drops, then $\hat{\alpha}^r < 0$ which implies that the effect of the national supply shift on the equilibrium price is less than the effect of the national demand shift as outlined in Section 3.2.3. If the NYC retail apple demand curve remains unchanged, then $\beta_4^r = 0$. As seen in equation D.18 in Appendix D, the net effect of information at the NYC level is determined by two components. Therefore, $\hat{\gamma}^r$ should be less than 0. Note that this hypothesis assumes that there is no supply shift at the national level associated with health-risk information.



NYC Region   Other Regions   Nation

Figure 3.2 Hypothesis II

Hypothesis three is that the change in apple sales in the NYC region is due to <u>both</u> a change in the national price induced by information <u>and</u> a regional demand shift. This hypothesis is represented under three cases. These cases are represented by Figures 3.3, 3.4 and 3.5. This hypothesis implies that the Alar incident causes a downward demand shift at the NYC region, i.e., the NYC retail apple demand shifts down from d_1^r to d_2^r. This hypothesis also implies that the national retail apple demand curve shifts down from d_1^n to d_2^n such that the price changes from p_1^n to p_2^n at the national level and thus changes from p_1^r to p_2^r at the NYC region as seen in Figures 3.3, 3.4 and 3.5. Since this hypothesis implies that there is a downward demand shift at the NYC region, then $\hat{\beta}_4^r<0$. The sign on $\hat{\alpha}^r$ and on $\hat{\gamma}^r$ depends on the following three cases:

The first case is that the impact on equilibrium quantity purchased in the NYC region due to a regional demand shift is offset by the change in price at the national level induced by information. Note that in Figure 3.3, the national retail apple demand curve shifts down from d_1^n to d_2^n. This means that the national price drops from p_1^n to p_2^n and thus the NYC region's price drops from p_1^r to p_2^r as a result of the downward demand shift at the national retail market. The demand curve at the NYC region also shifts down from d_1^r to d_2^r such that the equilibrium quantity consumed remains unaffected ($q_1^r = q_2^r$). If the retail apple price at the NYC region drops, then $\hat{a}^r < 0$ which implies that the effect of the national supply shift on the equilibrium price is less than the effect of the national demand shift as outlined in Section 3.2.3. As seen in equation D.18 in Appendix D, the net effect of information at the NYC level is determined by two components. Therefore the effect of the drop in price on the equilibrium per capita apple consumption at the NYC retail market is even with the effect of the downward demand shift at the NYC retail market such that $\hat{q}^r = 0$.

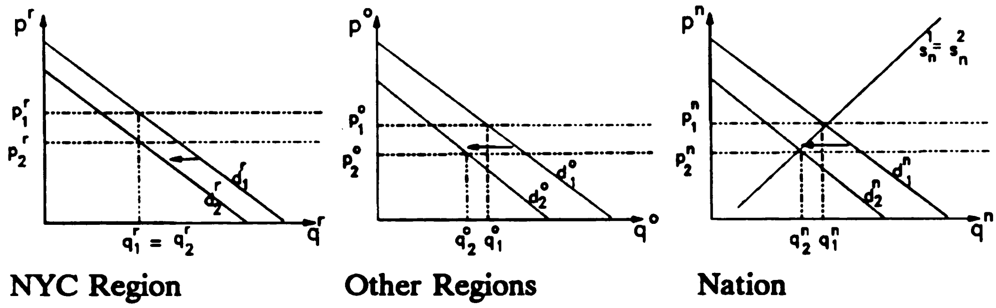


Figure 3.3 Hypothesis III, Case 1

The second case is that the equilibrium per capita apple consumption at the NYC region increased after the Alar incident. The reason is that the impact on q^r of the change in price at the national level induced by information is greater than the impact on q^r of the demand shift at the regional level. As seen in Figure 3.4, the national retail apple demand shifts down from d_1^n to d_2^n. The downward shift in national retail apple demand shift causes national retail apple price to drop from p_1^n to p_2^n. Therefore the retail price at the NYC region drops from p_1^r to p_2^r. The demand curve at the NYC region also shifts down from d_1^r to d_2^r. The equilibrium per capita apple consumption at the NYC region increases from q_1^r to q_2^r. If the retail apple price at the NYC region drops, then $\hat{\alpha}^r < 0$ which implies that the effect of the national supply shift on the equilibrium price is less than the effect of the national demand shift as outlined in Section 3.2.3. As seen in equation D.18 in Appendix D, the net effect of information at the NYC level is determined by two components. According to this case, the effect of the drop in price on the equilibrium per capita apple consumption at the NYC retail market is greater than the effect of the downward demand shift at the NYC retail market such that $\hat{\gamma}^r > 0$.

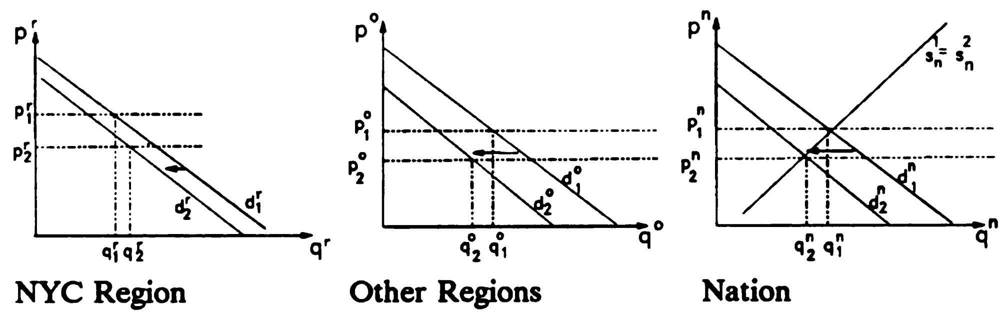
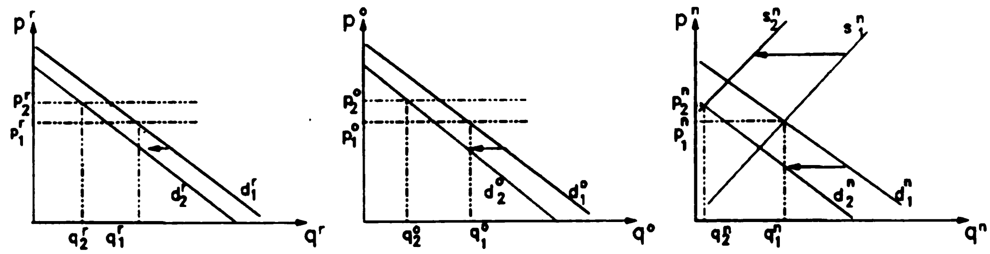


Figure 3.4 Hypothesis III, Case 2

Note that in both of the above cases, it is assumed that there is no shift in supply at the national level associated with the health-risk information.

As seen in Figure 3.5, the third case is that the supply shift at the national level is greater than the national demand shift such that the national apple prices increase from p_1^n to p_2^n due to health-risk information. The equilibrium price at the NYC region therefore increases from p_1^r to p_2^r. The decrease on the equilibrium quantity purchased at the NYC region is associated both with the downward demand shift at the regional level an also with a price increase at the national level. Therefore the equilibrium per capita apple consumption decreases from q_1^r to q_2^r. Since the retail apple price at the NYC region increases, then $\hat{\alpha}^r > 0$ which implies that the effect of the national supply shift on the equilibrium price is greater than the effect of the national demand shift as outlined in Section 3.2.3. As seen in equation D.18 in Appendix D, the net effect of information at the NYC level is determined by two components. Therefore the effect on the equilibrium per capita apple consumption a the NYC region is the sum of the price increase and the downward demand shift at the NYC region such that $\hat{p}^r > 0$.

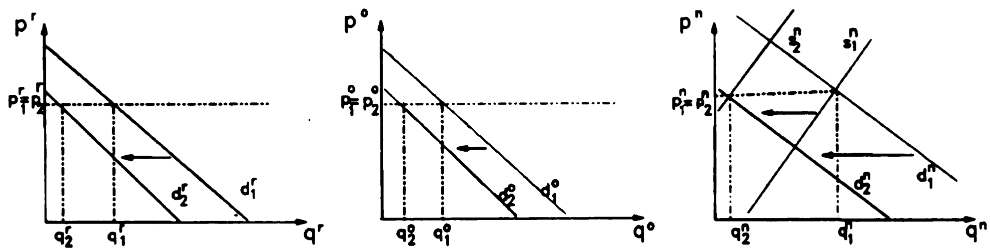


NYC Region Other Regions Nation

Figure 3.5 Hypothesis III, Case 3

Hypothesis four is that the change on quantity purchased in the NYC region is due only to a demand shift at the regional level. This hypothesis is represented by Figure 3.6. The national retail apple demand shifts down from d_1^n to d_2^n. There is a commensurate supply shift at the national retail level such that the retail apple supply shifts down from s_1^n to s_2^n such that the national retail apple price remains unaffected after the Alar incident, i.e., $p_1^n = p_2^n$. If the national price remains unaffected, then the regional prices should also remain unaffected, such that $p_1^o = p_2^o$ and $p_1^r = p_2^r$. This hypothesis also implies that there was a downward demand shift at the NYC region such that demand dropped from d_1^r to d_2^r such that the equilibrium per capita apple consumption dropped from q_1^r to q_2^r as seen in Figure 3.6. Since the retail apple price at the NYC region remains unchanged, then $\hat{p}^r = 0$ which implies that the effect of the national supply shift on the equilibrium price is equal to the effect of the national demand shift as outlined in Section 3.2.3. As seen in equation D.18 in Appendix D, the net effect of information at the NYC level is determined by thwo components. Since the

NYC retail apple demand curve shifts down, then $\beta_4^r < 0$. Since there was no effect of information on price, the effect of information on the equilibrium per capita apple consumption at the NYC region should be less than zero (i.e., $\gamma^r = 0$).



NYC Region | Other Regions | Nation

Figure 3.6 Hypothesis IV

3.3 <u>Methods for Estimating the Reduced-Form Equations and the Demand Equation</u>

The first step in estimating the reduced-form equations and the demand equation was to determine the error structure associated with their dependent variables: q_t^r and p_{qt}^r. This allows us to account for the time-series component in these variables. It is then possible to explore the effects of the explanatory variables on q_t^r and p_{qt}^r in the reduced-form equations and in the demand equation in isolation from the time-series component of the model.

Following van Ravenswaay and Hoehn (1991), the functional form used to estimate the reduced-form equations and the demand equation in this study is log-linear. Therefore, the time series model was specified for the logarithms of q_t^r and p_{qt}^r.

3.3.1 Specifying Time-Series Model for the $\ln p_t^r$ and the $\ln p_t^r$ Variables

When the errors are serially correlated and have a seasonal pattern, they can be modelled by a seasonal integrated autoregressive moving average (Seasonal ARIMA or SARIMA) models[1]. The methods to estimate a time-series model for the error terms associated with the $\ln q_t^r$ and $\ln p_t^r$ are described in section 4.1.1.

After an appropriate specification of the error structures for the dependent variables, the reduced-form equations and the demand equations can be estimated by incorporating the relevant exogenous variables.

The econometric model outlined in Section 3.1 suggests that there may be a simultaneity bias in the demand equation due to the impact of the health-risk information at the national level on national, and thus on the regional prices. The following section discusses how the demand equation will be estimated and how a possible simultaneity bias in the demand equation may be detected.

3.3.2 The Estimation Procedure for the Demand Equation and Methods to Detect Simultaneity Bias

When a regressor is contemporaneously correlated with the disturbance term, estimates are biased and inconsistent. For example, in the NYC region apple demand equation, the apple price variable may be correlated with the disturbance term. One way to deal with this problem is to find an instrument for the regressor. That is, a variable that is correlated with the regressor but not with the disturbance term. Good instrumental variables are hard to find, however. One method is to use the two-stage

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[1] George, G. Judge and others, The Theory and Practice of Econometrics, 2d ed., (New York: John Wiley and Sons, 1985), pp. 224-271.

least squares technique. The two-stage least squares technique is a special case of the instrumental variable method.[1]

The two-stage least squares method is based on the idea that the exogenous variables in the system of equation are good candidates for being instruments for the variable that is suspected to be correlated with the error term. In this study, this variable is the price variable. The problem is to find out which exogenous variable is the best instrument for the price variable. One suggestion is to regress the price variable on all the exogenous variables in the system and obtain the fitted values for the reduced form. These fitted values can then be used as an instrument for the price variable or they can be used in place of the price variables in the demand equation.[2]

Most econometric software packages can do the instrumental variable estimation and provide the coefficient estimates as well as the estimates of the asymptotic covariance matrix. This procedure can be done both in the linear and the nonlinear least squares context. However, in the presence of a multiplicative error component in the estimation procedure, it is currently not possible to find an econometric package that can do the instrumental variable estimation. An alternative method is to estimate the coefficient estimates for the demand model by applying the two-stage least squares procedure [3] and then calculate the asymptotic covariance matrix for the demand equation. The formula to calculate the asymptotic covariance matrix which is used to calculate the asymptotic covariance matrix for the demand equation with instrument for the price variable is derived in Appendix E.

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[1]Peter Kennedy, p. 134.

[2] William H. Greene, pp. 622-624.

[3]Applying the two stage least squares procedure means that the price variable is first regressed on all the exogenous variables in the system. From this first regression the fitted values of the price variable is obtained. These fitted values are then used as the price variable in a separate regression.

The presence of simultaneity bias in the demand equation may be detected with the specification test developed by Hausman.[1] Under the null hypothesis of no misspecification, there exists a consistent, asymptotically normal and efficient estimator. The alternative hypothesis is that the estimator will be biased and inconsistent.[2]

An alternative to the Hausman test for simultaneity bias in the regression estimate is to perform the regression based specification test.[3] This test is based on testing whether the estimated residuals from the equation with no instrumental variables are correlated with a particular linear combination of the exogenous variables in the system.[4]

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[1]J.A. Hausman, "Specification Tests in Econometrics," Econometrica 6 (46) (November 1978), pp. 1251-1271.

[2]Hausman test statistic: $(\beta_{iv}-\beta_{niv})(cov_{iv}-cov_{niv})^{-1}(\beta_{iv}-\beta_{niv})$, where, β_{iv} is the vector of coefficient estimates with instrumental variable, $\hat{\beta}_{niv}$ is the vector of coefficient estimates with no instrumental variable, cov_{iv} is the estimate of the covariance matrix with instrumental variable and cov_{niv} is the estimate of the covariance matrix with no instrumental variable. Under the null hypothesis, the Hausman test statistic is $\chi^2(k)$ distributed, where k denotes the number of unknown parameters.

[3]Jeffrey M. Wooldridge, "Score Diognastics for Linear Models Estimated by Two Stage Least Squares" (East Lansing: Michigan State University, Department of Economics, October 1992), pp. 20-21, photocopy.

[4]The regression based specification test: Let X_{1t} be the set of exogenous variables and X_{2t} be the variable that is suspected to be correlated with the error term (for example the price variable in the demand equation in this study). Let $\hat{u}_t$ be the residuals from the regression with no instruments for the X_{2t}. Let $\hat{X}_{2t}$ be the fitted values of the X_{2t} when it is regressed on the exogenous variables in the system. The regression based specification test is based on regressing $\hat{u}_t$ on X_{1t}, X_{2t}, and $\hat{X}_{2t}$ and test whether the coefficient estimate on $\hat{X}_{2t}$ is statistically different than zero. If it is zero, this implies that the estimator without the instrumental variable is not biased.

CHAPTER IV

THE ECONOMETRIC RESULTS

This chapter summarizes the econometric findings of the study. Section One starts with describing the methods to determine a stochastic model for the error term. This section then specifies a time-series model for the dependent variables in the demand equation and the reduced-form equations. These variables are per capita apple consumption and apple prices in the NYC region. After the time-series model of the dependent variable is specified, one must determine whether the apple price variable and the error term are correlated in the NYC apple demand equation. This step involves detecting the simultaneity bias in the demand equation. It is summarized in Section Two. Section Three and Section Four estimate the demand equation for the different specifications of the information variable and determine the information effect. Section Three outlines the econometric findings for the period of January 1980 through July 1989. This section starts with specification of a time-series model for the dependent variable in the demand equation for the January 1980-July 1989 period. The information variables are then incorporated into the demand equation. The truncated observation period allows us to compare the results with the ones from a nonseasonal specification for the error term that van Ravenswaay and Hoehn (1991) report. The observation period was then extended through July 1991. The results for this observation period are reported in Section Four. Section Five summarizes the findings for the information effect on quantity and price in the reduced-form equations. Section Six reports the estimates of the change in total apple sales associated with the risk information that are computed from the estimated demand models. Section Seven summarizes the estimates of the change in consumer surplus associated with the risk information ad derives consumer's willingness to pay to avoid health risks.

4.1 Specifying a Time-Series Model for the Quantity and the Price Variables

The time-series components for $\ln q_r^t$ and $\ln p_{qt}^r$ were specified using the Box-Jenkins approach. This approach involves three steps: identification, estimation and diagnostic checking. The following section describes the Box-Jenkins approach.

4.1.1 Methods for Determining a Stochastic Model for the Error Term

The time-series models offer a framework for predicting the values of a particular variable by observing its past values. This method does not depend on economic knowledge about the process through which the data is generated. The underlying assumption is that the data are generated by a stochastic process. The model that represents this process is defined and estimated by using statistical tools.

The Box-Jenkins approach is a method to construct a time-series model for a stochastic process that may have generated the observed data.[1] This method consists of three stages: identification, estimation, and diagnostic checking.

In the identification stage, a tentative time-series model is specified on the basis of autocorrelations and partial autocorrelations. The autocorrelations are the correlation coefficients between the value of the variable at time t and the value of the same variable lagged a number of periods. The partial autocorrelations show the correlation between the value of the variable at time t and the value of the same variable lagged a number of periods, when the previous lags are already accounted for in the

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[1]For a discussion of the time series models see, for example, George, G. Judge and others, The Theory and Practice of Econometrics, pp. 224-271.

model. If a seasonal model is adequate, it is also possible to make a tentative specification for a seasonal time-series model by observing the autocorrelations and the partial autocorrelations.

The nonseasonal component of the time series model is illustrated by the following model:

$$(4.1)\qquad (1-\phi_1 L^1-...-\phi_p L^p)(1-L)^d x_t=(1+\theta_1 L^1+...+\theta_q L^q)\xi_t$$

where,

$\phi_1,...,\phi_p$ = Parameters of the autoregressive (AR) process of order p,

$\theta_1,...,\theta_q$ = Parameters of the moving average (MA) process of order q,

L = Lag operator,

d = Number of differencing,

x_t = Value of the variable x at time t. In the context of the research, the variable x may be $\ln q_t^r$ or $\ln p_t^r$.

ξ_t = Error term at time t.

The error term, ξ_t in equation (4.1) may be correlated with the error terms for the same month across the years. The error term ξ_t in April, for example, may be correlated with the error terms in April in the previous years. Seasonality in the data series indicates a high degree of correlation between the values during the same season across years. In the presence of seasonality, multiplicative seasonal models can be used.[1] Suppose that this relationship can be explained by the following model:

$$(4.2)\qquad (1-\Phi_1 L^1-...-\Phi_P L^P)(1-L)^D \xi_t=(1+\Theta_1 L^1+...+\Theta_Q L^Q)\epsilon_t$$

where,

$\Phi_1,...,\Phi_P$ = Parameters of the seasonal autoregressive (AR(Seas)) process of order P,

[1]George E.P. Box and Gwilym M. Jenkins, Time Series Analysis Forecasting and Control (San Francisco: Holden Day, 1976), p. 303.

$\Theta_1,\ldots,\Theta_Q$ = Parameters of the seasonal moving average (MA(Seas)) process of order Q,

L = Lag operator,

D = Number of seasonal differencing,

ϵ_t = Stochastic error term at time t, where $\epsilon_t \sim N(0,\sigma^2)$.

Substituting equation (4.2) into equation (4.1) , the following multiplicative model is obtained.

$$(4.3)\quad \begin{aligned}(1-\phi_1L^1-\ldots-\phi_pL^p)(1-\Phi_1L^1-\ldots-\Phi_PL^P)(1-L)^D(1-L)^d\, x_t = \\ (1+\theta_1L^1+\ldots+\theta_qL^q)(1+\Theta_1L^1+\ldots+\Theta_QL^Q)\epsilon_t\end{aligned}$$

The model represented in equation (4.3) is a multiplicative seasonal integrated autoregressive moving average (ARIMA) model of order (p,d,q)x(P,D,Q)$_s$, where s is the number of periods that the series show periodic behavior. For example for a monthly data the basic time interval is one month and the period is s=12.

After a tentative ARIMA or multiplicative seasonal ARIMA model is specified and estimated, the model is tested for specification. A common method to test for specification in time-series models is to do a residual analysis. In the residual analysis, the estimated residual autocorrelations are examined. If the residuals of the estimated model are white noise, the residual autocorrelations should be within twice the approximate standard error bounds of the estimated autocorrelations, $\pm 2/\sqrt{T}$, where T is the sample size. The overall acceptability of the residual autocorrelations is tested by the portmanteau test statistic (Q-statistic).[1]

The following section presents the results from each stage of specification for the $\ln q_t^r$ and the $\ln p_{qt}^r$ series.

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[1] $Q = T(T+2)\sum_{k=1}^{K} \frac{1}{T-k} r_k$. Here, the r_k are the autocorrelations of the estimated residuals and K is some prespecified number (for example 1/5 of the total number of observations). The Q statistic is approximately χ^2-distributed with K-p-q degrees of freedom (see, George E. Judge and others, Introduction to the Theory and Practice of Econometrics, 2d ed., (New York: John Wiley and Sons, 1988), p. 705).

4.1.2 Identification

The autocorrelations and the partial autocorrelations of the series are the primary sources in identifying a time- series model. The autocorrelation function for both the $\ln q_t^r$ and the $\ln p_{qt}^r$ variables imply that there is seasonality in the series. The inspection of the autocorrelation functions for these two series suggests nonstationarity in the seasonal component of the series since the autocorrelations for the observations twelve months away do not die out. Both of the series were thus seasonally differenced.

After seasonally differencing, we observe the autocorrelation and the partial autocorrelation functions to identify the time-series model. As noted in 4.1.1, time-series models in the presence of seasonality can be modelled as multiplicative ARIMA models. This model involves a seasonal and a nonseasonal component for the error structure. The autocorrelation and the partial autocorrelation functions for the seasonally differenced $\ln q_t^r$ and $\ln p_{qt}^r$ suggest that the seasonal component of the series can be represented by a first-order seasonal moving average model. For the nonseasonal component, the autocorrelation and the partial autocorrelation functions for the seasonally differenced $\ln q_t^r$ series recommend a first-order moving average model. The same analysis for the seasonally differenced $\ln p_{qt}^r$ variable suggests a first-order autoregression in the series.

In summary, after the identification stage the $\ln q_t^r$ variable is represented by a seasonal multiplicative ARMA model of order $(0,0,1)x(0,1,1)_{12}$. The $\ln p_{qt}^r$ variable is represented by a seasonal multiplicative ARMA model of order $(1,0,0)x(0,1,1)_{12}$.

4.1.3 Estimation and Diagnostic Checking

After the time-series model is identified, one can estimate the coefficients of the model. The coefficients were estimated using the RATS econometric package (version

Table 4.1. Estimate of Seasonal ARMA models for Per Capita Apple Consumption and Retail Price of Apples in the NYC Region (January 1980-July 1989)

DEPENDENT VARIABLE	Δ_{12}ln (per capita apple consumption) (T=127)	Δ_{12}ln (retail apple price) (T=126)[a]
Constant	-0.035 (-3.201)*	-0.013 (-1.044)
MA	0.577 (7.834)*	
AR		0.856 (17.73)*
MA(Seas)	-0.771 (-11.618)*	-0.782 (-13.461)*
Q-Stat (lag=24)	23.402	15.043
Adj. R^2	0.590	0.713

(Figures in Parentheses are t-statistics.)
* Significant at the $\alpha \leq 0.01$ level
[a] Note that the "BOXJENK" command in RATS econometric package (version 3.1) for personal computers drops one observation when estimating a time-series model with an AR(1) error structure. Therefore the number of observations here is 126 instead of 127.
Δ_{12} : Seasonal difference operator
T : Number of observations
(The variables are defined in Table 4.12.)

3.1) for personal computers. The "BOXJENK" command in this econometric package uses the nonlinear least squares method to derive the coefficient estimates for the seasonal ARIMA model.[1] Table 4.1 reports the estimated time-series models for the $\ln q_t^r$ and the $\ln p_{qt}^r$ variables.

To check the overall acceptability of the models, the Q-statistics were examined. The Q-statistic for both models suggest that these specifications correctly represent the

[1]Note that the nonlinear least squares estimate is not the maximum likelihood since it involves the Jacobian term (Peter Kennedy, p. 344). In deriving the full maximum likelihood estimate it is necessary to take into account the stochastic nature of the vector of starting values. For this reason, ARIMA models that are estimated by the nonlinear least squares method are not the full maximum likelihood estimators but they are approximate maximum likelihood estimators.

time-series model for the $\ln q_t^r$ and the $\ln p_{qt}^r$ variables. The critical value for the $\chi^2(21)$ is equal to 29.62 at the $\alpha \leq 0.10$ level, where 21 is the degrees of freedom. This number is obtained by subtracting 3 from 24, where 24 is one fifth of the total number of observations and 3 is the number of the estimated seasonal ARMA coefficients (including the constant term). The Q-statistics for both models are lower than the critical value at the 10% significance level. Therefore, we must fail to reject the null hypothesis that there is no serial correlation between the error terms for these two specifications at the 1%, 5% and 10% significance levels.

Another check for the specification of the time-series model is to examine the autocorrelations of the residuals. The significance of the residual autocorrelations is compared with twice the approximate standard error of the estimated autocorrelations ($\pm 2/\sqrt{T}$), where T is the number of observations. If the estimated residual autocorrelations exceed $\pm 2/\sqrt{T}$, the model should be reestimated using a different specification for the error structure. The residual autocorrelations for both of the series suggested that the specifications are acceptable.

4.2 Checking for Simultaneity Bias in the Demand Equation

After the specification of the time-series model of the dependent variable in the demand equation, one must check for simultaneity bias in the demand equation from the correlation between the apple price variable and the disturbance term in the NYC retail apple demand equation.[1] The two methods that are discussed in Section 3 of Chapter III are used to test for simultaneity bias.

[1]For the source of the possible simultaneity bias in the demand equation and methods to detect the simultaneity bias, see the discussion in Chapter III.

To test for simultaneity bias, the Hausman test was used to compare the demand equation with the instrument for the price variable with the one without the instrument for the price variable. The first step was to find an instrument for the price variable.

An instrument for the price variable was created by regressing the price variable on all the exogenous variables in the system of equations. These exogenous variables are the regional price of bananas, the regional disposable income, the national apple storage holdings and the regional health-risk information.[1] The predicted values from this equation were then used as the price variable to estimate the demand equation in a separate regression.

Two demand equations were estimated. These are, the demand equation without an instrument for the price variable and the demand equation with an instrument for the price variable. Initially, the other exogenous variables in the demand equations were price of bananas, disposable income and risk information. The price of bananas and the income variables did not provide significant coefficient estimates. Therefore, these variables were excluded from the demand equation. The estimated demand equations are reported in Table 4.2. Note that the covariance matrix for the demand equation with an instrument for the price variable was calculated using the method outlined in Appendix E. The covariance matrix for the demand equation with no instrument for the price variable is the one reported in the regression output of the RATS econometric package (version 3.1).

The Hausman test statistic was found to be 0.310. The critical value from the χ^2 distribution with 5 degrees of freedom at the $\alpha \leq 0.10$ level is equal to 9.24. Since the Hausman statistic is lower than this critical value, we must fail to reject the null hypothesis that there is no simultaneity bias in the demand equation when the equation is estimated without an instrument for the price variable at the 1%, 5% and 10%

[1]The information variables that are used in the demand models when testing for simultaneity bias are the ones that are measured in the nominal scale (S_{1t}, S_{2t}, S_{3t}).

Table 4.2. Estimate of the Demand Equation With Seasonal ARMA Errors With and Without an Instrument for the Price Variable (January 1980-July 1991)[a]

MODEL	DEMAND[b] EQUATION WITH INSTRUMENT[c] FOR THE PRICE VARIABLE[d] (T=127)	DEMAND EQUATION WITH NO INSTRUMENT FOR THE PRICE VARIABLE[e] (T=127)
Constant	-0.021 (-0.761)	-0.031 (-1.419)
$\Delta_{12}\ln p_{qt}$	-1.200 (-1.820)**	-0.739 (-2.782)*
$\Delta_{12}S_{1t}$	-0.227 (-3.547)*	-1.199 (-1.678)**
$\Delta_{12}S_{2t}$	-0.396 (-3.883)*	-0.314 (-2.107)**
$\Delta_{12}S_{3t}$	-0.236 (-1.586)	-0.105 (-0.544)
MA	0.563 (4.541)*	0.548 (7.103)*
MA(Seas)	-0.765 (-10.241)*	-0.780 (-11.042)*
Adj. R^2	0.628	0.664
SSE	7.027	6.681
Q-Stat (lag=24)	23.165	27.441

(Figures in parentheses are t-statistics.)

* Significant at the $\alpha \leq 0.01$ level.

** Significant at the $\alpha \leq 0.05$ level.

[a] The dependent variable: $\Delta_{12} \ln q_t$.

[b] The significance levels for the coefficients on the $\ln p_{qt}$ and the information variables are from a one tail test and the other variables are from a two tail test.

[c] The instrument for the price variable was created by regressing $\ln p_{qt}$ on $\ln p_{yt}, \ln h_t, \ln m_t, S_{1t}, S_{2t}$ and S_{3t} to obtain the predicted values for $\ln p_{qt}$.

[d] The estimated standard errors for the demand equation with the instrument for the price variable are calculated by using the method outlined in Appendix E.

[e] The estimated standard errors for the demand equation with no instrument for the price variable are the ones reported in the output from the RATS econometric package (version 3.1) for personal computers.

Δ_{12} : Seasonal difference operator.

T: Number of observations.

(The variables are defined in Table 4.12.)

significance levels.

The regression-based test for the simultaneity bias also supports this finding.[1] When the estimated error terms from the demand equation without an instrument for the price variable is regressed on all of the exogenous variables in the demand equation including the price variable and the predicted values for the price variable from regressing price on all the exogenous variables in the system of equations, the t-statistic on the fitted values for the price variable was equal to 1.558. This implies that the estimate of the coefficient for the fitted values for the price variable is not statistically different than zero. We therefore conclude that when the demand equation is estimated without an instrument for the price variable, the residuals are not correlated with the price variable. This implies that there is no problem of simultaneity bias in the estimated demand equation when the observed values for the price variable are included.

4.3 The Information Effect on the NYC Region's Apple Demand for the January 1980-July 1989 Observation Period[2]

The time-series component of the $\ln q_t^r$ variable for the period of January 1980-July 1989 was specified using the Box-Jenkins approach as discussed in Section 4.1.1. The autocorrelation and the partial autocorrelation functions of the truncated sample also suggest seasonality; seasonal differencing is thus necessary. After seasonal differencing, the autocorrelations and the partial autocorrelations were reexamined. The time-series component of this variable was specified as a multiplicative seasonal ARMA model of order $(0,0,1)x(0,1,1)_{12}$.

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[1]For the description of the regression-based test for simultaneity bias, see Section 3.3.2.

[2]To maintain consistency in comparing results with the ones reported in van Ravenswaay and Hoehn (1991), the data used for the January 1980-July 1989 observation period is identical to the ones reported in Guyton (1990)

After specifying the time-series model of the dependent variable in the demand equation, the next step was to search for the impact of the explanatory variables on the per capita apple purchases by incorporating these variables into the demand equation. The information variables that are initially incorporated are identical to the ones that are reported in van Ravenswaay and Hoehn (1991). The same set of information variables from the previous study is used because we want to be able to compare the information effect on per capita apple purchases under two specifications for the error structure in the demand equation for the same observation period. One specification is the AR(1) specification that is reported in van Ravenswaay and Hoehn (1991). The other specification is the multiplicative seasonal ARMA specification. The only difference of this model from the one reported in van Ravenswaay and Hoehn (1991) is that the variable that measures the presence or the absence of the reported risk by the cumulative number of articles was excluded since this variable is non-stationary. After seasonally differencing the dependent and the independent variables to obtain stationarity in the series, the cumulative variable no longer measures the cumulative effect. Therefore, only the S_{1t}, NYT_t, NYT_{t-1}, NYT_{t-2} and NYT_{t-3} were incorporated to the model estimates. The results are reported in Table 4.3.

In Table 4.3, the unrestricted model represents the hypothesis that information on risk does not affect apple purchases and it embodies all of the information variables.[1] To test the hypothesis that the risk information did not have any effect on apple purchases, the unrestricted model was compared to the model that restricts the coefficients of the information variables to be zero. The likelihood ratio test was

[1]Note that to maintain consistency with the van Ravenswaay and Hoehn (1991) study, the information variables are S_{1t} and the current and three period lagged NYT_t variable. In this specification, S_{2t} was not included in the unrestricted model since this variable was not reported among the regression results in the study by van Ravenswaay and Hoehn (1991).

Table 4.3. Estimate[a] of the Demand Equation[b] with Seasonal ARMA Errors (January 1980-July 1989)[c]

	UNRESTRICTED MODEL (T=100)[d]	RESTRICTED MODEL (T=103)
Constant	-0.045 (-1.750)***	-0.071 (-5.179)*
$\Delta_{12}\ln p_{qt}$	-0.991 (-3.337)**	-0.967 (-3.250)*
$\Delta_{12}\ln p_{yt}$	-0.024 (-0.069)	-0.088 (-0.270)
$\Delta_{12}S_{1t}$	-0.143 (-1.059)	
$\Delta_{12}NYT_t$	-0.013 (-1.304)	
$\Delta_{12}NYT_{t-1}$	-0.018 (-1.705)**	
$\Delta_{12}NYT_{t-2}$	-0.0007 (0.064)	
$\Delta_{12}NYT_{t-3}$	-0.010 (-0.843)	
MA	0.658 (8.143)*	0.637* (7.928)
MA(Seas)	-0.836 (-11.365)*	-0.844 (-12.125)*
Adj. R^2	0.661	0.680
D-W	2.134	2.081
Q-Stat. (lag=20)	20.185	17.776
SSR	5.412	5.873

(Figures in Parentheses are t-statistics.)
* Significant at the $\alpha \leq 0.01$ level.
** Significant at the $\alpha \leq 0.05$ level.
*** Significant at the $\alpha \leq 0.10$ level.
[a]The demand equation was estimated without an instrument for the price variable.
[b]The dependent variable: $\Delta_{12}\ln q_t$.
[c]The significance levels for the coefficients of the $\ln p_{qt}$, $\ln p_{yt}$ and the information variables are from a one tail test and the other variables are from a two tail test.
[d] Note that T reduces to 100 from 103 when we include a three-period lagged value of the NYT_t variable.
Δ_{12} : Seasonal difference operator.
T : Number of observations. (The variables are defined in Table 4.12.)

employed to test this hypothesis.[1]

The likelihood ratio value was calculated by using the SSR^R, the SSR^U and the number of observations that are reported in Table 4.3. The likelihood ratio value was 8.17. The critical value in the χ^2 distribution table at the 5 degrees of freedom is 9.24 at the $\alpha \leq 0.10$ level. This implies that we fail to reject the null hypothesis at the 1%, 5% and 10% significance levels such that the restricted model is not superior when compared with the unrestricted model. This finding implies that the information variables do not add any additional explanatory power to the demand model at these significance levels.

In the above specification of the information variables, when the current and lagged values of the NYT_t variable were included in the demand equation as the only information variables, the estimates of the coefficients for the NYT_t and the NYT_{t-1} were significant while the estimates of the coefficients for the NYT_{t-2} and NYT_{t-3} were not significant. These two variables were therefore excluded from the unrestricted model. The inclusion of the retail price of bananas also fail to provide additional explanatory power to the equation estimates. This variable was thus also eliminated from the equation estimates. The demand model was respecified by using only the apple prices and the remaining information variables as the independent variables. The information variables are the variables that represent the second, third and fourth hypotheses (S_{1t}, NYT_t, NYT_{t-1} and S_{2t}) variable. The results are reported in table 4.4.

When the restricted model is compared to the unrestricted model, the likelihood ratio value was 7.92. The critical value at the 4 degrees of freedom is 7.78 at the $\alpha \leq 0.10$

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[1]The likelihood ratio value was obtained by using the following formula: $LR = T*[\ln(\frac{SSR^R}{SSR^U})]$, where the SSR^R is the sum of square residuals obtained from the restricted model, SSR^U is the sum of square residuals obtained from the unrestricted model. T is the number of observations. The likelihood ratio value is asymptotically distributed as $\chi^2(K)$ where K represents the number of restrictions. See, Jan Kmenta, Elements of Econometrics, 2d ed., (New York: Macmillan Publishing Co., 1986), p. 492.

Table 4.4. Estimate[a] of the Demand Equation[b] With Seasonal ARMA Errors (January 1980-July 1989)[c]

	UNRESTRICTED MODEL (T=102)[d]	RESTRICTED MODEL (T=103)
Constant	-0.043 (-1.779)***	-0.070 (-5.621)*
$\Delta_{12}\ln p_{qt}$	-0.965 (-3.301)*	-0.973 (-3.296)*
$\Delta_{12}S_{1t}$	-0.147 (-1.115)	
$\Delta_{12}S_{2t}$	0.010 (0.054)	
$\Delta_{12}NYT_t$	-0.012 (-1.301)	
$\Delta_{12}NYT_{t-1}$	-0.023 (-2.160)*	
MA	0.650 (8.180)*	0.638 (7.989)*
MA(Seas)	-0.840 (-11.767)*	-0.843 (-12.204)*
Adj.R^2	0.686	0.683
D-W	2.147	2.083
Q-Stat (lag=20)	23.247	17.948
SSE	5.438	5.877

(Figures in Parentheses are t-statistics.)
* Significant at the $\alpha \leq 0.01$ level.
** Significant at the $\alpha \leq 0.05$ level.
*** Significant at the $\alpha \leq 0.10$ level.
[a]The demand equation was estimated without an instrument for the price variable.
[b]The dependent variable: $\Delta_{12}\ln q_t$.
[c]The significance levels for the coefficients of the $\ln p_{qt}$ and the information variables are from a one tail test and the significance levels of all other coefficients are from a two tail test.
[d] Note that T reduces to 102 from 103 when we include a one-period lagged value of the NYT_t variable.
Δ_{12} : Seasonal difference operator.
T : Number of observations.
(The variables are defined in Table 4.12.)

level, 9.49 at the $\alpha \leq 0.05$ level and 13.28 at the $\alpha \leq 0.01$ level. The result suggest that we do not reject the null hypothesis that the information variables are all equal to zero at the 1% and 5% significance levels while we reject it at the 10% significance level. This implies that the unrestricted model in Table 4.4 is superior to the restricted model at the 10% significance level when the error structure is specified with the seasonal error structure.

The same hypothesis was tested in van Ravenswaay and Hoehn (1991) where the error structure was specified by an AR(1) process. The demand equations from the study by van Ravenswaay and Hoehn (1991) were replicated and are reported in Table 4.5.[1] When the restricted model is compared with the unrestricted model, the likelihood ratio value was found to be 15.32. The critical value from the χ^2 distribution at the 6 degrees of freedom is 10.64 at the $\alpha \leq 0.10$ level, 12.59 at the $\alpha \leq 0.05$ level and 16.81 at the $\alpha \leq 0.01$ level. The calculated likelihood ratio value is greater than the χ^2 values at the 5% and 10% levels. Therefore we conclude that we must reject the null hypothesis that the information variables are all equal to zero at the 5% and 10% significance levels while we fail to reject at the 1% significance level. This implies that the unrestricted model in Table 4.5 is superior to the restricted model at the 5% and 10% significance levels when the error structure is specified with an AR(1) model.

To test which specification of the error structure for the demand equation is correct, the Q-test was applied to the estimated demand equations under the two specifications (the AR(1) specification and the multiplicative seasonal specification). The null hypothesis is that there is no serial correlation between the error terms. When Model 1 in van Ravenswaay and Hoehn (1991) is duplicated, the Q-statistic was 36.92.

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[1]Note that the information variables in this model incorporates the information variables of the unrestricted model in Table 4.3 plus the variable that measures the cumulative number of articles on Alar. Also note that the data is identical to the data reported in Guyton (1990), i.e., the population figures covers a larger metropolitan area than the population figures used in this study.

Table 4.5. Estimate[a] of the Demand Equation[b] with AR(1) Errors (January 1980-July 1989)[c]

	UNRESTRICTED MODEL (T=111)[d]	RESTRICTED MODEL (T=114)
Constant	-0.631 (-1.614)*	-0.772 (-1.967)*
ln p_{qt}	-2.052 (-6.098)*	-1.957 (-5.650)*
ln p_{yt}	0.303 (0.758)	0.328 (0.852)
ln S_{1t}	-0.260 (-1.813)*	
$CNYT_t$	-0.003 (-0.459)	
NYT_t	-0.0005 (-0.040)	
NYT_{t-1}	-0.016 (-1.250)	
NYT_{t-2}	-0.009 (-0.613)	
NYT_{t-3}	-0.017 (-1.264)	
AR	0.587 (7.135)*	0.717 (10.479)*
Adj.R^2	0.619	0.598
D-W	1.702	1.753
Q-Stat (lag=20)	36.915	36.003
SSE	7.352	8.440

(Figures in Parentheses are t-statistics.)
* Significant at the $\alpha \leq 0.01$ level.
** Significant at the $\alpha \leq 0.05$ level.
[a]The demand equation was estimated without an instrument for the price variable.
[b]The dependent variable: $\ln p_t$.
[c]The significance levels for the coefficients of the $\ln p_{qt}$, $\ln p_{yt}$ and the information variables are from a one tail test and the significance levels of all other coefficients are from a two tail test.
[d]Note that T reduces to 111 from 114 when we include a three-period lagged value of the NYT_t variable.
T : Number of observations. (The variables are defined in Table 4.12.)

This value is compared with the $\chi^2(19)$, where 19 is the degrees of freedom. This value is obtained by subtracting 1 from 20. 20 is one fifth of the total observations and 1 is the number of ARMA coefficients in the specification. The critical value from the χ^2 table at the 19 degrees of freedom is 27.20 at the $\alpha \leq 0.10$ level, 30.14 at the $\alpha \leq 0.05$ level and 36.19 at the $\alpha \leq 0.01$ level. This implies that we reject the null hypothesis that there is no serial correlation at the 1%, 5% and 10% significance levels and the error structure is misspecified with the AR(1) specification.

The Q-statistics for the demand models with the seasonal error structure are reported in Table 4.3 and 4.4. These values are compared with the $\chi^2(17)$, where 17 is obtained by subtracting 3 from 20. 20 is one fifth of the total observations and 3 is the number of the estimated seasonal ARMA coefficients (including the constant term). The critical value from the χ^2 table at the 17 degrees of freedom is 24.77 at the $\alpha \leq 0.10$ level, 27.59 at the $\alpha \leq 0.05$ level and 33.41 $\alpha \leq 0.01$ level. This means that we do not reject the null hypothesis that there is no serial correlation at the 1%, 5% and 10% significance levels. This result suggests that when compared to the AR(1) model, the multiplicative seasonal model is the correct specification for the error structure at the 1%, 5% and 10% significance levels.

The results imply that when the seasonal error structure is employed to estimate the demand function over the observation period of January 1980 to July 1989, the information variables do not add any explanatory power to the equation estimate at the 1% and 5% significance levels while they are all significant at the 10% significance level. The Q-Statistics imply that the seasonal ARMA specification is the correct specification for the demand equation when compared to the AR(1) specification. However, the information variables are significant only at the 10% level with the seasonal ARMA specification while they are significant at the 5% level with the AR(1) specification . Since with the seasonal ARMA specification we are able to reject the null hypothesis that the coefficient estimates of the information variables are all equal to zero only at a higher significance level (10%), it is ambiguous that the Alar incident had any impact on apple demand in the NYC region at all.

In order to find out whether the information about Alar had any impact on apple purchases, the next step is to extend the observation period to see if additional observations would make any difference in the equation estimates. This means that we add 24 more observations to the sample. The following subsection summarizes the findings for the extended observation period.

4.4 The Information Effect on the NYC Region's Apple Demand for the January 1980-July 1991 Observation Period[1]

The hypotheses about the effect of risk information on apple purchases were tested by estimating the demand model for the extended time period. The results are reported in Table 4.6. The numbers 1-6 in Table 4.6 indicates the models that embody the hypotheses on modelling the risk information effect presented in 2.3.

To test whether the information on Alar had any impact on apple purchases, the unrestricted model (model 1) was compared to the restricted model (model 6) with a likelihood ratio test. The likelihood ratio was 13.98. The critical value at the 5 degrees of freedom is 9.24 at the $\alpha \leq 0.10$ level, 11.07 at the $\alpha \leq 0.05$ level and 15.09 at the $\alpha \leq 0.01$ level. Therefore, the null hypothesis that the restricted model is superior to the unrestricted model was rejected at the 5% and 10% significance levels but not rejected at the 1% significance level. This result implies that there is evidence that all of the information variables are different than zero for the extended observation period since they all are different than zero at the 5% and 10% significance levels.

[1]The data used to estimate the models for the January 1980-July 1991 observation period are the ones described in Appendix A and reported in Appendix B and C.

Table 4.6. **Estimate[a] of the Demand Equation[b] with Seasonal ARMA Errors Under Different Specifications for the Information Variable (January 1980-July 1991)[c]**

MODEL	1(T=126)[d]	2(T=127)	3(T=127)	4(T=126)	5(T=127)	6(T=127)
Constant	-0.031 (-1.391)	-0.041 (-3.385)*	-0.050 (-4.115)*	-0.043 (-3.445)*	-0.031 (-1.419)	-0.054 (-4.563)*
$\Delta_{12}\ln p_{q}$	-0.775 (-2.931)*	-0.693 (-2.587)*	-0.915 (-3.525)*	-0.780 (-2.966)*	-0.739 (-2.782)*	-0.889 (-3.303)*
$\Delta_{12}S_{1t}$	-0.184 (-1.536)	-0.175* (-2.753)		-0.125 (1.877)**	-0.199** (-1.678)	
$\Delta_{12}S_{2t}$	-0.032 (-0.142)				-0.314 (2.107)**	
$\Delta_{12}S_{3t}$	-0.118 (-0.601)				-0.105 (-0.544)	
$\Delta_{12}NYT_{t}$	-0.012 (-1.039)		-0.016** (-1.696)	-0.013 (-1.317)		
$\Delta_{12}NYT_{t-1}$	-0.025 (1.657)**		-0.030 (-3.205)*	-0.025 (2.551)**		
MA	0.565 (7.331)*	0.558 (7.385)*	0.590 (7.922)*	0.569 (7.481)*	0.548 (7.103)*	0.585 (7.934)*
MA (Seas)	-0.760 (-10.376)*	-0.784 (-11.368)*	-0.763 (-10.372)*	-0.762 (-10.525)*	-0.780 (-11.042)*	-0.792 (-11.472)*
Adj.R^2	0.660	0.640	0.634	0.641	0.664	0.631
SSR	6.581	6.928	6.794	6.602	6.681	7.353
Q-Stat (lag=24)	23.830	25.366	21.061	23.720	27.441	23.93

Table 4.6. (Cont'd)

(Figures in Parentheses are t-statistics.)

* Significant at the $\alpha \leq 0.01$ level.

** Significant at the $\alpha \leq 0.05$ level.

[a] The demand equation was estimated without an instrument for the price variable.

[b] The dependent variable: $\Delta_{12} \ln q_t$.

[c] The significance levels for the coefficients of the $\ln p_{qt}$ and the information variables are from a one tail test and the other information variables are from a two tail test.

[d] Note that T reduces to 126 from 127 when we include a one-period lagged value of the NYT_t variable.

Δ_{12}: Seasonal difference operator.

T: Number of observations.

(The variables are defined in Table 4.12.)

Since we fail to reject the first hypothesis that there is no impact of risk information on purchases and since we do not know what the appropriate specification for the information effect is, the hypotheses that are outlined in Section 2.3 for the alternative specifications of the information effect were tested.

The second hypothesis that the consumers do not forget the risk information available to them is embodied in model 2. The estimate for the coefficient on the information variable in this model suggest that we fail to reject the hypothesis meaning that the information about risk is not forgotten until the announcement is made that the source of risk is eliminated from the market. The reason that this hypothesis is not rejected is that the estimate of the coefficient on the S_{1t} variable is significant which implies that there is a one time and a sustained demand shift associated with the initial announcement on the presence of the risk.

The third hypothesis is that the intensity of the reporting on the presence or absence of risk intensifies consumer's risk perception and thus causes a downward shift in individual apple demand. Model 3 incorporates the information variables that represent this hypothesis. Following the discussion in Section 2.3, note that we cannot test this hypothesis with model 3 since the period during which there was intense media coverage on the presence of risk involves February 1989, the month when the revised risk estimates were released. We cannot distinguish the effect of the intensity of the media coverage that is measured by the current and the lagged values of the NYT_t variable from the effect of the variable that measures the presence or absence of the revised risk estimates (S_{2t}) since these variables are highly correlated. The correlation coefficient between S_{2t} and NYT_t is 0.76 and NYT_{t-1} is 0.77.

Models 4 and 5 incorporate the variables that represent the fourth hypothesis. The coefficients on S_{1t} in both models 4 and 5 are significant indicating that there is a one time and a sustained shift in demand with the initial health-risk information in July 1984. The lagged value of the NYT_t variable is negative and significant in model 4. The

S_{2t} variable is negative and significant in model 5. The significance of the coefficients of NYT_{t-1} and S_{2t} suggests that the consumers continuously revise their risk perceptions when they receive additional information on health-risk.

The fifth question is whether there is a long-run effect of the Alar controversy. Model 5 incorporates the S_{3t} variable that measures the presence or the absence of Alar in the market. If the hypothesis that the sales return to the pre-announcement levels is correct, then the coefficient on the S_{3t} should be insignificant while the coefficient estimates on S_{1t} and S_{2t} will be negative and significant. The results suggest that this hypothesis is true.

4.5 The Information Effect on Quantity and Price in the Reduced-Form Equations

After the information effect in the demand equation is specified, the next step is to examine the information effect in the reduced-form equations for quantity and price. As noted in Sections 3.2 and 3.3, by looking at the coefficient estimates of the information variables in the reduced-form equations for quantity and price, we can understand the effect of the health-risk information on the equilibrium price and quantity levels at the NYC region. This section reports the findings on the information effect from the reduced-form equations for quantity and price.

As the Hausman test and the regression-based specification test suggest in Section 2 of this Chapter, the simultaneity bias is rejected in the estimated demand equation. This implies that the price variable in the demand equation is not correlated with the error term in this equation. Therefore, if there is a change in per capita apple purchases in the NYC region because of the health-risk information, it is associated only with the demand shift in that region and not with the change in national price due to the information at the national level. The results from the estimated reduced-form equations are also consistent with this finding.

Table 4.7 and Table 4.8 report the results from the estimated reduced-form equation for quantity and price, respectively. The numbers 1-6 in Tables 4.7 and 4.8 indicate the models that embody the hypotheses presented in Section 2.3. The results are used to discuss the hypotheses on the information coefficients in the reduced-form equations and in the demand equation. The hypotheses on the effect of information on the reduced-form equations and on the demand equation are outlined in Section 3.2.4.

The first hypothesis is that there is no effect of health-risk information on apple purchases in the NYC region. If this hypothesis is true, then the coefficient estimates of the information variables in the reduced-form equations for price and quantity and the demand equation should all be zero, i.e, $\hat{\gamma}^r=0$, $\hat{\alpha}^r=0$ and $\beta_4^r=0$. This hypothesis is rejected since in the sections above, we already concluded that risk information is a significant variable in the demand equation.

The second hypothesis is that the change in apple sales is associated only with the change in apple prices in the national market induced by risk information. If this hypothesis is true, then the coefficient estimate for the information variable in the reduced-form equation for price should be greater than zero, i.e., $\hat{\alpha}^r>0$ and the coefficient estimate for the information variable in the demand equation should be insignificant, i.e., $\beta_4^r=0$. This hypothesis is rejected since the estimated coefficients for all of the information variables in the reduced-form equation for price are statistically equal to zero since the likelihood ratio value that compares model 1 (unrestricted model) to model 6 (restricted model) in Table 4.8 is 2.98. The critical value at the 5 degrees of freedom is 9.24 at the $\alpha\leq0.10$ level, 11.07 at the $\alpha\leq0.05$ level and 15.09 at the $\alpha\leq0.01$ level. Since 2.98 is smaller than these critical values, we conclude that the information variables are statistically not different than zero. Furthermore, we already concluded in Section 4.4 that the coefficient estimates for the information variables in

Table 4.7. Estimate of the Reduced-Form Equation[a] for Per Capita Apple Purchases with Seasonal ARMA Errors[b]

MODEL	1(T=126)[c]	2(T=127)	3(T=127)	4(T=126)	5(T=127)	6(T=127)
Constant	-0.024 (-0.908)	-0.033 (-2.594)*	-0.032 (-2.301)**	-0.032 (-2.376)**	-0.026 (-1.028)	-0.033 (-2.449)*
$\Delta_{12}\ln p_{yt}$	-0.377 (-1.249)	-0.479 (-1.632)***	-0.278 (-1.010)	-0.396 (-1.346)	-0.392 (-1.301)	-0.278 (-0.974)
$\Delta_{12}\ln m_t$	-0.393 (-0.473)	0.264 (0.333)	-1.237 (-1.946)***	-0.320 (-0.404)	0.021 (0.025)	-1.225 (1.915)***
$\Delta_{12}\ h_t$	0.213 (1.181)	0.111 (0.628)	0.284 (1.661)***	0.222 (1.267)	0.165 (0.907)	0.198 (1.095)
$\Delta_{12}\ S_{1t}$	-0.201 (-1.539)	-0.259 (-3.064)*		-0.169 (-1.876)**	-0.236 (-1.848)**	
$\Delta_{12}\ S_{2t}$	-0.016 (-0.067)				-0.252 (-1.559)***	
$\Delta_{12}\ S_{3t}$	-0.075 (-0.340)				-0.049 (-0.229)	
$\Delta_{12}\ NYT_t$	-0.010 (-0.854)		-0.014 (-1.413)***	-0.010 (-1.030)		
$\Delta_{12}\ NYT_{t-1}$	-0.023 (-1.480)***		-0.029 (-2.983)*	-0.023 (-2.213)**		
MA	0.616 (7.783)*	0.568 (7.230)*	0.672 (9.391)*	0.617 (7.866)*	0.577 (7.319)*	0.628 (8.667)*
MA(Seas)	-0.742 (-10.259)*	-0.766 (-11.146)*	-0.749 (-10.650)*	-0.741 (-10.369)*	-0.763 (-10.875)*	-0.767 (-11.365)*
Adj.R^2	0.643	0.623	0.632	0.618	0.625	0.598
SSR	6.912	7.136	7.114	6.918	6.985	7.675
Q-Stat.	22.925	22.641	20.283	22.611	24.238	19.481

"Table 4.7. (Cont'd)"

(Figures in parentheses are t-statistics.)
* Significant at the $\alpha \leq 0.01$ level.
** Significant at the $\alpha \leq 0.05$ level.
*** Significant at the $\alpha \leq 0.10$ level.
[a] The dependent variable: Δ_{12} $\ln q_t$.
[b] The significance levels for the coefficients of the information variables are from a one tail test and the significance levels of all other coefficients are from a two tail test.
[c] Note that T reduces to 126 from 127 when we include a one-period lagged value of the NYT_t variable. Δ_{12} : Seasonal difference operator.
T: Number of observations.
(The variables are defined in Table 4.12.)

Table 4.8. Estimate of the Reduced-Form Equation[a] for Retail Apple Price with Seasonal AR MA Errors[b]

MODEL	1(T=126)[c]	2(T=127)	3(T=127)	4(T=126)	5(T=127)	6(T=127)
Constant	0.0003 (0.018)	-0.015 (-1.305)	-0.013 (-1.077)	-0.014 (-1.127)	-0.003 (-0.180)	-0.015 (-1.254)
$\Delta_{12}\ln p_{yt}$	0.002 (0.027)	0.011 (0.150)	-0.0008 (-1.011)	-0.0005 (-0.007)	0.011 (0.141)	0.012 (0.158)
$\Delta_{12}\ln m_t$	0.271 (1.185)	0.320 (1.460)	0.292 (1.304)	0.284 (1.254)	0.314 (1.418)	0.329 (1.514)
$\Delta_{12}\ h_t$	-0.065 (-1.220)	-0.052 (-1.034)	-0.050 (-0.970)	-0.050 (-0.980)	-0.066 (-1.269)	-0.051 (-1.016)
$\Delta_{12}\ S_{1t}$	0.483 (0.816)	0.012 (0.320)		0.012 (0.285)	-0.047 (-0.804)	
$\Delta_{12}\ S_{2t}$	-0.006 (-0.090)				-0.004 (-0.073)	
$\Delta_{12}\ S_{3t}$	-0.136 (-1.275)				-0.121 (-1.167)	
$\Delta_{12}\ NYT_t$	0.0004 (0.139)		0.001 (-0.408)	0.010 (0.342)		
$\Delta_{12}\ NYT_{t-1}$	-0.001 (-0.288)		0.001 (0.241)	0.0004 (0.127)		
AR	0.848 (16.608)*	0.843 (16.270)*	0.846 (16.480)*	0.843 (16.104)*	0.851 (16.834)*	0.846 (16.659)*
MA(Seas)	-0.767 (-12.153)*	-0.773 (-12.796)*	-0.771 (-12.542)*	-0.771 (-12.475)*	-0.768 (-12.406)*	-0.774 (-12.896)*
Adj.R^2	0.705	0.709	0.708	0.705	0.708	0.711
SSR	0.459	0.470	0.467	0.466	0.463	0.470
Q-Stat.	17.511	15.032	16.691	16.882	15.429	14.979

Table 4.8. (Cont'd)

(Figures in parentheses are t-statistics.)
* Significant at the $\alpha \leq 0.01$ level.
[a] The dependent variable: Δ_{12} $\ln p_{qt}$.
[b] The significance levels for the coefficients of the information variables are from a one tail test and the significance levels of all other coefficients are from a two tail test.
[c] Note that T reduces to 126 from 127 when we include a one-period lagged value of the NYT_t variable.
Δ_{12} : Seasonal difference operator.
T: Number of observations.
(The variables are defined in Table 4.12.)

the demand equation are all negative and significant.

We also reject the third hypothesis that the effect on sales is due to both to a national price change and to a regional demand shift. This is justified by the finding from the second hypothesis that price is not affected by the health-risk information.

Models 4 and 5 in Table 4.8 indicate that the retail price of apples in the NYC region was not affected with the initial announcement of the health risk in July 1984. The presence or absence of this risk is measured by S_{1t}. The coefficient estimate of this variable is statistically equal to zero. The retail price remained unaffected with the series of events after February 1989. The added effect after this date is represented by the S_{2t} and/or the current and the lagged values of the NYT_t variable.[1]The estimated coefficients in models 4 and 5 show that both the initial announcement and the subsequent announcements on health risk did not cause any effect on the equilibrium, price level at the NYC region.

After rejecting the first three hypotheses we conclude that the we do not reject the fourth hypothesis which states that the impact on quantity purchased in the NYC region is due only to the demand shift at the regional level. This hypothesis also implies that there is no change in the retail apple price at the NYC region associated with the risk information. This hypothesis suggests that $\delta^r = 0$, $\gamma^r < 0$ and $\beta_4^r < 0$. We do not reject this hypothesis because the estimates of the coefficients of all the information variables in the reduced-form equation for price are not significant while they are significant in the reduced-form equation for quantity, i.e., $\delta^r = 0$ and $\gamma^r < 0$. The likelihood ratio value that compares model 1 (unrestricted model) to model 6 (restricted model) in Table 4.7 is equal to 13.19. The critical value at the 5 degrees of freedom is 9.24 at the $\alpha \leq 0.10$ level, 11.07 at the $\alpha \leq 0.05$ level and 15.09 at the $\alpha \leq 0.01$ level.Since this value is greater than the critical value at the 5% and 10% significance levels we conclude

[1]For the definitions of the information variables, see Section 2.2 and Table 4.12.

that the coefficient estimates of all of the information variables in the reduced-form equation for quantity are significant. In addition to this finding, we already noted in Section 4.4 that the coefficient estimates for the information variables in the demand equation are all negative and significant, i.e., $\beta_4^r < 0$.

In summary, the findings from the reduced-form equations imply that there is no evidence of a price change at the NYC region associated with the risk information. The findings from the reduced-form equations imply that there is a drop in the equilibrium level of per capita purchases in the NYC region and this drop is due only to a demand shift in the NYC region. As outlined in Section 3.1, there are several interpretations which might explain why the price at the NYC region did not change. One reason may be that wholesale prices dropped as a result of a downward shift in wholesale apple demand, but retailers did not adjust apple prices at the retail level. Still another reason may be that there was a commensurate supply shift at the retail apple market such that the retail apple prices remained unaffected. Note that in this research we cannot test which of the above interpretations is true. The findings from the reduced-form equations only tell us that the retail price at the NYC region remained unaffected by the Alar incident. Further research on the effect of the Alar incident at the national market is needed to understand the reason why the regional retail price remained unchanged. We also need additional research to examine the impact of the Alar incident in other regions across the nation. When we examine the other regions, however, we should consider the possibility that the change in the equilibrium quantity in those regions may be associated with both a change in retail price and a downward demand shift at the regional level. In other words, we cannot generalize the result obtained from the NYC region that the retail price was unaffected in the other regions across the nation.

4.6 Estimating the Change in Revenue to the NYC Region Fresh Apple Retailers

The estimates of the demand equation under alternative specifications of the information variable reported in section 4.4 can be used to estimate the total change in retail apple sales in the NYC region associated with the risk information during the January 1980-July 1989 period. This gives an estimate of the revenue loss to the retailers of fresh apples in the NYC region. The estimate of the revenue loss is the difference between the estimated actual sales and the projected sales that would have occurred had the Alar incident never occurred[1]. The mathematical derivation to calculate the estimated actual sales, the estimate of sales without the risk effect and the estimate of the lost revenue is presented in Appendix F.

The estimates for the actual sales and the projected sales without the Alar controversy were calculated for models 4 and 5 reported in Table 4.5.[2] These two models represent the hypothesis that there is a one time, sustained demand shift associated with the initial health-risk information. The consumer continuously updates his/her health-risk perception as he/she receives additional information on health risk. Figures 4.1 and 4.2 show the projected sales without the Alar incident and the estimated actual sales that are calculated using models 4 and 5.

The area under the curve that represents the projected sales without the risk information is the total projected sales without the Alar incident. The area under the curve that represents the estimated actual sales is the total estimated sales with the Alar

[1]In estimating the change in sales, estimated actual sales rather than the observed values of the sales were used. The reason to use this approach is to minimize the errors is sales loss estimates (see, Mark Smith and others, 1988; Eileen van Ravenswaay and John Hoehn, 1991).

[2]Since the coefficient estimate of the S_{3t} variable was not significant, model 5 was reestimated without the S_{3t} when making the sales projections.

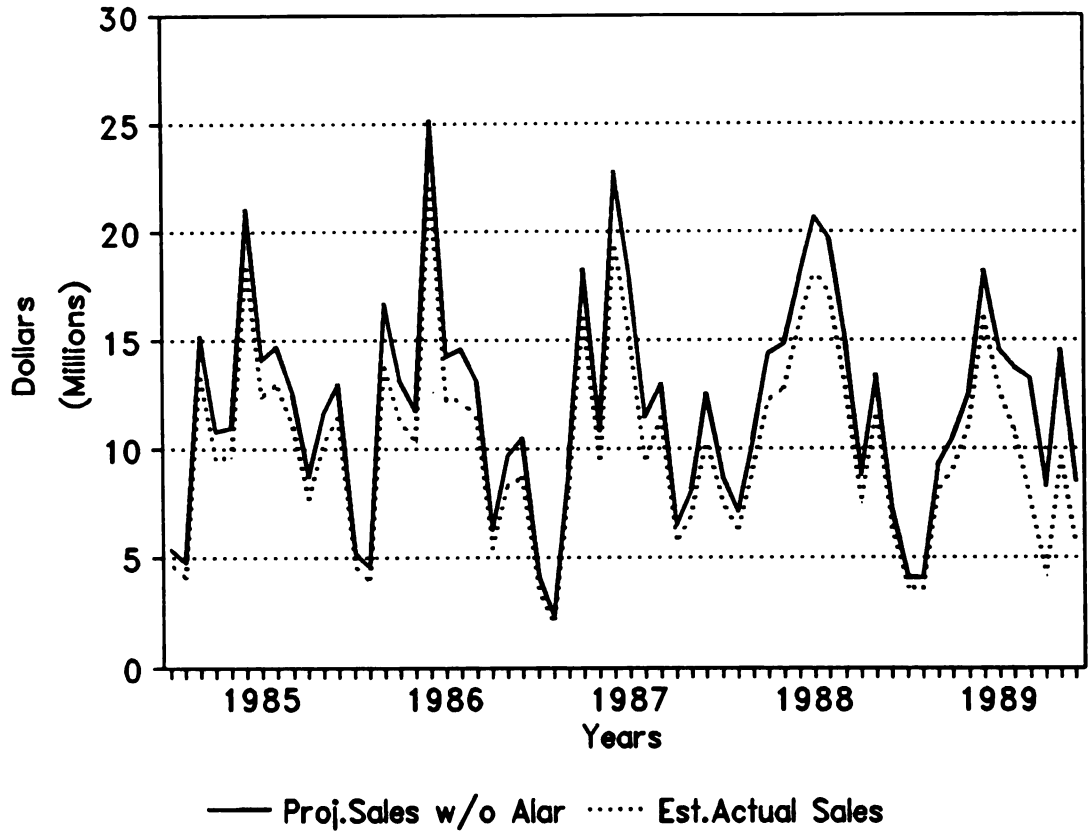

Figure 4.1. Estimates of the Apple Sales in the New York Region With and Without the Risk Information (Model 4)

incident. The area between these two curves gives an estimate of the lost revenue to the retailers due to the Alar controversy between the period of July 1984 to June 1989. These estimates are reported in Table 4.9.

The results indicate that the Alar incident caused a sales loss of approximately 15% during the July 1984 to June 1989 period. The majority of this sales loss is attributable to the initial announcement on the presence of the risk that is represented by the dummy variable, S_{1t}. According to both of the models, the share of the events in and after February 1989 was relatively small in total revenue loss. In other words, the sales declined around %12 after the initial risk announcement by the EPA an the revenue loss increased as much as to 15% following February 1989. Consistent with the study by van Ravenswaay and Hoehn (1991), the results suggest that the events in and

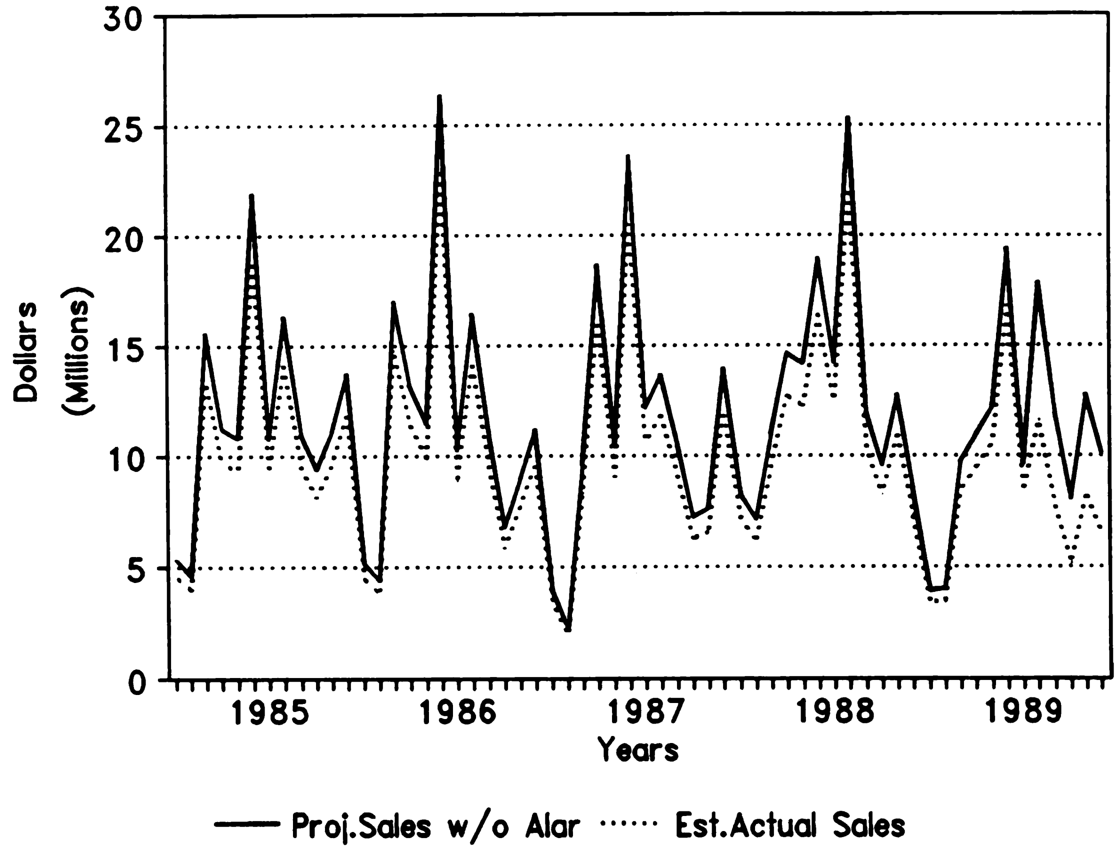

Figure 4.2. Estimates of the Apple Sales in the New York Region With and Without the Risk Information (Model 5)

after February 1989 accounts for a relatively small portion in the total sales loss. Note that we do not know the real reason for the additional shift in demand in February 1989. It can be the intense media coverage on the presence of the risk in and after February 1989 or it can be the release of the revised risk estimates made by the EPA and the NRDC in February 1989.

4.7 Estimating the Change in Consumer Surplus Associated With the Risk Information

The estimates of the change in consumer surplus associated with the risk information can be calculated using the estimated demand curves. The mathematical derivation of

Table 4.9. Estimates of Total Apple Sales in the New York Region With and Without the Effect of Alar for the July 1984-June 1989 Period (1983 Dollars)

REVENUE ESTIMATES	MODEL 4	MODEL 5
1. Projected sales without the risk Information	$ 716,816,422	$ 715,139,655
2. Actual estimated sales	$ 610,549,321	$ 606,971,036
3. Change in sales = (1-2)	$ 106,267,321	$ 108,168,618
4. % Change in sales = (3/1)*100	% 14.8	% 15.1
5. Change in sales due to S_{1t}	$ 84,228,150	$ 88,343,595
6. Share of S_{1t} in total change in sales =(5/3)*100	% 79.3	% 81.7
7. Change in sales in July 1984-January 1989 period	$ 87,713,103	$ 94,676,810
8. Share of July 1984-January 1989 period in total change in sales=(7/3)*100	% 82.54	% 87.53
9. % Change in sales in July 1984-January 1989 period=(7/1)*100	% 12.24	% 13.24

the expected value of the consumer surplus with and without the risk information is presented in Appendix G. In order to calculate the expected value of the consumer surplus from an estimated log-linear demand curve, the price elasticity of demand should be greater than one. Otherwise, the value of the consumer surplus and thus its expected value approaches infinity (see Appendix G). The previous research does not reach a consensus as to the "correct" estimate for the price elasticity of demand for fresh apples at the retail level. It is reported, however, that the demand for apples at the retail level is price elastic both for the studies using annual data and for intraseasonal demand studies.[1]

The estimated demand curves in this study suggest that apple demand is inelastic at the retail level. This result should be interpreted with caution because of the highly seasonal apple demand and apple price. The observation period covers only 11 years. When the price and quantity variations due to seasonality are taken into account during this time period, there is very little variation left in the price and quantity variations. It is then difficult to estimate a reliable price elasticity. This may explain why the price elasticity estimates reported in this study are so low.

Since it is not possible to use the estimated price elasticities from this study to estimate the consumer surplus, the next best alternative is to use the range of own-price elasticity estimates from other studies. The studies that use monthly data have estimated the retail level own-price apple demand elasticities to be between -1.3 and -4.6[2]. Several values from this range of elasticities were used to calculate the expected value of the change in consumer surplus. The estimates from model 4 and model 5 are virtually identical. Therefore, the results from model 4 are reported in Table 4.9. The annual change in consumer surplus associated with the information on the presence of the risk due to Alar can be interpreted as the consumer's annual willingness to pay to avoid health risks due to consuming apples that are treated with Alar.[3] Following van Ravenswaay and Hoehn (1991), dividing annual willingness to pay to avoid health risks due to Alar by the individual's perceived risk of experiencing the health-problem gives an

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[1]Harry S. Baumes, Jr. and Roger K. Conway, An Econometric Model of the U.S. Apple Market ERS Staff Report No. AGES850110, 1985 (Washington, D.C.: Economic Research Service, U.S. Department of Agriculture).

[2]See, for example, Henry S. Baumes and Roger K. Conway, 1985; Dana G. Dalymple, "Economic Aspects of Apple Marketing in the United States" (Ph.D. diss., Michigan State University, 1962).

[3]See the discussion on section 4 of Chapter II.

Table 4.10. The Expected Value of the Annual Change in Consumer Surplus Under Alternative Elasticity Estimates (1983 Dollars)

Elasticity	-1.2	-1.4	-1.6	-1.8	-2.0	-2.2
1984[1]	2.68	1.35	0.90	0.68	0.55	0.46
1985	6.17	3.11	2.09	1.58	1.27	1.07
1986	7.15	3.49	2.27	1.67	1.30	1.06
1987	6.84	3.41	2.26	1.69	1.35	1.12
1988	5.85	2.95	1.98	1.50	1.20	1.10
1989[2]	9.40	4.75	3.21	2.43	1.97	1.66

[1] The estimates for the change in consumer surplus represents only the last six months of 1984. The implied change in consumer surplus for this year under the alternative price elasticities are: $5.35 ,$2.69, $1.81, $1.37, $1.13 and $0.92 for own price elasticities of -1.2, -1.4, -1.6. -1.8, -2.0 and -2.2, respectively.

[2] The estimates for the change in consumer surplus represents only the first six months in 1989. The implied change in consumer surplus for this year under the alternative price elasticities are: $18.81, $9.51, $6.41, $4.86, $3.94 and $3.32 for own price elasticities of -1.2, -1.4, -1.6, -1.8, -2.0 and -2.2, respectively.

estimate of the marginal willingness to pay for risk reduction. Since the individual's risk perceptions associated with the consumption of apples that are treated with Alar are not known, the next best alternative is to assume that the individuals believe that the risks are similar to the ones reported in the media. Therefore, these risk levels will be used to estimate the marginal willingness to pay for risk reduction. van Ravenswaay and Hoehn (1991) use a similar approach and employ several alternative assumptions for the risk perception of the consumer.[1] Table 4.11 summarizes the individual's implicit willingness to pay to avoid annual cancer deaths that are calculated by using Model 4. This table replicates the estimates of the implicit willingness to pay that are reported in van Ravenswaay and Hoehn (1991). There are two major differences, however. The first difference is that the demand functions in this study are estimated by using a seasonal error structure, rather than an AR(1) specification. The second is that several own price elasticities were used since a reliable elasticity estimate could not be obtained.

The implicit willingness to pay to avoid a one in one million risk of cancer death can be compared with the willingness to pay to save a statistical life. The results in Table 4.11 suggest that for a higher range of own price elasticity estimates, the willingness to pay to avoid cancer deaths are very close to the range that are reported in the value of life studies.[2] This result is consistent with the findings by van Ravenswaay and Hoehn (1991). It implies that the consumers react to risks associated with the consumption of Alar-treated apples consistent with their behavior toward other health-risks, assuming the own price elasticity of apples at the retail level is high and/or that consumer's risk perceptions were similar to the EPA's initial risk estimate and the risk estimate by the NRDC.

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[1]The derivation of the annual risk estimates from consuming Alar treated apples are explained in van Ravenswaay and Hoehn (1991). The authors use a linear dose-response model such that the lifetime risk increase linearly and can be annualized dividing by individual's life expectancy (e.g., 70 years). It is also reported in van Ravenswaay and Hoehn (1991) that approximately 17% of the risk from Alar in all food sources is due to the consumption of fresh apples. Therefore, the reported health risk is multiplied by 0.17 to obtain the health risk associated with the consumption of apples treated with Alar. The authors note that the value of life studies are based on assumptions about perceived mortality risks. The assumptions about perceived risk here are based on risks of getting cancer. The NYT initially reported the risks as cancer death risks but it is not known whether the subsequent cancer risk estimates are equated with mortality risks. Therefore, the implicit willingness to pay estimates for reduced death in this study should be treated as rough indicators.

[2]The willingness to pay to save a statistical life is approximately $1.44 to $7.64 in 1983 Dollars. See van Ravenswaay and Hoehn, 1991; A. Fisher and others, "The Value of Reducing Risks of Death: A Note on New Evidence," Journal of Policy Analysis and Management 8(1989), pp. 88-100.

Table 4.11. The Implicit Willingness to Pay for an Annual Reduction of One in One Million (1×10^{-6}) Risk of Cancer Death (1983 Dollars)

	ESTIMATE OF LIFETIME CANCER RISK FROM ALAR= EPA (1985) : 1.7×10^{-5}					
OWN PRICE ELASTICI-TIES	-1.2	-1.4	-1.6	-1.8	-2.0	-2.2
1984	22.03	11.08	7.45	5.64	4.65	3.79
1985	25.41	12.81	8.61	6.51	5.23	4.41
1986	29.44	14.37	9.35	6.88	5.35	4.36
1987	28.16	14.04	9.31	6.96	5.56	4.61
1988	24.09	12.15	8.15	6.18	4.94	4.53
1989	77.45	39.16	26.39	20.01	16.22	13.67
	ESTIMATE OF LIFETIME CANCER RISK FROM ALAR = NRDC (1989) : 4.1×10^{-5}					
1984	9.13	4.59	3.09	2.34	1.93	1.57
1985	10.53	5.31	3.57	2.70	2.17	1.83
1986	12.21	5.96	3.88	2.85	2.22	1.81
1987	11.68	5.82	3.86	2.89	2.30	1.91
1988	9.99	5.04	3.38	2.56	2.05	1.88
1989	32.11	16.24	10.94	8.30	6.73	5.67
	ESTIMATE OF LIFETIME CANCER RISK FROM ALAR= EPA (1989) : 6.0×10^{-6}					
1984	62.42	31.38	21.12	15.98	13.18	10.73
1985	71.98	36.28	24.38	18.43	14.82	12.48
1986	83.42	40.72	26.48	19.48	15.17	12.37
1987	79.80	39.78	26.37	19.72	15.75	13.07
1988	68.25	34.42	23.10	17.50	14.00	12.83
1989	219.5	111.0	74.78	56.70	45.97	38.73

Table 4.12. Definitions of the Variables Used in the Econometric Model

VARIABLES	
p_{qt}	Deflated retail price of apples in the NYC market at time t.
p_{yt}	Deflated retail price of bananas in the NYC market at time t.
m_t	Per capita deflated earnings in the NYC market at time t.
h_t	National apple storage holdings at time t.
S_{1t}	Dummy variable that takes the value of 1 between July 1984 through June 1989 and 0 otherwise.
S_{2t}	Dummy variable that takes the value of 1 between February 1989 through June 1989 and 0 otherwise.
S_{3t}	Dummy variable that takes the value of 1 after June 1989 through July 1991 and 0 otherwise.
$CNYT_t$	Cumulative number of articles in the New York Times on the presence of health risk associated with Alar at time t.
NYT_t	Number of articles in the New York Times on the presence of health risk associated with Alar at time t-1.
NYT_{t-1}	One period lagged value of NYT_t.
NYT_{t-2}	Two period lagged value of NYT_t.
NYT_{t-3}	Three period lagged value of NYT_t.
MA	Moving average term.
AR	Autoregressive term.
MA(Seas)	Seasonal moving average term.

CHAPTER V

CONCLUSIONS, POLICY ISSUES, AND FURTHER RESEARCH

5.1 Summary of Research Problem and Methods

This research investigated how food purchases are affected when consumers receive information on the existence of a health-risk associated with the consumption of a particular food. More specifically, it examined the effect of the Alar scare on retail fresh apple purchases in the NYC region. The observation period was January 1980 through July 1991. Having data on apple purchases two years after the date Alar was withdrawn from the market allowed us to examine whether the Alar controversy had a long-term effect on apple demand in the NYC region.

In answering this research question, Chapter II developed a conceptual model of consumption that incorporates the health-risk information in a demand function. The information variables that would measure the risk were then identified and the hypotheses specifying the impact of changes in health-risk information on food purchases were developed. Chapter III defined the econometric model for apple demand and derived the reduced-form equations for quantity and price. The methods to empirically estimate the demand equation and the reduced-form equations were presented. Chapter IV reported the empirical findings of the research.

The following sections in this Chapter summarize the empirical results of the study that are reported in Chapter IV and derive policy implications. Further research needs stemming from this research are identified later in the Chapter.

5.2 Summary of the Research Results

5.2.1 The Importance of Considering Seasonality when Estimating the Regression Equation

This research demonstrates that seasonal variation in variables, such as the variable that measures the per capita apple purchases in the NYC apple demand model, must be taken into account in estimating a time-series econometric model. If we do not correct for seasonality, we do not know whether the variation in the dependent variable is due to the seasonal variation or to the variations in the nonseasonal factors. The seasonal variation is specified by a seasonal ARMA model and the variations associated with the nonseasonal factors are explained by the exogenous variables in the demand model.

In order to determine how the seasonal error specification affects the demand-equation estimates and thus the coefficient estimates for the information variables, the demand model reported in van Ravenswaay and Hoehn was reestimated using a seasonal error structure. It was found that with a seasonal error structure, the information variables do not provide any additional explanatory power to the equation estimate at the 1% and 5% significance levels in the January 1980-July 1989 observation period and they are significant only at the 10% significance level. Without the seasonal component in the equation for the same observation period, however, the information variables were jointly significant at both the 5% and 10% significance levels.[1] The Q-statistic, which tests the overall acceptability of the residual autocorrelations, suggests that for the AR(1) specification the serial correlation in the demand model was not yet eliminated. When we specify a seasonal error structure, the Q-statistic suggests that the serial correlation in

[1] Eileen van Ravenswaay and John Hoehn, 1991.

the model was eliminated. This implies that the seasonal ARMA model is the correct specification when compared to the AR(1) model. Since with the seasonal error specification we are able to reject the null hypothesis that the coefficients for all of the information variables are equal to zero only at the 10% significance level but not at the 5% and 1% significance levels, it is not certain whether the Alar incident caused a downward shift in apple demand in the NYC region at all.

When the observation period was extended two years beyond the removal of Alar from the market, we found that the information effect on the quantity demanded was significant with the seasonal model at the 5% and 10% significance levels. This implies that there is a stronger evidence of the impact of Alar on apple demand in NYC region with the extended observation period. This may mean that a longer observation period added more precision to the demand equation estimate.

5.2.2 Simultaneity Bias in the Demand Equation

The results from the tests for simultaneity bias in the NYC demand equation confirm that the price variable and the error term are not correlated. This finding implies that simultaneity bias is not an issue in analyzing the impact of health-risk information in the regional market such as the NYC market when the incident actually covers the whole nation.

The findings from the reduced-form equations for the NYC retail apple price also support this finding. In the reduced-form equation for price, we found that risk information at the national level does not affect the NYC region's retail apple prices.

One possible reason why the NYC retail price did not change may be that there was an offsetting supply shift at the national retail market for apples such that the retail price of apples in the national retail market and thus at the regional retail markets was not affected by the risk information. Another reason may be that the national wholesale price may drop as a result of a demand shift in the national wholesale market but the regional retailers do not change their prices. We do not know which of the above interpretations is true in explaining the reason why the NYC retail price did not change. To find out which interpretation is true, further research is needed to examine what happened to quantity and price of apples at the national wholesale and the retail apple markets as a result of information on Alar.

5.2.3 Information Effect

Consumers show a swift and systematic response when they are informed about the presence or absence of the reported risk in the market. Consistent with the findings by van Ravenswaay and Hoehn (1991), the effect of the Alar incident in the NYC region started in July 1984, when the EPA first announced the potential health effects associated with the lifetime consumption of Alar-treated apples. The findings show that consumers update their risk perceptions as they receive additional information on health risk. In other words, the events in and after February 1989 caused an additional shift in apple demand. Note that with the available data, we are not able to distinguish the real cause of the additional shift in demand. It could have been the presence of the revised risk estimates released by the EPA and the NRDC or it could have been the intense media coverage. Both of these two incidents happened between February 1989 to June 1989. The variable that measures the presence or absence of the revised risk estimates (S_{2t}) is closely correlated with the current and one period lagged value of the variable that measures the intensity of the reporting (NYT_t). There is not sufficient information that will enable us to differentiate between the impact of these two variables on the per capita apple purchases. If the period during which there was intense media coverage did not overlap with the period during which the revise estimates were released, it would have been possible to estimate the separate effects of the intense media coverage and the release of new risk estimates on the per capita apple purchases.

5.2.4 Own-Price Elasticities

The price elasticity of apple demand was estimated to be less than one. This estimated own-price elasticity is smaller than that estimated by previous research.[1] An inelastic own-price elasticity estimate may be a result of the variations in apple price and apple purchases being explained by the seasonality in the demand model. When we account for seasonality in the demand model, there is little variation left to estimate a reliable own-price elasticity figure. A longer time series would allow us to estimate a more reliable own-price elasticity.

5.2.5 Change in Total Apple Sales Associated with the Information on Alar

The apple sales at the retail market in the NYC market would have been 15% higher had the Alar event never occurred. This implies that a drop in apple sales of almost $100 million was realized in the NYC region during the June 1984-July 1989 period. About 80% of this drop in apples sales is attributable to a one-time and persistent demand shift associated with the initial announcement made by the EPA that Alar was a potential carcinogen.

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[1] See, Henry S. Baumes and Roger K. Conway, 1985.

5.2.6 Change in Consumer Surplus Associated with Information on Alar

Since it was not possible to estimate a reliable price elasticity of demand, several different assumptions on the price elasticity had to be made in order to calculate the change in expected consumer surplus. Following previous research[1] the assumed own-price elasticity was between -1.3 to -4.6. It was found that as the assumption on the magnitude of the price elasticity was increased, the change in the expected consumer surplus became increasingly smaller. Following the discussion in Section 4 of Chapter II, the change in expected consumer surplus can be approximated to represent the consumer's willingness to pay to avoid Alar residues. If we assume that the consumer's perceived risk is similar to the risks reported in the media, it is possible to infer the implicit willingness to pay for an annual reduction of one in one million risk of cancer death. For higher own-price elasticity estimates (-1.8 to -2.2), the implicit willingness to pay to avoid cancer deaths was close to the range that was reported in value of life studies. Following van Ravenswaay and Hoehn (1991), it should be noted that the implicit willingness to pay estimates in this research are based on very restrictive assumptions on the risk perceptions of consumers.[2]

5.3 Policy Issues

This research shows that consumers respond immediately once they are informed on the presence or absence of the reported risk in the market. Sales of apples drop even further as consumers receive additional information on health risk. This result has important implications for policy makers making decisions in the presence of health-

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[1]Henry S. Baumes and Roger K. Conway, 1985; Dana G. Dalymple, 1962.

[2]See Section 4.7.

scare events such as the Alar incident. Since many of the older pesticides currently used have not yet been fully tested for toxicity, it is likely that as new toxicity estimates are released, conflicts similar to the Alar controversy will arise. Consumers are likely to shift away from foods that contain residues of toxic substances. In order to minimize the revenue losses to the food industry, the government could recall the suspected chemical as soon as the initial reporting of the toxicity of a substance is released. In the Alar controversy, for example, the drop in apple demand that took place between July 1984 to June 1989 could have been avoided had the Government recalled the existing quantities and suspended the sale of Alar in July 1984 while it continued the toxicity studies. An alternative policy option for the Government could have been not announcing the preliminary findings of the toxicity studies until a consensus was reached regarding health risks associated with Alar. Still another policy could be that the interest groups releasing statements about risks prior to definitive government study be subject to product disparagement suits.

We would not know which policy option is the most feasible to implement unless we estimate the benefits and costs associated with each policy alternative. The estimate of the risk reduction benefits from this study provides information on the benefits of a policy that would eliminate health risks associated with Alar. The findings of this study indicate that the consumers are willing to pay amounts of money that are consistent with the previous literature on the value of life, i.e., between the range of $1.44 and $7.64 in 1983 dollars.[1] This result implies that in similar health scare incidents in the future, if the costs of a policy such as product recalling that would eliminate health risks from the chemical are smaller than this estimated range, the Government should implement that policy option.

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[1]We note in Section 4.7 that the estimate of the benefits from avoiding risks from Alar is based on very restrictive assumptions about risk perceptions and we assume that own price elasticity of apples are high.

The food industry might also learn from the findings of this study. In the future, when conflicts similar to the Alar incident arise, in order to minimize the revenue losses the food industry may announce that they voluntarily stop using the chemical right after the chemical is announced to be harmful to human health. The food industry may therefore minimize likely conflicts. Alternatively, the food industry may direct its policies to ask Government to recall the chemical or not to announce the preliminary findings until the toxicity studies are finalized.

5.4 Needs for Future Research

The findings of this research suggest that the Alar controversy affected the apple demand in the NYC market. The research should be duplicated to other markets to test whether the Alar incident had the same effect across the nation. We also find in this research that the problem of simultaneity bias is not an issue in analyzing the effect of the information on Alar in apple demand in a regional retail market using a single equation model. This means that there was no evidence of a price change associated with the Alar incident at the NYC region. The reason why the retail apple price at the NYC region did not change can be interpreted in several ways.[1]

The finding that the price at the NYC level did not change with the Alar incident could not be generalized to the other markets at the nation unless we find that the price at the other regions remained unaffected. Further research is needed to examine the other regions across the nation. Another way to support the results obtained from this research is to examine the effect of the Alar controversy in the national retail apple market. Examining the effect of health-risk information at the national retail market using a simultaneous supply and demand model may strengthen the finding of this study

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[1]See the discussion in Section 3.1.

if we find that the retail price at the national market was not affected by the Alar controversy. This would confirm that we need not worry about the simultaneity bias when estimating apple demand in a regional market by a single equation, when the event actually covers the whole nation.

The effect of the Alar incident on the processed apple market could also be explored in further research. A downward shift in processed apple demand would also be expected associated with the reports in the media on the toxicity of UDMH, a derivative of Alar which is found in processed apple products.

APPENDIX A

DESCRIPTION OF DATA

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DESCRIPTION OF DATA

The data consist of monthly observations of apple purchases, population, retail prices of fresh apples and bananas, consumer price index, disposable income, number of articles on the presence of Alar reported in the New York Times (NYT) and the national fresh apple holdings. As stated in Section 1.7 of Chapter I, the data used in this study is largely identical to the one reported in Guyton (1990). The difference in the two data sets is related with the definition of the population area in the NYC market and we include variables on income and national fresh apple storage holdings to the model. Data described below is reported in Appendix B.[1]

TOTAL FRESH APPLE PURCHASES: Monthly data on fresh apple purchases consist of the arrivals of fresh apples to the NYC market reported by the United States Department of Agriculture (USDA).[2]

POPULATION: The population figures in this study cover a smaller area than the ones reported in Guyton. This is because the monthly arrivals of apples for fresh consumption to the New York-Newark metropolitan area covers five Primary Metropolitan Statistical Areas (PMSA) in the New York-Northern New Jersey, Long Island Consolidated Metropolitan Statistical Area (CMSA). These PMSAs are, Bergen-

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[1]For a detailed description of data on total fresh apple purchases, retail prices of apples and bananas and articles on the presence of Alar reported in the NYT, see, William P. Guyton, 1990.

[2]U.S. Department of Agriculture, Agricultural Marketing Service, Fresh Fruit and Vegetable Arrivals in Eastern Cities, Washington, D.C., January 1980 - July 1991.

Passaic, Jersey City, Nassau-Suffolk, New York and Newark.[1] The population figures that are reported in Guyton cover the whole CMSA. Since only annual population figures were available, the monthly figures were derived from the annual data by using the following formula that demonstrates as an example of the calculation procedure for the monthly growth rate between 1981 and 1982:

$$1981\ \textit{population estimate}(1+r)^{12}=1982\ \textit{population estimate}$$

where r is the monthly population growth rate and 12 denotes the number of months between two annual observations. Since we have the 1981 and 1982 population estimates that are reported in July of 1981 and 1982, we can solve for r and then use this growth rate to calculate the monthly population rate. Similar procedure was used to calculate the monthly population figures for each year.

The 1989 population estimate was not available since the population estimates are usually not released for the years before the census year. Therefore, the population figures for the months between July 1988 and April 1990 were calculated in the similar way for the 21 months as described in the example above. Note that for the census years (1980 and 1990) the population figures were released in April and for the remaining years the population figures were released in July.

The population estimate for 1991 was not yet released. Therefore, the projection for the months after the 1990 population figure was based on the growth rate from April 1980 to April 1990 by using the following formula:

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[1]The population estimates are not reported in the years before the census, i.e., 1979 and 1989. The population estimate for the years of census are reported in April and for all other years they are reported in July. Annual population data for 1978 - 1988 were obtained fron U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P25, 1978 - 1988. The population for 1990 was obtained from U.S. Department of Commerce, Bureau of the Census, Summary Population and Housing Characteristics, CPH-1, 1990.

$$1980\ population\ estimate(1+r)^{120}=1990\ population\ estimate$$

The growth rate is calculated by solving for r. This figure was multiplied by the population estimate in 1990 and then added to the 1990 population estimate to get the subsequent month's figure. This procedure was repeated until July 1991's population estimate was obtained.

FRESH APPLE AND BANANA PRICES: Prices of fresh apples and bananas were obtained from the monthly market basket reports published by the NYC Department of Consumer Affairs.[1] Both prices were deflated by the consumer price index for all urban consumers (CPI-U) for the New York City-Newark Metropolitan Area.

We chose bananas to be a substitute for fresh apples in the demand model because bananas were the only fruit whose prices were reported in the NYC Market Basket Reports. Guyton (1991) reports that oranges may be used as another substitute for fresh apples. He incorporated a variable that measures the regional deflated retail prices of oranges. However, the coefficient for the orange price variable yielded a negative sign. He therefore dropped the orange price variable. The possibility of incorporating the prices of other fresh fruits was therefore restricted. For example, we wanted to incorporate a variable that measures the availability of specialty fruits in the market. The reason to have such a variable in the model is to be able to account for the increasing availability of such fruits which may cause consumers to shift away from consuming apples.[2] However, since the retail price of such fruits were not reported, the option of constructing such a variable was dropped.

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[1]New York City of Consumer Affairs, Market Basket Report, New York, January 1980 - July 1991.

[2]USDA, Agricultural Marketing Service, Fresh Fruit and Vegetable Shipments in the United States, Washington, D.C., January 1980 - July 1991.

INCOME: A proxy to represent the personal income variable was sought. The closest variable that would measure the personal income with no seasonal adjustment across the months were the earnings data that are reported monthly by The State of New York, Department of Labor.[1] The Department of Labor reports the number of employees and weekly earnings in nonagricultural establishments by industry in New York City. The industries for which both the number of employees and weekly earnings are, manufacturing, construction, telephone and telegram, electric gas and sanitary services, and wholesale trade. The total weekly earnings were calculated by multiplying the number of employees in that industry with the average weekly earnings in each industry. The average total weekly earnings was obtained by dividing the total weekly earnings by the total number of employees in the five industries. The average weekly earnings was expressed in 1983 dollars through dividing by the NYC consumer price index for all urban consumers (CPI-U). Deflated average monthly earnings was obtained by multiplying the deflated weekly average earnings with the number of weeks in each month. The data that are used to calculate the monthly earnings is reported in Appendix C.

APPLE HOLDINGS: Another variable that was not used in the study by van Ravenswaay and Hoehn (1991) but was included in this research is the national fresh apple holdings. The variable that represents the monthly national fresh apple holdings was obtained from the International Apple Institute.[2] The data involves the total fresh apple holdings of all varieties in cold storage and controlled atmosphere excluding the processor's holdings.

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[1]State of New York, Department of Labor, Employment Review, New York, January 1980 - July 1991.

[2]International Apple Industry, National and International Apple News, Mc Lean, Virginia, January 1980 - July 1991.

National fresh apple holdings were used as one explanatory variable in the national retail apple supply equation in the econometric model. The data represent holdings at the wholesale level. Apples are stored when they are at the wholesale market. There are three types of storage facilities: common storage, cold storage and controlled atmosphere storage.[1] The supply of fresh apples from wholesale market to retail market and thus from retail market to consumer is determined by the quantity of fresh apple holdings at the wholesale market. Therefore, a variable that measures the quantity of fresh apple holdings at the wholesale market was incorporated in the retail apple supply equation.

Note that in July - October, the holdings are reported to be zero. The reason for this is that since the holdings are very small at those months, the International Apple Institute does not report apple holdings these months. In the econometric model the logarithms of the holding variable were used. Therefore we add 1 to the variable that measures holdings (HOLD) in order to gat a variable in logarithms (lnh_t = ln(HOLD+1)).

ARTICLES ON THE PRESENCE OF ALAR: Following Guyton (1990), since the NYT had the largest circulation size, we chose this newspaper as a proxy for the newspaper coverage on Alar. Using the "Alar" and "Daminozide" keywords, a search of the full text of the NYT article from the Nexis data base of the full text of the NYT articles from January 1980-July 1991 was performed.

Figure A.1 shows the per capita apple consumption and retail price of apples in the NYC region for the extended observation period.

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[1]John Mark Halloran, " Price Forecasting Model for Michigan Fresh Apples." M.S. Thesis, Michigan State University, 1981, pp.22-23.

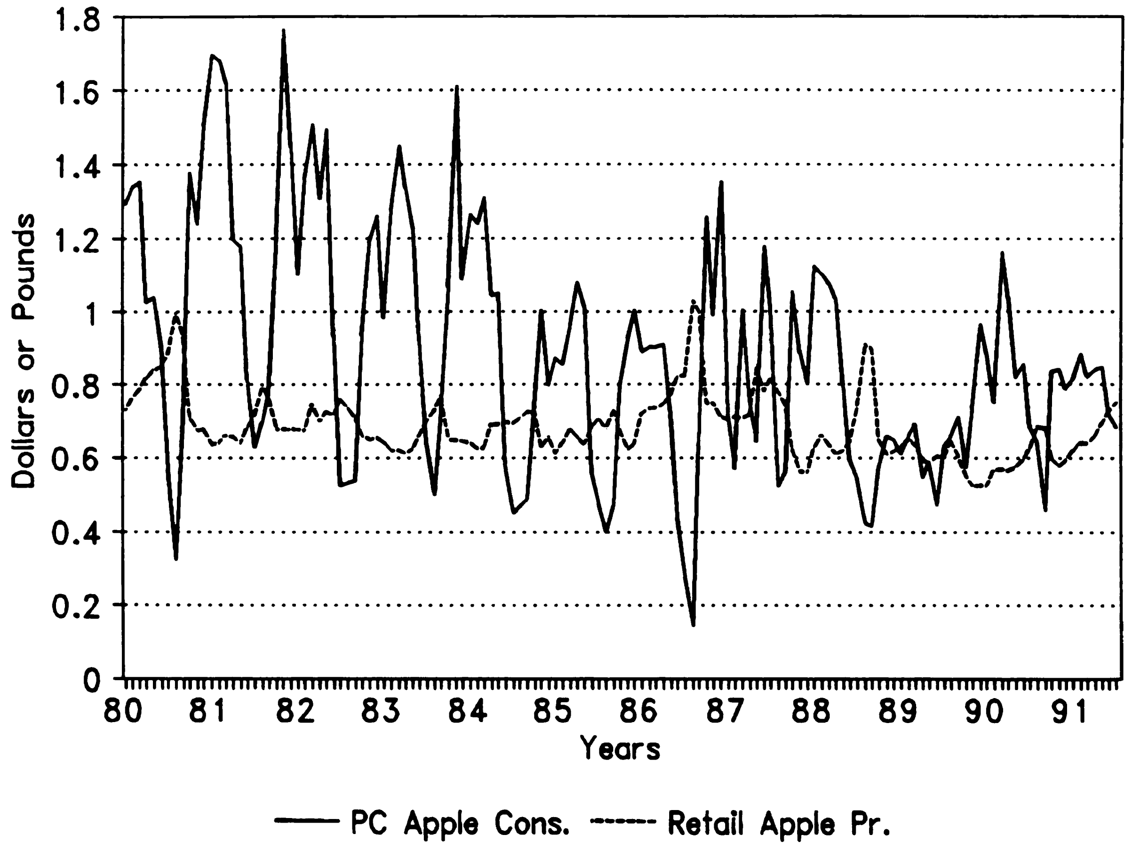

Figure A.1. Retail Fresh Apple Prices (1983 Dollars) and Per Capita Fresh Apple Purchases in the NYC Region (Pounds)

APPENDIX B

THE DATA

APPENDIX B

THE DATA

	MONTHS	QNY[1]	POPNY[2]	PCQNY[3]
1980	Jan.	18,900,000	14,645,742	1.290477
	Feb.	19,600,000	14,633,820	1.339363
	Mar.	19,800,000	14,621,909	1.354132
	Apr.	15,000,000	14,610,000	1.026694
	May	15,200,000	14,610,999	1.040312
	June	13,200,000	14,611,999	0.903367
	July	8,300,000	14,612,998	0.567987
	Aug.	4,700,000	14,613,998	0.321609
	Sep.	10,300,000	14,614,997	0.704756
	Oct.	20,100,000	14,615,997	1.375206
	Nov.	18,100,000	14,616,997	1.238284
	Dec.	22,000,000	14,617,997	1.504994
1981	Jan.	24,800,000	14,618,996	1.696423
	Feb.	24,600,000	14,619,996	1.682627
	Mar.	23,700,000	14,620,996	1.620957
	Apr.	17,500,000	14,621,996	1.196827
	May	17,200,000	14,622,997	1.176230
	June	11,900,000	14,623,997	0.813731
	July	9,200,000	14,625,000	0.629060
	Aug.	10,200,000	14,626,416	0.697368
	Sep.	11,300,000	14,627,832	0.772500
	Oct.	17,700,000	14,629,248	1.209905
	Nov.	25,800,000	14,630,664	1.763420
	Dec.	21,200,000	14,632,080	1.448871
1982	Jan.	16,100,000	14,633,496	1.100216
	Feb.	19,900,000	14,634,913	1.359762
	Mar.	22,100,000	14,636,329	1.509941
	Apr.	19,100,000	14,637,746	1.304846
	May	21,900,000	14,639,163	1.495987
	June	13,600,000	14,640,580	0.928925
	July	7,700,000	14,642,000	0.525884
	Aug.	7,800,000	14,645,246	0.532596
	Sep.	7,900,000	14,648,493	0.539305
	Oct.	13,700,000	14,651,741	0.935042
	Nov.	17,400,000	14,654,989	1.187309
	Dec.	18,500,000	14,658,238	1.262089
1983	Jan.	14,400,000	14,661,488	0.982165
	Feb.	18,700,000	14,664,738	1.275168

	Mar.	21,300,000	14,667,989	1.452142
	Apr.	19,600,000	14,671,241	1.335947
	May	18,000,000	14,674,494	1.226618
	June	13,500,000	14,677,747	0.919760
	July	9,400,000	14,681,000	0.640283
	Aug.	7,300,000	14,687,981	0.497005
	Sep.	10,300,000	14,694,965	0.700920
	Oct.	15,700,000	14,701,952	1.067885
	Nov.	23,700,000	14,708,943	1.611265
	Dec.	16,000,000	14,715,937	1.087257
1984	Jan.	18,600,000	14,722,935	1.263335
	Feb.	18,200,000	14,729,935	1.235579
	Mar.	19,300,000	14,736,940	1.309634
	Apr.	15,400,000	14,743,947	1.044496
	May	15,500,000	14,750,958	1.050779
	June	8,500,000	14,757,972	0.575960
	July	6,600,000	14,765,000	0.447003
	Aug.	6,900,000	14,772,230	0.467093
	Sep.	7,200,000	14,779,464	0.487162
	Oct.	11,000,000	14,786,702	0.743912
	Nov.	14,800,000	14,793,943	1.000409
	Dec.	11,800,000	14,801,188	0.797233
1985	Jan.	12,900,000	14,808,436	0.871125
	Feb.	12,700,000	14,815,687	0.857200
	Mar.	14,300,000	14,822,943	0.964721
	Apr.	16,000,000	14,830,201	1.078879
	May	15,000,000	14,837,464	1.010954
	June	8,300,000	14,844,730	0.559121
	July	7,100,000	14,852,000	0.478050
	Aug.	5,900,000	14,851,667	0.397262
	Sep.	7,000,000	14,851,333	0.471338
	Oct.	11,800,000	14,851,000	0.794559
	Nov.	13,700,000	14,850,667	0.922518
	Dec.	14,900,000	14,850,333	1.003344
1986	Jan.	13,200,000	14,850,000	0.888889
	Feb.	13,400,000	14,849,667	0.902377
	Mar.	13,400,000	14,849,333	0.902397
	Apr.	13,500,000	14,849,000	0.909152
	May	10,700,000	14,848,667	0.720603
	June	6,500,000	14,848,333	0.437760
	July	4,100,000	14,848,000	0.276131
	Aug.	2,100,000	14,851,662	0.141398
	Sep.	9,500,000	14,855,324	0.639501
	Oct.	18,700,000	14,858,987	1.258498
	Nov.	14,700,000	14,862,651	0.989056
	Dec.	20,100,000	14,866,317	1.352050
1987	Jan.	10,700,000	14,869,983	0.719570
	Feb.	8,500,000	14,873,650	0.571480
	Mar.	14,900,000	14,877,317	1.001525
	Apr.	11,200,000	14,880,986	0.752638
	May	9,600,000	14,884,656	0.644959
	June	17,500,000	14,888,326	1.175418
	July	15,000,000	14,892,000	1.007252

	Aug.	7,800,000	14,894,829	0.523672
	Sep.	8,400,000	14,897,659	0.563847
	Oct.	15,700,000	14,900,490	1.053657
	Nov.	13,200,000	14,903,321	0.885709
	Dec.	12,000,000	14,906,153	0.805037
1988	Jan.	16,700,000	14,908,985	1.120130
	Feb.	16,400,000	14,911,818	1.099799
	Mar.	16,000,000	14,914,651	1.072771
	Apr.	15,400,000	14,917,485	1.032346
	May	11,900,000	14,920,319	0.797570
	June	8,900,000	14,923,154	0.596389
	July	8,100,000	14,926,000	0.542677
	Aug.	6,300,000	14,920,504	0.422238
	Sep.	6,200,000	14,915,011	0.415689
	Oct.	8,600,000	14,909,519	0.576813
	Nov.	9,800,000	14,904,029	0.657540
	Dec.	9,700,000	14,898,541	0.651070
1989	Jan.	9,100,000	14,893,056	0.611023
	Feb.	9,800,000	14,887,572	0.658267
	Mar.	10,300,000	14,882,091	0.692107
	Apr.	8,100,000	14,876,611	0.544479
	May	8,800,000	14,871,133	0.591750
	June	7,000,000	14,865,658	0.470884
	July	9,400,000	14,860,184	0.632563
	Aug.	9,800,000	14,854,713	0.659723
	Sep.	10,600,000	14,849,243	0.713841
	Oct.	8,500,000	14,843,776	0.572631
	Nov.	10,900,000	14,838,310	0.734585
	Dec.	14,300,000	14,832,847	0.964077
1990	Jan.	13,100,000	14,827,385	0.883500
	Feb.	11,100,000	14,821,926	0.748891
	Mar.	17,200,000	14,816,469	1.160870
	Apr.	15,300,000	14,811,000	1.033016
	May	12,100,000	14,812,687	0.816867
	June	12,700,000	14,814,374	0.857276
	July	10,100,000	14,816,061	0.681693
	Aug.	9,500,000	14,817,749	0.641123
	Sep.	6,800,000	14,819,437	0.458857
	Oct.	12,400,000	14,821,125	0.836644
	Nov.	12,500,000	14,822,813	0.843295
	Dec.	11,700,000	14,824,501	0.789234
1991	Jan.	12,100,000	14,826,190	0.816123
	Feb.	13,100,000	14,827,878	0.883471
	Mar.	12,200,000	14,829,567	0.822681
	Apr.	12,500,000	14,831,256	0.842815
	May	12,600,000	14,832,946	0.849460
	June	10,700,000	14,834,635	0.721285
	July	10,100,000	14,836,325	0.680762

1. Fresh apple purchases in the NYC region (pounds).

2.NYC population.

3.Per capita apple purchases in the NYC region (QNY/POPNY).

	MONTHS	DRPANY[4]	DRPBNY[5]	CPINY[6]
1980	Jan.	0.728900	0.409207	0.782
	Feb.	0.760456	0.456274	0.789
	Mar.	0.787500	0.475000	0.800
	Apr.	0.818859	0.459057	0.806
	May	0.838471	0.468557	0.811
	June	0.852619	0.426309	0.821
	July	0.883777	0.411622	0.826
	Aug.	0.996399	0.432173	0.833
	Sep.	0.933014	0.430622	0.836
	Oct.	0.713436	0.404281	0.841
	Nov.	0.673759	0.413712	0.846
	Dec.	0.678363	0.421053	0.855
1981	Jan.	0.637312	0.428737	0.863
	Feb.	0.640732	0.423341	0.874
	Mar.	0.660592	0.444191	0.878
	Apr.	0.656852	0.430351	0.883
	May	0.641892	0.450450	0.888
	June	0.681564	0.413408	0.895
	July	0.715859	0.396476	0.908
	Aug.	0.796943	0.393013	0.916
	Sep.	0.763441	0.419355	0.930
	Oct.	0.679612	0.399137	0.927
	Nov.	0.680346	0.399568	0.926
	Dec.	0.679612	0.399137	0.927
1982	Jan.	0.678149	0.409042	0.929
	Feb.	0.676692	0.397422	0.931
	Mar.	0.745946	0.421622	0.925
	Apr.	0.700431	0.431034	0.928
	May	0.725720	0.405550	0.937
	June	0.721003	0.397074	0.957
	July	0.761210	0.354536	0.959
	Aug.	0.737279	0.353063	0.963
	Sep.	0.710608	0.370752	0.971
	Oct.	0.660569	0.335366	0.984
	Nov.	0.652396	0.346585	0.981
	Dec.	0.656410	0.338462	0.975
1983	Jan.	0.644172	0.378323	0.978
	Feb.	0.622449	0.377551	0.980
	Mar.	0.621814	0.377166	0.981
	Apr.	0.615540	0.454087	0.991
	May	0.623742	0.482897	0.994
	June	0.661986	0.471414	0.997
	July	0.700000	0.450000	1.000
	Aug.	0.729271	0.439560	1.001
	Sep.	0.772277	0.425743	1.010
	Oct.	0.651530	0.394867	1.013
	Nov.	0.648968	0.363815	1.017
	Dec.	0.648330	0.353635	1.018
1984	Jan.	0.642023	0.359922	1.028
	Feb.	0.628627	0.377176	1.034
	Mar.	0.626808	0.366442	1.037
	Apr.	0.691643	0.384246	1.041

	May	0.691643	0.374640	1.041
	June	0.699904	0.383509	1.043
	July	0.696565	0.381679	1.048
	Aug.	0.710900	0.369668	1.055
	Sep.	0.725047	0.329567	1.062
	Oct.	0.725730	0.367578	1.061
	Nov.	0.629108	0.309859	1.065
	Dec.	0.657277	0.328638	1.065
1985	Jan.	0.609185	0.365511	1.067
	Feb.	0.643057	0.382106	1.073
	Mar.	0.679070	0.390698	1.075
	Apr.	0.658017	0.417053	1.079
	May	0.638298	0.388529	1.081
	June	0.683287	0.378578	1.083
	July	0.710332	0.359779	1.084
	Aug.	0.677656	0.357143	1.092
	Sep.	0.729927	0.374088	1.096
	Oct.	0.673953	0.346084	1.098
	Nov.	0.623306	0.316170	1.107
	Dec.	0.639640	0.396396	1.110
1986	Jan.	0.724508	0.357782	1.118
	Feb.	0.735426	0.367713	1.115
	Mar.	0.735426	0.376682	1.115
	Apr.	0.746403	0.458633	1.112
	May	0.775473	0.477908	1.109
	June	0.823635	0.384960	1.117
	July	0.826667	0.355556	1.125
	Aug.	1.029281	0.346051	1.127
	Sep.	1.000000	0.362832	1.130
	Oct.	0.749559	0.361552	1.134
	Nov.	0.750221	0.370697	1.133
	Dec.	0.711775	0.333919	1.138
1987	Jan.	0.706190	0.348736	1.147
	Feb.	0.711188	0.364267	1.153
	Mar.	0.708117	0.371330	1.158
	Apr.	0.720412	0.351630	1.166
	May	0.852515	0.383632	1.173
	June	0.780985	0.373514	1.178
	July	0.814249	0.347752	1.179
	Aug.	0.782170	0.336417	1.189
	Sep.	0.742905	0.358932	1.198
	Oct.	0.623960	0.332779	1.202
	Nov.	0.564315	0.340249	1.205
	Dec.	0.563847	0.339967	1.206
1988	Jan.	0.623330	0.356189	1.123
	Feb.	0.660125	0.401427	1.121
	Mar.	0.633745	0.370370	1.215
	Apr.	0.611746	0.358891	1.226
	May	0.619397	0.374898	1.227
	June	0.641755	0.446791	1.231
	July	0.736246	0.380259	1.236
	Aug.	0.909823	0.338164	1.242
	Sep.	0.896825	0.341270	1.260

	Oct.	0.649762	0.340729	1.262
	Nov.	0.611597	0.357427	1.259
	Dec.	0.619048	0.365079	1.260
1989	Jan.	0.629921	0.346457	1.270
	Feb.	0.650470	0.352665	1.276
	Mar.	0.636152	0.403413	1.289
	Apr.	0.594595	0.440154	1.295
	May	0.591398	0.460829	1.302
	June	0.605364	0.413793	1.305
	July	0.604900	0.367534	1.306
	Aug.	0.649351	0.366692	1.309
	Sep.	0.605144	0.363086	1.322
	Oct.	0.549699	0.384036	1.328
	Nov.	0.525526	0.360360	1.332
	Dec.	0.525131	0.360090	1.333
1990	Jan.	0.525537	0.399704	1.351
	Feb.	0.569106	0.428677	1.353
	Mar.	0.571010	0.409956	1.366
	Apr.	0.568099	0.393299	1.373
	May	0.575802	0.393586	1.372
	June	0.598104	0.364697	1.371
	July	0.628613	0.440751	1.384
	Aug.	0.685714	0.385714	1.400
	Sep.	0.681818	0.383523	1.408
	Oct.	0.600282	0.360169	1.416
	Nov.	0.579505	0.360424	1.415
	Dec.	0.593220	0.360169	1.416
1991	Jan.	0.622378	0.370629	1.430
	Feb.	0.640669	0.376045	1.436
	Mar.	0.641562	0.446304	1.434
	Apr.	0.661100	0.424495	1.437
	May	0.694444	0.451389	1.440
	June	0.726141	0.421853	1.446
	July	0.750689	0.385675	1.452

4.Deflated retail apple price in the NYC region (1983 dollars).

5.Deflated retail banana price in the NYC region (1983 dollars).

6.Consumer price index in the NYC region for all items.

	MONTHS	INCOME[7]	HOLD[8]	NYT[9]
1980	Jan.	1578.634	49,868,000	0
	Feb.	1476.705	39,613,000	0
	Mar.	1551.665	30,095,000	0
	Apr.	1474.719	20,564,000	0
	May	1526.071	13,042,000	0
	June	1477.181	6,240,000	0
	July	1532.385	0	0
	Aug.	1515.234	0	0
	Sep.	1474.841	0	0
	Oct.	1542.238	0	0
	Nov.	1522.024	89,392,000	0
	Dec.	1574.549	77,355,000	0
1981	Jan.	1570.320	63,066,000	0
	Feb.	1400.637	51,904,000	0
	Mar.	1561.691	40,676,000	0
	Apr.	1494.169	30,190,000	0
	May	1539.756	20,497,000	0
	June	1481.312	12,057,000	0
	July	1515.616	0	0
	Aug.	1528.019	0	0
	Sep.	1463.309	0	0
	Oct.	1540.839	0	0
	Nov.	1516.792	71,452,000	0
	Dec.	1583.651	60,775,000	0
1982	Jan.	1581.489	49,363,000	0
	Feb.	1388.502	40,059,000	0
	Mar.	1604.991	31,689,000	0
	Apr.	1527.768	23,233,000	0
	May	1583.073	15,507,000	0
	June	1516.135	9,294,000	0
	July	1563.020	0	0
	Aug.	1570.380	0	0
	Sep.	1518.425	0	0
	Oct.	1568.507	0	0
	Nov.	1568.832	79,833,000	0
	Dec.	1662.004	69,116,000	0
1983	Jan.	1643.152	58,092,000	0
	Feb.	1453.454	47,807,000	0
	Mar.	1626.420	38,169,000	0
	Apr.	1567.737	27,063,000	0
	May	1615.443	17,254,000	0
	June	1569.354	9,743,000	0
	July	1617.066	0	0
	Aug.	1514.769	0	0
	Sep.	1567.353	0	0
	Oct.	1644.196	0	0
	Nov.	1631.270	76,283,000	0
	Dec.	1688.571	68,390,000	0
1984	Jan.	1641.401	56,534,000	0
	Feb.	1525.934	45,410,000	0
	Mar.	1605.585	36,336,000	0
	Apr.	1581.505	26,613,000	0

	May	1631.301	17,884,000	0
	June	1584.119	10,349,000	0
	July	1635.834	0	1
	Aug.	1626.068	0	0
	Sep.	1592.595	0	0
	Oct.	1665.451	0	0
	Nov.	1636.418	76,680,000	0
	Dec.	1718.671	68,295,000	0
1985	Jan.	1672.560	56,450,000	0
	Feb.	1516.377	45,997,000	0
	Mar.	1667.883	35,751,000	0
	Apr.	1599.447	26,865,000	0
	May	1669.996	17,832,000	0
	June	1631.009	10,839,000	0
	July	1696.756	0	0
	Aug.	1676.381	0	2
	Sep.	1647.302	0	1
	Oct.	1694.433	0	0
	Nov.	1682.624	69,153,000	0
	Dec.	1751.948	59,239,000	0
1986	Jan.	1715.945	47,907,000	2
	Feb.	1532.789	37,639,000	0
	Mar.	1719.671	28,523,000	1
	Apr.	1668.059	19,800,000	0
	May	1742.229	11,642,000	2
	June	1678.300	5,889,000	1
	July	1724.353	0	2
	Aug.	1689.381	0	0
	Sep.	1691.428	0	0
	Oct.	1725.194	0	0
	Nov.	1727.925	77,452,000	1
	Dec.	1789.157	65,529,000	0
1987	Jan.	1762.128	52,849,000	3
	Feb.	1543.497	42,499,000	0
	Mar.	1730.284	32,524,000	0
	Apr.	1664.993	23,049,000	0
	May	1740.462	14,484,000	2
	June	1691.758	8,274,000	1
	July	1763.116	0	0
	Aug.	1735.950	0	0
	Sep.	1692.276	0	1
	Oct.	1737.629	0	1
	Nov.	1715.832	96,453,000	0
	Dec.	1759.852	81,291,000	0
1988	Jan.	1846.423	67,832,000	0
	Feb.	1728.918	55,176,000	1
	Mar.	1741.795	42,897,000	1
	Apr.	1656.813	29,700,000	0
	May	1721.739	19,180,000	0
	June	1669.664	10,614,000	0
	July	1729.196	0	0
	Aug.	1707.874	0	0
	Sep.	1643.642	0	1

	Oct.	1721.664	0	0
	Nov.	1698.880	87,027,000	0
	Dec.	1760.965	73,754,000	0
1989	Jan.	1711.916	61,161,000	1
	Feb.	1532.095	50,372,000	7
	Mar.	1707.559	39,433,000	20
	Apr.	1664.113	29,730,000	5
	May	1684.681	21,397,000	12
	June	1640.445	13,673,000	0
	July	1692.289	0	0
	Aug.	1675.431	0	0
	Sep.	1633.923	0	0
	Oct.	1681.306	0	0
	Nov.	1654.425	102,000,000	0
	Dec.	1714.878	86,341,000	0
1990	Jan.	1655.626	71,382,000	0
	Feb.	1503.807	57,629,000	0
	Mar.	1551.338	46,366,000	0
	Apr.	1567.521	33,852,000	0
	May	1660.109	23,137,000	0
	June	1610.297	14,027,000	0
	July	1650.857	0	0
	Aug.	1522.613	0	0
	Sep.	1586.543	0	0
	Oct.	1521.130	0	0
	Nov.	1482.130	87,827,000	0
	Dec.	1462.946	74,361,000	0
1991	Jan.	1610.991	62,877,000	0
	Feb.	1455.881	50,479,000	0
	Mar.	1612.496	39,553,000	0
	Apr.	1556.808	29,361,000	0
	May	1606.141	20,278,000	0
	June	1552.139	13,378,000	0
	July	1583.827	0	0

7.The derivation of the income variable is explained in Appendix C.

8.National fresh apple holdings (bushels).

9.Number of articles in the New York Times on the presence of health risk associated with Alar.

APPENDIX C

WEEKLY DATA ON EARNINGS

APPENDIX C

WEEKLY DATA ON EARNINGS

	MONTHS	MAEM[1]	MAWER[2]	COEM[3]	COWER[4]
1980	Jan.	492,600	229.40	71,400	393.54
	Feb.	503,700	232.63	70,500	396.89
	Mar.	508,900	233.25	72,100	396.23
	Apr.	493,000	227.76	73,300	394.28
	May	501,400	231.25	76,000	400.58
	June	503,000	234.47	78,000	412.62
	July	480,900	234.33	79,100	421.11
	Aug.	492,400	234.15	79,400	418.74
	Sep.	496,800	234.21	80,200	421.61
	Oct.	497,800	239.85	80,800	409.52
	Nov.	494,400	245.23	80,800	424.45
	Dec.	483,500	250.21	80,400	436.93
1981	Jan.	469,900	249.75	75,500	438.70
	Feb.	482,700	250.43	76,700	416.29
	Mar.	488,600	254.25	78,900	447.58
	Apr.	488,500	253.27	80,800	446.40
	May	491,300	253.57	82,200	441.77
	June	496,000	254.76	84,100	452.45
	July	478,900	253.46	84,400	445.42
	Aug.	489,400	252.50	85,400	465.26
	Sep.	495,700	255.76	86,000	455.70
	Oct.	487,500	259.78	86,200	444.04
	Nov.	483,600	263.75	85,200	455.68
	Dec.	469,500	267.81	85,100	470.02
1982	Jan.	452,800	265.36	79,900	469.22
	Feb.	642,600	268.28	79,300	449.88
	Mar.	466,000	271.57	82,400	479.82
	Apr.	455,000	265.72	84,100	467.82
	May	456,700	267.91	86,600	488.07
	June	459,200	269.37	88,500	499.85
	July	438,800	270.03	85,300	490.10
	Aug.	449,100	267.89	86,000	499.37
	Sep.	453,000	270.05	87,900	504.75
	Oct.	445,800	275.15	87,900	499.73
	Nov.	440,300	282.96	88,500	525.62
	Dec.	430,500	287.36	87,900	531.80
1983	Jan.	417,200	283.75	81,900	536.51
	Feb.	426,100	278.17	81,100	527.95
	Mar.	432,300	284.34	83,600	535.36
	Apr.	430,300	287.73	86,800	542.36

	May	432,900	289.25	88,300	548.63
	June	439,000	291.19	90,100	559.40
	July	421,400	289.38	90,200	565.39
	Aug.	435,600	286.04	91,100	561.34
	Sep.	441,900	291.40	91,400	569.88
	Oct.	441,800	298.34	91,300	554.21
	Nov.	441,800	300.58	91,700	589.26
	Dec.	432,800	303.62	91,400	592.96
1984	Jan.	420,700	299.02	87,200	584.82
	Feb.	431,600	299.84	87,900	577.81
	Mar.	437,800	298.74	89,200	573.13
	Apr.	431,700	302.29	91,600	588.06
	May	433,100	301.10	93,500	592.92
	June	436,300	303.32	95,700	584.22
	July	420,300	299.67	95,600	578.14
	Aug.	432,200	299.92	96,800	584.77
	Sep.	435,700	306.64	97,900	603.88
	Oct.	429,200	310.70	99,400	604.76
	Nov.	427,300	322.34	99,700	601.43
	Dec.	419,100	326.86	99,800	621.23
1985	Jan.	403,800	313.05	95,500	605.63
	Feb.	411,900	318.84	95,000	607.34
	Mar.	416,100	317.46	97,800	623.90
	Apr.	407,600	314.03	102,800	627.99
	May	410,100	317.83	105,200	639.48
	June	411,700	318.20	107,600	646.65
	July	398,700	320.62	108,900	643.32
	Aug.	407,200	315.25	110,000	657.37
	Sep.	410,100	320.79	112,000	666.85
	Oct.	407,200	322.65	112,600	651.48
	Nov.	408,300	333.14	114,100	681.90
	Dec.	399,600	336.90	113,800	692.65
1986	Jan.	388,600	329.15	106,300	694.90
	Feb.	395,600	326.68	106,100	652.91
	Mar.	399,000	330.93	108,900	687.02
	Apr.	392,500	330.71	110,900	693.41
	May	392,000	330.62	112,500	703.64
	June	392,800	330.30	114,900	699.74
	July	383,500	328.33	116,600	715.17
	Aug.	390,700	332.84	117,500	713.22
	Sep.	395,100	333.16	119,000	736.06
	Oct.	393,100	335.07	117,700	678.46
	Nov.	390,900	342.00	117,200	729.96
	Dec.	384,000	347.22	116,300	726.14
1987	Jan.	370,000	345.03	110,500	701.06
	Feb.	378,400	345.20	109,500	639.54
	Mar.	384,100	346.30	112,400	707.49
	Apr.	377,700	344.28	115,700	705.39
	May	379,800	348.94	118,500	722.87
	June	382,600	350.81	121,500	741.90
	July	373,200	346.45	121,400	748.70
	Aug.	380,800	341.50	122,800	752.72
	Sep.	384,900	344.93	123,800	742.77

Oct.	382,800	350.34	123,000	714.99
Nov.	382,500	350.02	123,300	776.75
Dec.	377,800	351.87	123,200	763.75
1988 Jan.	362,100	339.84	112,800	736.99
Feb.	370,000	347.26	114,100	689.64
Mar.	375,000	350.62	117,800	752.84
Apr.	369,600	338.89	119,300	748.70
May	369,900	342.80	120,100	757.20
June	372,300	343.17	122,700	779.39
July	362,700	340.40	121,200	778.87
Aug.	370,400	345.38	121,300	776.14
Sep.	374,700	346.39	124,100	777.45
Oct.	372,900	356.38	123,000	786.37
Nov.	374,400	360.61	123,100	830.65
Dec.	367,100	362.33	121,800	823.25
1989 Jan.	353,300	359.41	113,100	797.16
Feb.	360,200	356.96	113,600	778.96
Mar.	363,700	360.98	116,700	821.38
Apr.	361,700	359.20	119,000	835.89
May	362,100	356.96	120,600	818.44
June	364,100	358.30	123,300	828.07
July	354,800	356.72	122,600	834.77
Aug.	362,600	360.51	124,100	828.37
Sep.	365,000	360.14	125,900	868.23
Oct.	360,000	361.72	124,100	857.38
Nov.	357,400	366.92	123,900	891.70
Dec.	349,200	372.25	123,300	862.07
1990 Jan.	332,900	366.83	112,600	823.37
Feb.	338,500	368.56	112,400	827.64
Mar.	342,900	376.29	115,100	596.54
Apr.	337,700	364.97	113,400	779.80
May	341,500	377.03	114,500	822.11
June	343,900	378.42	115,500	819.36
July	333,700	378.38	113,800	815.78
Aug.	339,700	377.68	113,700	606.70
Sep.	341,600	376.66	113,500	853.76
Oct.	338,200	378.96	112,300	619.28
Nov.	333,100	379.25	110,800	635.38
Dec.	326,400	338.13	106,800	609.61
1991 Jan.	316,100	379.34	100,300	835.67
Feb.	320,600	381.55	96,500	847.39
Mar.	323,200	383.63	98,500	844.88
Apr.	321,600	382.21	99,700	841.66
May	322,700	382.21	100,800	844.73
June	324,100	386.05	102,300	843.01
July	316,800	381.30	100,700	845.15

1.Number of employees in the manufacturing industry.

2.Average weekly earnings in the manufacturing industry.

3.Number of employees in the construction industry.

4.Average weekly earnings in the construction industry.

	MONTHS	TEEM[5]	TEWER[6]	ELEM[7]	ELWER[8]
1980	Jan.	59,000	402.79	24,800	413.34
	Feb.	59,400	421.26	24,900	419.24
	Mar.	59,600	401.60	24,900	410.35
	Apr.	59,000	389.65	24,800	403.92
	May	59,000	390.85	24,800	410.18
	June	59,300	393.22	24,900	413.88
	July	59,900	391.02	25,200	414.54
	Aug.	59,200	392.00	25,300	448.16
	Sep.	59,000	408.00	25,100	467.42
	Oct.	58,500	455.20	24,800	463.76
	Nov.	58,300	463.61	24,900	480.24
	Dec.	59,000	452.09	24,900	465.70
1981	Jan.	59,400	449.63	24,800	470.81
	Feb.	60,100	465.19	24,800	483.57
	Mar.	60,200	435.51	24,800	472.94
	Apr.	59,800	417.76	24,700	470.55
	May	59,900	427.60	24,700	456.46
	June	60,200	423.87	25,000	455.52
	July	60,600	428.79	25,600	449.96
	Aug.	60,500	464.09	25,500	481.50
	Sep.	60,000	487.81	25,400	490.35
	Oct.	59,600	491.78	24,800	503.70
	Nov.	59,300	501.90	24,800	515.57
	Dec.	59,400	497.90	24,800	496.34
1982	Jan.	59,300	473.98	24,700	503.18
	Feb.	59,700	495.81	24,600	524.61
	Mar.	59,700	472.42	24,600	497.80
	Apr.	59,300	469.64	24,600	503.14
	May	59,300	466.88	24,400	488.92
	June	59,700	476.39	24,600	501.83
	July	59,700	465.68	25,000	490.99
	Aug.	59,500	499.28	25,000	520.57
	Sep.	58,600	503.79	24,700	551.69
	Oct.	58,500	521.11	24,700	550.95
	Nov.	58,400	525.71	24,700	578.16
	Dec.	57,700	513.20	24,800	558.39
1983	Jan.	57,600	512.00	24,500	541.68
	Feb.	57,700	518.46	24,500	542.88
	Mar.	57,400	506.09	24,500	537.35
	Apr.	57,000	517.69	24,500	527.85
	May	56,700	499.50	24,400	538.32
	June	56,600	505.60	24,700	525.68
	July	56,600	519.79	9,600	519.84
	Aug.	34,600	304.80	9,700	540.35
	Sep.	56,300	530.32	24,400	540.60
	Oct.	55,400	560.05	24,300	573.70
	Nov.	56,100	620.49	24,300	575.46
	Dec.	56,400	581.30	24,200	567.60
1984	Jan.	55,300	529.99	24,200	590.67
	Feb.	56,300	543.35	24,000	590.39
	Mar.	55,200	514.56	23,900	581.09
	Apr.	54,300	524.40	23,800	580.13

	May	54,100	518.90	23,900	576.15
	June	54,000	529.20	24,000	585.90
	July	53,400	557.69	24,200	599.71
	Aug.	53,000	559.47	24,200	616.28
	Sep.	53,000	565.65	23,700	641.78
	Oct.	52,500	575.74	23,700	629.58
	Nov.	52,100	589.36	23,700	652.74
	Dec.	52,200	574.73	23,700	633.14
1985	Jan.	51,400	561.56	23,700	625.10
	Feb.	51,300	599.63	23,600	632.91
	Mar.	50,900	553.42	23,500	621.65
	Apr.	50,600	545.27	23,400	619.06
	May	50,200	552.42	23,400	627.27
	June	49,900	554.21	23,700	610.61
	July	49,400	551.60	23,800	623.17
	Aug.	49,100	583.78	23,800	604.78
	Sep.	48,500	584.99	23,400	667.93
	Oct.	47,500	592.59	23,300	703.95
	Nov.	47,700	624.70	23,400	696.78
	Dec.	47,600	596.96	23,300	663.34
1986	Jan.	44,900	588.63	23,200	650.60
	Feb.	45,200	605.05	23,200	669.11
	Mar.	45,300	587.73	23,100	654.99
	Apr.	43,300	591.34	23,100	649.30
	May	43,100	600.07	23,100	647.79
	June	40,000	615.68	23,100	644.54
	July	42,800	590.24	23,500	642.64
	Aug.	26,600	477.59	23,500	576.67
	Sep.	42,300	595.50	20,800	744.11
	Oct.	41,600	641.45	20,600	737.38
	Nov.	41,500	685.97	22,800	677.30
	Dec.	41,000	671.23	22,900	681.33
1987	Jan.	40,500	678.26	22,800	676.82
	Feb.	40,400	640.90	22,800	700.13
	Mar.	40,400	654.91	22,700	690.99
	Apr.	39,700	638.15	22,700	682.08
	May	39,800	631.31	22,800	678.51
	June	40,000	633.23	22,800	677.04
	July	39,800	686.99	23,200	686.45
	Aug.	39,800	688.42	23,200	686.71
	Sep.	39,900	716.72	22,700	699.08
	Oct.	39,900	743.15	22,600	733.04
	Nov.	40,000	745.07	22,600	687.04
	Dec.	40,200	698.21	22,600	727.72
1988	Jan.	40,600	694.59	22,600	679.90
	Feb.	40,500	736.79	22,500	670.23
	Mar.	40,500	706.48	22,400	718.96
	Apr.	40,600	687.52	22,600	657.61
	May	40,300	687.52	22,600	707.19
	June	40,500	673.32	22,900	696.14
	July	40,300	664.26	23,300	721.11
	Aug.	40,400	669.06	23,300	712.75
	Sep.	40,200	664.47	22,800	736.50

	Oct.	40,800	654.46	22,800	740.15
	Nov.	40,900	652.76	22,900	736.56
	Dec.	41,200	699.34	22,900	743.04
1989	Jan.	40,300	642.80	22,900	745.04
	Feb.	40,400	647.54	23,000	732.34
	Mar.	40,600	622.05	23,000	739.47
	Apr.	38,800	634.81	23,000	749.83
	May	38,700	624.87	23,000	745.27
	June	38,900	608.79	23,200	734.60
	July	38,500	609.52	23,600	729.17
	Aug.	21,300	637.78	23,500	704.16
	Sep.	18,800	626.94	22,700	769.52
	Oct.	19,700	652.69	22,500	784.80
	Nov.	19,300	629.53	22,400	790.27
	Dec.	37,800	628.62	22,400	817.78
1990	Jan.	36,600	633.29	22,300	795.22
	Feb.	36,900	633.36	22,300	779.68
	Mar.	35,000	634.92	22,300	779.64
	Apr.	36,700	633.04	22,400	767.37
	May	36,900	643.36	22,400	766.04
	June	35,900	641.03	22,500	753.86
	July	35,700	647.60	22,900	769.63
	Aug.	35,600	659.15	22,900	752.80
	Sep.	35,600	669.61	22,300	792.51
	Oct.	35,900	701.78	22,200	796.72
	Nov.	35,600	696.80	22,200	802.68
	Dec.	35,600	664.97	22,100	786.92
1991	Jan.	34,900	675.68	22,200	789.70
	Feb.	35,100	694.55	22,100	804.69
	Mar.	35,200	668.68	22,100	803.73
	Apr.	35,200	656.00	22,100	796.21
	May	35,000	652.38	22,100	801.10
	June	35,000	648.76	22,200	789.26
	July	35,300	635.90	22,600	795.07

5.Number of employees in the telephone and telegram industry.

6.Average weekly earnings in the telephone and telegram industry.

7.Number of employees in the electric, gas and sanitary services.

8.Average weekly earnings in the electric, gas and sanitary services.

	MONTHS	WHEM[9]	WHWER[10]	TWER[11]	STEM[12]
1980	Jan.	245,000	301.18	249,000,000	892,800
	Feb.	245,600	299.83	254,000,000	904,100
	Mar.	247,300	301.13	256,000,000	912,800
	Apr.	245,100	302.44	248,000,000	895,200
	May	245,900	300.58	254,000,000	907,100
	June	246,400	301.38	258,000,000	911,600
	July	244,900	304.37	254,000,000	890,000
	Aug.	245,100	301.32	257,000,000	901,400
	Sep.	245,800	305.04	261,000,000	906,900
	Oct.	246,300	306.16	266,000,000	908,200
	Nov.	246,900	313.96	272,000,000	905,300
	Dec.	247,800	314.42	272,000,000	895,600
1981	Jan.	246,300	321.58	268,000,000	875,900
	Feb.	246,700	323.95	273,000,000	891,000
	Mar.	247,500	328.10	279,000,000	900,000
	Apr.	247,300	327.75	277,000,000	901,100
	May	247,300	330.75	280,000,000	905,400
	June	248,400	327.62	283,000,000	913,700
	July	246,300	332.63	278,000,000	895,800
	Aug.	247,100	337.19	287,000,000	907,900
	Sep.	247,700	334.43	291,000,000	914,800
	Oct.	248,600	344.96	292,000,000	906,700
	Nov.	248,800	348.23	296,000,000	901,700
	Dec.	248,500	348.30	294,000,000	887,300
1982	Jan.	246,400	357.93	286,000,000	863,100
	Feb.	246,200	363.65	340,000,000	1,052,400
	Mar.	246,600	357.96	295,000,000	879,300
	Apr.	246,600	353.81	288,000,000	869,600
	May	246,600	358.52	293,000,000	873,600
	June	246,800	360.02	298,000,000	878,800
	July	243,900	361.95	289,000,000	852,700
	Aug.	243,900	364.62	295,000,000	863,500
	Sep.	243,200	364.34	298,000,000	867,400
	Oct.	242,200	366.49	299,000,000	859,100
	Nov.	242,000	374.40	307,000,000	853,900
	Dec.	421,700	380.16	374,000,000	1,022,600
1983	Jan.	237,400	387.54	297,000,000	818,600
	Feb.	236,300	378.62	294,000,000	825,700
	Mar.	237,500	383.53	301,000,000	835,300
	Apr.	238,400	378.13	303,000,000	837,000
	May	237,900	376.50	305,000,000	840,200
	June	239,400	377.88	310,000,000	849,800
	July	239,300	380.46	298,000,000	817,100
	Aug.	240,600	359.07	278,000,000	811,600
	Sep.	241,100	381.58	316,000,000	855,100
	Oct.	242,200	389.06	322,000,000	855,000
	Nov.	242,600	395.64	332,000,000	856,500
	Dec.	242,200	399.19	329,000,000	847,000
1984	Jan.	240,600	395.37	316,000,000	828,000
	Feb.	241,400	395.20	320,000,000	841,200
	Mar.	243,100	391.23	319,000,000	849,200
	Apr.	243,700	402.34	325,000,000	845,100

	May	244,800	400.60	326,000,000	849,400
	June	246,700	403.10	330,000,000	856,700
	July	246,600	404.46	325,000,000	840,100
	Aug.	248,200	403.77	331,000,000	854,400
	Sep.	247,900	406.73	339,000,000	858,200
	Oct.	248,600	410.08	341,000,000	853,400
	Nov.	249,000	411.92	346,000,000	851,800
	Dec.	248,600	420.92	349,000,000	843,400
1985	Jan.	245,700	417.58	331,000,000	820,100
	Feb.	245,800	414.63	337,000,000	827,600
	Mar.	247,000	414.32	338,000,000	835,300
	Apr.	246,100	405.75	334,000,000	830,500
	May	245,600	407.96	340,000,000	834,500
	June	245,700	419.14	346,000,000	838,600
	July	242,400	420.66	342,000,000	823,200
	Aug.	242,500	414.32	344,000,000	832,600
	Sep.	241,100	421.47	352,000,000	835,100
	Oct.	242,000	415.45	350,000,000	832,600
	Nov.	243,000	426.72	364,000,000	836,500
	Dec.	242,200	436.24	363,000,000	826,500
1986	Jan.	237,500	435.86	347,000,000	800,500
	Feb.	237,600	436.54	345,000,000	807,700
	Mar.	238,300	436.97	353,000,000	814,600
	Apr.	238,500	430.14	350,000,000	808,300
	May	238,200	433.96	353,000,000	808,900
	June	238,600	437.76	354,000,000	809,400
	July	237,900	431.67	352,000,000	804,300
	Aug.	237,700	429.79	342,000,000	796,000
	Sep.	238,400	435.85	364,000,000	815,600
	Oct.	238,600	440.63	359,000,000	811,600
	Nov.	239,300	450.07	371,000,000	811,700
	Dec.	240,100	453.66	370,000,000	804,300
1987	Jan.	235,400	457.25	356,000,000	779,200
	Feb.	235,200	456.32	350,000,000	786,300
	Mar.	236,000	446.31	360,000,000	795,600
	Apr.	236,100	450.30	359,000,000	791,900
	May	236,200	460.31	368,000,000	797,100
	June	237,200	458.89	374,000,000	804,100
	July	234,000	462.22	372,000,000	791,600
	Aug.	234,100	458.89	373,000,000	800,700
	Sep.	234,000	477.88	381,000,000	805,300
	Oct.	234,300	470.78	379,000,000	802,600
	Nov.	234,000	479.42	387,000,000	802,400
	Dec.	233,200	473.69	382,000,000	797,000
1988	Jan.	230,800	477.92	360,000,000	768,900
	Feb.	231,800	484.38	364,000,000	778,900
	Mar.	232,700	480.95	377,000,000	788,400
	Apr.	230,200	493.01	371,000,000	782,300
	May	230,700	487.30	374,000,000	783,600
	June	231,800	485.01	379,000,000	790,200
	July	231,200	494.92	376,000,000	778,700
	Aug.	231,800	480.53	377,000,000	787,200
	Sep.	232,900	490.81	384,000,000	794,700

	Oct.	233,000	496.44	389,000,000	792,500
	Nov.	234,400	496.37	397,000,000	795,700
	Dec.	234,900	492.53	395,000,000	787,900
1989	Jan.	229,500	490.68	373,000,000	759,100
	Feb.	229,700	499.53	375,000,000	766,900
	Mar.	230,500	501.42	385,000,000	774,500
	Apr.	229,000	509.76	388,000,000	771,500
	May	228,900	497.07	383,000,000	773,300
	June	230,000	505.02	389,000,000	779,500
	July	227,300	497.79	383,000,000	766,800
	Aug.	226,800	493.49	376,000,000	758,300
	Sep.	226,400	496.87	383,000,000	758,800
	Oct.	226,400	496.49	380,000,000	752,700
	Nov.	227,000	503.26	386,000,000	750,000
	Dec.	226,300	501.40	392,000,000	759,000
1990	Jan.	220,400	500.83	366,000,000	724,800
	Feb.	220,800	512.86	372,000,000	730,900
	Mar.	222,000	520.51	353,000,000	737,300
	Apr.	220,100	521.14	367,000,000	730,300
	May	221,300	520.13	379,000,000	736,600
	June	222,000	524.37	381,000,000	739,800
	July	219,800	521.88	375,000,000	725,900
	Aug.	218,900	519.99	352,000,000	730,800
	Sep.	217,400	522.96	381,000,000	730,400
	Oct.	217,200	517.78	353,000,000	725,800
	Nov.	215,600	518.16	351,000,000	717,300
	Dec.	214,500	528.99	330,000,000	705,400
1991	Jan.	211,000	527.39	356,000,000	684,500
	Feb.	210,000	530.46	358,000,000	684,300
	Mar.	210,700	529.92	360,000,000	689,700
	Apr.	210,100	533.27	360,000,000	688,700
	May	210,400	531.84	361,000,000	691,000
	June	211,400	531.88	364,000,000	695,000
	July	209,300	522.15	356,000,000	684,700

9.Number of employees in the wholesale trade.

10.Average weekly earnings in the wholesale trade.

11.Total employees:
(MAEM*MAWER)+(COEM*COWER)+(TEEM*TWER)+(ELEM*ELWER)+(WHEM*WHWER).

12.Total employees: MAEM+COEM+TEEM+ELEM

	MONTHS	AVEWER[13]	DAVEWER[14]	WEEK[15]	INC[16]
1980	Jan.	278.7923	356.5119	4.428	1578.634
	Feb.	281.2262	356.4338	4.143	1476.705
	Mar.	280.3370	350.4213	4.428	1551.665
	Apr.	277.3917	344.1584	4.285	1474.719
	May	279.5040	344.6412	4.428	1526.071
	June	283.0258	344.7331	4.285	1477.181
	July	285.8515	346.0672	4.428	1532.385
	Aug.	285.0475	342.1939	4.428	1515.234
	Sep.	287.7404	344.1870	4.285	1474.841
	Oct.	292.9137	348.2921	4.428	1542.238
	Nov.	300.4976	355.1981	4.285	1522.024
	Dec.	304.0288	355.5893	4.428	1574.549
1981	Jan.	306.0494	354.6343	4.428	1570.320
	Feb.	306.0392	350.1593	4.000	1400.637
	Mar.	309.6578	352.6854	4.428	1561.691
	Apr.	307.9000	348.6977	4.285	1494.169
	May	308.7859	347.7318	4.428	1539.756
	June	309.3989	345.6971	4.285	1481.312
	July	310.7902	342.2800	4.428	1515.616
	Aug.	316.0943	345.0812	4.428	1528.019
	Sep.	317.5910	341.4957	4.285	1463.309
	Oct.	322.5741	347.9763	4.428	1540.839
	Nov.	327.7829	353.9772	4.285	1516.792
	Dec.	331.5367	357.6448	4.428	1583.651
1982	Jan.	331.7984	357.1565	4.428	1581.489
	Feb.	323.1738	347.1255	4.000	1388.502
	Mar.	335.2793	362.4641	4.428	1604.991
	Apr.	330.8679	356.5387	4.285	1527.768
	May	334.9909	357.5143	4.428	1583.073
	June	338.6093	353.8237	4.285	1516.135
	July	338.5131	352.9855	4.428	1563.020
	Aug.	341.5257	354.6477	4.428	1570.380
	Sep.	344.0817	354.3581	4.285	1518.425
	Oct.	348.5571	354.2247	4.428	1568.507
	Nov.	359.1656	366.1219	4.285	1568.832
	Dec.	365.9563	375.3398	4.428	1662.004
1983	Jan.	362.9184	371.0822	4.428	1643.152
	Feb.	356.0961	363.3634	4.000	1453.454
	Mar.	360.3248	367.3036	4.428	1626.420
	Apr.	362.5734	365.8662	4.285	1567.737
	May	362.6355	364.8245	4.428	1615.443
	June	365.1448	366.2436	4.285	1569.354
	July	365.1910	365.1910	4.428	1617.066
	Aug.	342.4308	342.0887	4.428	1514.769
	Sep.	369.4343	365.7766	4.285	1567.353
	Oct.	376.1450	371.3179	4.428	1644.196
	Nov.	387.1650	380.6932	4.285	1631.270
	Dec.	388.2035	381.3394	4.428	1688.571
1984	Jan.	381.0661	370.6868	4.428	1641.401
	Feb.	380.8389	368.3162	4.143	1525.934
	Mar.	376.0143	362.5982	4.428	1605.585
	Apr.	384.2115	369.0793	4.285	1581.505

	May	383.5105	368.4058	4.428	1631.301
	June	385.5860	369.6894	4.285	1584.119
	July	387.1622	369.4296	4.428	1635.834
	Aug.	387.4213	367.2240	4.428	1626.068
	Sep.	394.7109	371.6675	4.285	1592.595
	Oct.	399.0612	376.1180	4.428	1665.451
	Nov.	406.7177	381.8945	4.285	1636.418
	Dec.	413.3659	388.1370	4.428	1718.671
1985	Jan.	403.0310	377.7235	4.428	1672.560
	Feb.	406.7681	379.0942	4.000	1516.377
	Mar.	404.9173	376.6673	4.428	1667.883
	Apr.	402.7547	373.2666	4.285	1599.447
	May	407.6932	377.1445	4.428	1669.996
	June	412.2248	380.6323	4.285	1631.009
	July	415.3756	383.1878	4.428	1696.756
	Aug.	413.4164	378.5864	4.428	1676.381
	Sep.	421.3402	384.4345	4.285	1647.302
	Oct.	420.1642	382.6632	4.428	1694.433
	Nov.	434.6941	392.6776	4.285	1682.624
	Dec.	439.1739	395.6522	4.428	1751.948
1986	Jan.	433.2489	387.5213	4.428	1715.945
	Feb.	427.2649	383.1972	4.000	1532.789
	Mar.	433.0247	388.3630	4.428	1719.671
	Apr.	432.8778	389.2786	4.285	1668.059
	May	436.3441	393.4573	4.428	1742.229
	June	437.4939	391.6687	4.285	1678.300
	July	438.0977	389.4202	4.428	1724.353
	Aug.	429.9757	381.5224	4.428	1689.381
	Sep.	446.0476	394.7324	4.285	1691.428
	Oct.	441.8179	389.6102	4.428	1725.194
	Nov.	456.8819	403.2497	4.285	1727.925
	Dec.	459.8150	404.0554	4.428	1789.157
1987	Jan.	456.4501	397.9513	4.428	1762.128
	Feb.	444.9130	385.8742	4.000	1543.497
	Mar.	452.4996	390.7596	4.428	1730.284
	Apr.	453.0645	388.5630	4.285	1664.993
	May	461.0575	393.0584	4.428	1740.462
	June	465.0854	394.8093	4.285	1691.758
	July	469.4475	398.1743	4.428	1763.116
	Aug.	466.1348	392.0394	4.428	1735.950
	Sep.	473.1263	394.9302	4.285	1692.276
	Oct.	471.6871	392.4186	4.428	1737.629
	Nov.	482.5151	400.4275	4.285	1715.832
	Dec.	479.3093	397.4372	4.428	1759.852
1988	Jan.	468.2775	416.9880	4.428	1846.423
	Feb.	467.8053	417.3107	4.143	1728.918
	Mar.	477.9316	393.3593	4.428	1741.795
	Apr.	474.0379	386.6541	4.285	1656.813
	May	477.0943	388.8299	4.428	1721.739
	June	479.6630	389.6532	4.285	1669.664
	July	482.6752	390.5139	4.428	1729.196
	Aug.	479.0377	385.6986	4.428	1707.874
	Sep.	483.3112	383.5803	4.285	1643.642

	Oct.	490.6820	388.8130	4.428	1721.664
	Nov.	499.1575	396.4714	4.285	1698.880
	Dec.	501.0876	397.6886	4.428	1760.965
1989	Jan.	490.9968	386.6116	4.428	1711.916
	Feb.	488.7382	383.0237	4.000	1532.095
	Mar.	497.0740	385.6276	4.428	1707.559
	Apr.	502.9233	388.3577	4.285	1664.113
	May	495.3603	380.4610	4.428	1684.681
	June	499.5989	382.8344	4.285	1640.445
	July	499.1258	382.1790	4.428	1692.289
	Aug.	495.2890	378.3720	4.428	1675.431
	Sep.	504.0949	381.3123	4.285	1633.923
	Oct.	504.2399	379.6987	4.428	1681.306
	Nov.	514.2811	386.0969	4.285	1654.425
	Dec.	516.2449	387.2805	4.428	1714.878
1990	Jan.	505.1379	373.8992	4.428	1655.626
	Feb.	508.6628	375.9518	4.000	1503.807
	Mar.	478.5745	350.3474	4.428	1551.338
	Apr.	502.2652	365.8159	4.285	1567.521
	May	514.3788	374.9116	4.428	1660.109
	June	515.2199	375.7986	4.285	1610.297
	July	515.9860	372.8223	4.428	1650.857
	Aug.	481.4044	343.8603	4.428	1522.613
	Sep.	521.3190	370.2550	4.285	1586.543
	Oct.	486.4320	343.5254	4.428	1521.130
	Nov.	489.4314	345.8879	4.285	1482.130
	Dec.	467.8256	330.3853	4.428	1462.946
1991	Jan.	520.2614	363.8192	4.428	1610.991
	Feb.	522.6611	363.9702	4.000	1455.881
	Mar.	522.2039	364.1589	4.428	1612.496
	Apr.	522.0847	363.3157	4.285	1556.808
	May	522.3223	362.7238	4.428	1606.141
	June	523.7789	362.2261	4.285	1552.139
	July	519.3578	357.6844	4.428	1583.827

13.Average weekly earnings: TWER/STEM

14.Deflated average weekly earnings: AVEWER/CPINY

15.Number of weeks in the month: number of days in the month/7

16.Deflated monthly income: DAVEWER*WEEK

APPENDIX D

DERIVATION OF THE REDUCED-FORM EQUATIONS FOR q_t^r and p_t^r

APPENDIX D

DERIVATION OF THE REDUCED-FORM EQUATIONS FOR q_t^r AND p_{qt}^r

Using equations (3.1),(3.2),(3.3) and (3.4) in Chapter III, we can derive the reduced-form equations for q_t^r and p_{qt}^r. For doing this, we first need to solve for the reduced- form equations for q_t^n and p_{qt}^n as functions of all the exogenous variables in the system.

The reduced-form equation for q_t^n is obtained by substituting p_{qt}^n in equation (3.4) into p_{yt}^o in equation (3.3). Note that $p_{qt}^o = p_{qt}^n$, since the transportation costs to region o is assumed to be equal to zero in equation (3.2).

(D.1)
$$q_t^n = \beta_1^o(\beta_5^n q_t^n + \beta_6^n h_t^n + \beta_7^n f_t^n) + \beta_2^o p_{yt}^o + \beta_3^o m_t^o + \beta_4^o f_t^o + \beta_1^r p_{qt}^r + \beta_2^r p_{yt}^r + \beta_3^r m_t^r + \beta_4^r f_t^r + \gamma_t$$

(D.2)
$$q_t^n = \frac{\beta_1^o\beta_6^n}{1-\beta_1^o\beta_5^n}h_t^n + \frac{\beta_1^o\beta_7^n}{1-\beta_1^o\beta_5^n}f_t^n + \frac{\beta_2^o}{1-\beta_1^o\beta_5^n}p_{yt}^o + \frac{\beta_3^o}{1-\beta_1^o\beta_5^n}m_t^o + \frac{\beta_4^o}{1-\beta_1^o\beta_5^n}f_t^o + \frac{\beta_1^r}{1-\beta_1^o\beta_5^n}p_{qt}^r + \frac{\beta_2^r}{1-\beta_1^o\beta_5^n}p_{yt}^r + \frac{\beta_3^r}{1-\beta_1^o\beta_5^n}m_t^r + \frac{\beta_4^r}{1-\beta_1^o\beta_5^n}f_t^r + \zeta_t$$

The reduced-form equation for p_{qt}^n is obtained by substituting q_t^n in equation (3.3) into q_t^n in equation (3.4).

(D.3)

$$p_{qt}^{n} = \beta_5^n(\beta_1^r p_{qt}^r + \beta_2^r p_{yt}^r + \beta_3^r m_t^r + \beta_4^r f_t^r + \beta_1^o p_{qt}^n + \beta_2^o p_{yt}^o + \beta_3^o m_t^o + \beta_4^o f_t^o) + \beta_6^n h_t^n + \beta_7^n f_t^n + v_t$$

(D.4)

$$\begin{aligned} p_{qt}^{n} = {} & \frac{\beta_6^n}{1-\beta_1^o\beta_5^n} h_t^n + \frac{\beta_7^n}{1-\beta_1^o\beta_5^n} f_t^n + \frac{\beta_5^n\beta_2^o}{1-\beta_1^o\beta_5^n} p_{yt}^o \\ & + \frac{\beta_5^n\beta_3^o}{1-\beta_1^o\beta_5^n} m_t^o + \frac{\beta_5^n\beta_4^o}{1-\beta_1^o\beta_5^n} f_t^o + \frac{\beta_5^n\beta_1^r}{1-\beta_1^o\beta_5^n} p_{qt}^r \\ & + \frac{\beta_5^n\beta_2^r}{1-\beta_1^o\beta_5^n} p_{yt}^r + \frac{\beta_5^n\beta_3^r}{1-\beta_1^o\beta_5^n} m_t^r + \frac{\beta_5^n\beta_4^r}{1-\beta_1^o\beta_5^n} f_t^r + z_t \end{aligned}$$

The reduced-form equation for p_{qt}^r is obtained by substituting the reduced-form equation for p_{qt}^n into $p_{qt}^r = c*p_{qt}^n$ in equation (3.1).

(D.5)

$$\begin{aligned} p_{qt}^{r} = {} & \frac{c\beta_6^n}{1-\beta_1^o\beta_5^n} h_t^n + \frac{c\beta_7^n}{1-\beta_1^o\beta_5^n} f_t^n + \frac{c\beta_5^n\beta_2^o}{1-\beta_1^o\beta_5^n} p_{yt}^o \\ & + \frac{c\beta_5^n\beta_3^o}{1-\beta_1^o\beta_5^n} m_t^o + \frac{c\beta_5^n\beta_4^o}{1-\beta_1^o\beta_5^n} f_t^r + \frac{c\beta_5^n\beta_1^r}{1-\beta_1^o\beta_5^n} p_{qt}^r \\ & + \frac{c\beta_5^n\beta_2^r}{1-\beta_1^o\beta_5^n} p_{yt}^r + \frac{c\beta_5^n\beta_3^r}{1-\beta_1^o\beta_5^n} m_t^r + \frac{c\beta_5^n\beta_4^r}{1-\beta_1^o\beta_5^n} f_t^r + \tau_t \end{aligned}$$

Let $K = 1 - \frac{c\beta_5^n\beta_1^r}{1-\beta_1^o\beta_5^n}$. Then we can simplify (D.5) as,

(D.6)

$$p_{qt}^{r} = [(\frac{c\beta_6^n}{1-\beta_1^o\beta_5^n})/K]h_t^n+[(\frac{c\beta_7^n}{1-\beta_1^o\beta_5^n})/K]f_t^n$$

$$+[(\frac{c\beta_5^n\beta_2^o}{1-\beta_1^o\beta_5^n})/K]p_{yt}^o+[(\frac{c\beta_5^n\beta_3^o}{1-\beta_1^o\beta_5^n})/K]m_t^o$$

$$+[(\frac{c\beta_5^n\beta_4^o}{1-\beta_1^o\beta_5^n})/K]f_t^o+[(\frac{c\beta_5^n\beta_2^r}{1-\beta_1^o\beta_5^N})/K]p_{yt}^r$$

$$+[(\frac{c\beta_5^n\beta_3^r}{1-\beta_1^o\beta_5^n})/K]m_t^r+[(\frac{c\beta_5^n\beta_4^r}{1-\beta_1^o\beta_5^n})/K]f_t^r+\varsigma_t$$

The reduced-form equation for q_t^r is obtained by substituting the reduced-form equation for p_{qt}^r into the p_{qt}^r in the demand equation for NYC region (equation (3.1)).

(D.7)

$$q_t^r = [(\frac{\beta_1^r c\beta_6^r}{1-\beta_1^o\beta_5^r})/K]h_t^n+[(\frac{\beta_1^r c\beta_7^n}{1-\beta_1^o\beta_5^n})/K]f_t^n$$

$$+[(\frac{\beta_1^r c\beta_2^o\beta_5^n}{1-\beta_1^o\beta_5^n})/K]p_{yt}^o+[(\frac{\beta_1^r c\beta_5^n\beta_3^o}{1-\beta_1^o\beta_5^n})/K]m_t^o$$

$$+[(\frac{\beta_1^r c\beta_5^n\beta_4^o}{1-\beta_1^o\beta_5^n})/K]f_t^o+([(\frac{\beta_1^r c\beta_5^n\beta_2^r}{1-\beta_1^o\beta_5^n})/K]+\beta_2^r)p_{yt}^r$$

$$+([(\frac{\beta_1^r c\beta_5^n\beta_3^r}{1-\beta_1^o\beta_5^n})/K]+\beta_3^r)m_t^r+([(\frac{\beta_1^r c\beta_5^n\beta_4^r}{1-\beta_1^o\beta_5^n})/K]+\beta_4^r)f_t^r+\xi$$

Equations (D.6) and (D.7) are the reduced-form equations for price and quantity in the NYC region.

The coefficients on the information variables in the reduced-form equation for price are as follows:

Coefficient for the f_t^m variable:

(D.8)
$$\alpha_2 = \frac{\dfrac{cb_7^m}{1-\beta_1^o\beta_5^m}}{1-\dfrac{c\beta_5^m\beta_1^r}{1-\beta_1^o\beta_5^m}} = \frac{c\beta_7^m}{1-\beta_5^m(\beta_1^o+c\beta_1^r)}$$

Coefficient for the f_t^o variable:

(D.9)
$$\alpha_5 = \frac{\dfrac{c\beta_5^m\beta_4^o}{1-\beta_1^o\beta_5^m}}{1-\dfrac{c\beta_5^m\beta_1^r}{1-\beta_1^o\beta_5^m}} = \frac{c\beta_5^m\beta_4^o}{1-\beta_5^m(\beta_1^o+c\beta_1^r)}$$

Coefficient for the f_t^r variable:

(D.10)
$$\alpha_8 = \frac{\dfrac{c\beta_5^m\beta_4^r}{1-\beta_1^o\beta_5^m}}{1-\dfrac{c\beta_5^m\beta_1^r}{1-\beta_1^o\beta_5^m}} = \frac{c\beta_5^m\beta_4^r}{1-\beta_5^m(\beta_1^o+c\beta_1^r)}$$

We can express equation (3.11) in Chapter III as,

(D.11)
$$\hat{\alpha}^r = \frac{c\beta_7^m}{1-\beta_5^m(\beta_1^o + c\beta_1^r)} + \frac{c\beta_5^m\beta_4^o}{1-\beta_5^m(\beta_1^o+c\beta_1^r)} + \frac{c\beta_5^m\beta_4^o}{1-\beta_5^m(\beta_1^o+c\beta_1^r)}$$

By collecting terms (D.11) can be expressed as,

(D.12)
$$\hat{\alpha}^r = \frac{c(\beta_7^m+\beta_5^m(\beta_4^o+\beta_4^r))}{1-\beta_5^m(\beta_1^o+c\beta_1^r)}$$

The coefficients on the information variables in the reduced-form equation for quantity are as follows:

Coefficient for the f_t^n variable:

(D.13)
$$\gamma_2 = \frac{\dfrac{c\beta_1^r\beta_7^n}{1-\beta_1^o\beta_5^n}}{1-\dfrac{c\beta_5^n\beta_1^r}{1-\beta_1^o\beta_5^n}} = \frac{c\beta_1^r\beta_7^n}{1-\beta_5^n(\beta_1^o+c\beta_1^r)}$$

Coefficient for the f_t^o variable:

(D.14)
$$\gamma_5 = \frac{\dfrac{c\beta_1^r\beta_5^n\beta_4^o}{1-\beta_1^o\beta_5^n}}{1-\dfrac{c\beta_5^n\beta_1^r}{1-\beta_1^o\beta_5^n}} = \frac{c\beta_1^r\beta_5^n\beta_4^o}{1-\beta_5^n(\beta_1^o+c\beta_1^r)}$$

Coefficient for the f_t^r variable:

(D.15)
$$\gamma_8 = \frac{\dfrac{c\beta_1^r\beta_5^n\beta_4^r}{1-\beta_1^o\beta_5^n}}{1-\dfrac{c\beta_5^n\beta_1^r}{1-\beta_1^o\beta_5^n}} = \frac{c\beta_1^r\beta_5^n\beta_4^r}{1-\beta_5^n(\beta_1^o+c\beta_1^r)}+\beta_4^r$$

We can express equation (3.7) in Chapter III as,

(D.16)
$$\hat{\gamma}^r = \frac{c\beta_1^r\beta_7^n}{1-\beta_5^n(\beta_1^o+c\beta_1^r)} + \frac{c\beta_1^r\beta_5^n\beta_4^o}{1-\beta_5^n(\beta_1^o+c\beta_1^r)} + \frac{c\beta_1^r\beta_5^n\beta_4^r}{1-\beta_5^n(\beta_1^o+c\beta_1^r)}+\beta_4^r$$

By collecting terms (D.16) can be expressed as,

(D.17)

$$\hat{\gamma}^{r} = \frac{c\beta_1^r(\beta_7^n + \beta_5^n(\beta_4^o + \beta_4^r))}{1 - \beta_5^n(\beta_1^o + c\beta_1^r)} + \beta_4^r$$

Substitute (D.12) into (D.17),

(D.18)

$$\hat{\gamma}_r = (\beta_1^r * \hat{\alpha}^r) + \beta_4^r$$

APPENDIX E

THE ASYMPTOTIC COVARIANCE MATRIX FOR THE TWO-STAGE LEAST SQUARES ESTIMATOR WITH SEASONAL ARIMA ERRORS

APPENDIX E

THE ASYMPTOTIC COVARIANCE MATRIX FOR THE TWO-STAGE LEAST SQUARES ESTIMATOR WITH SEASONAL ARIMA ERRORS

Demand equation for apples in the NYC region is,

$$q_t^r = f_t(\beta,\alpha)+e_t \tag{E.1}$$

where q_t^r is the per capita quantity of apples at time t, $f_t(\beta,\alpha)$ is the demand equation, β and α are vectors of regression parameters and e_t is the random error term at time t. Here, α is the parameter vector of the price equation that we use to obtain the fitted values for the price variable. These fitted values are then used in the demand equation in place of the observed values of the price variable. β denotes the vector of the parameters for all other variables in the demand equation.

The equation to estimate the fitted values for the price variable is,

$$p_{qt}^r = g_t(\alpha)+v_t \tag{E.2}$$

where p_{qt}^r is the retail price of apples at time t, $g_t(\alpha)$ is the price equation, α is the vector of regression parameters and v_t is the random error term at time t.

The fitted values of the price is estimated by equation (E.2) and is replaced in the demand equation in place of the price variable.

Nonlinear least squares method is used in estimating the equations in the presence of a seasonal error structure. The demand equation and the price equation are both defined to be nonlinear to obtain the general form of the asymptotic covariance matrix.

The criterion function to obtain the estimate β, $\hat{\beta}$, in the demand equation by nonlinear least squares is,

(E.3) $$S(\beta) = \sum_{t=1}^{T} [(q_t^r - f_t(\beta,\alpha)]^2$$

The first order conditions for a minimum are,

(E.4) $$-2\sum_{t=1}^{T} (\frac{\partial f_t}{\partial \beta}.e_t)|_{\hat{\beta}}=0$$

Equation (E.4) defines the standard problem in the nonlinear optimization, which can be solved by number of methods. One most frequently used method is the Gauss-Newton method. This method provides the correct estimate of the asymptotic covariance matrix for the parameter estimates.[1]

Divide both sides of (E.4) by -2,

(E.5) $$\sum_{t=1}^{T} (\frac{\partial f_t}{\partial \beta}.e_t)|_{\hat{\beta}}=0$$

The above equation can be rewritten in matrix form as:

(E.6) $$(\frac{\partial f'}{\partial \beta}.e)|_{\hat{\beta}} = 0$$

where $\frac{\partial f}{\partial \beta}$ is a (TxK) matrix and e is a (Tx1) vector. T denotes the number of observations and K denotes the number of estimated parameters in the demand equation.

[1]William H. Greene, p.336.

Following the central limit theorem that provides the asymptotic normality result of the least squares estimator,[1] we can write the following equality:

(E.7)
$$T^{-1/2}\frac{\partial f}{\partial \beta}'.e = 0$$

Using the mean-value theorem,[2] we can write (E.7) as,

(E.8)
$$T^{-1/2}\frac{\partial f}{\partial \beta}'.e = T^{-1/2}(\frac{\partial f}{\partial \beta}'.e)|_{\hat{\beta}}$$
$$+ [\frac{1}{T}(\frac{\partial^2 f}{\partial \beta^2}'.e)|_{\breve{\beta}} + \frac{1}{T}(\frac{\partial f}{\partial \beta}'.\frac{\partial e}{\partial \beta})|_{\breve{\beta}}]\sqrt{T}(\beta - \hat{\beta})$$

where, $\frac{\partial e}{\partial \beta}|_{\breve{\beta}} = -\frac{\partial f}{\partial \beta}|_{\breve{\beta}}$. The mean value of β, $\breve{\beta}$, is a value between β and the estimate of β, $\hat{\beta}$. Note that in equation (E.8), $T^{-1/2}\frac{\partial f}{\partial \beta}'.e|_{\hat{\beta}} = 0$. This result comes from (E.6). We can then write equation (E.8) as,

(E.9)
$$T^{-1/2}\frac{\partial f}{\partial \beta}'.e = [-\frac{1}{T}(\frac{\partial^2 f}{\partial \beta^2}'.e)|_{\breve{\beta}}$$
$$+ \frac{1}{T}(\frac{\partial f}{\partial \beta}'.\frac{\partial f}{\partial \beta})|_{\breve{\beta}}]\sqrt{T}(\hat{\beta} - \beta)$$

Define,

$$A = -\frac{1}{T}(\frac{\partial^2 f}{\partial \beta^2}'.e)|_{\breve{\beta}} + \frac{1}{T}(\frac{\partial f}{\partial \beta}'.\frac{\partial f}{\partial \beta})|_{\breve{\beta}}$$

and

$$K = T^{-1/2}\frac{\partial f}{\partial \beta}'.e$$

Then we can write (E.9) as,

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[1]William H. Greene, p.315-16.

[2]See, Alpha C. Chiang, Fundamental Method of Mathematical Economics, 3rd ed., (New York: McGraw-Hill Book Company, 1984), p. 261.

(E.10) $$\sqrt{T}(\hat{\beta}-\beta) = A^{-1}.K$$

Note that the price variable in the demand equation (equation (E.1)) is the fitted values of the price variable from equation (E.2). Following the mean-value theorem we can write K in equation (E.10) as,

(E.11) $$K = T^{-1/2}(\frac{\partial f}{\partial \beta}'.e)|_{\tilde{\alpha}} + [\frac{1}{T}(\frac{\partial^2 f}{\partial \beta \partial \alpha}'.e)|_{\tilde{\alpha}} + \frac{1}{T}(\frac{\partial f}{\partial \beta}'.\frac{\partial e}{\partial \alpha})|_{\tilde{\alpha}}]\sqrt{T}(\alpha-\hat{\alpha})$$

where, $\frac{\partial e}{\partial \alpha}|_{\tilde{\alpha}} = -\frac{\partial f}{\partial \alpha}|_{\tilde{\alpha}}$. The mean value of α, $\tilde{\alpha}$, is a value between α and the estimate of α, $\hat{\alpha}$.

Define,

$$B = -\frac{1}{T}(\frac{\partial^2 f}{\partial \beta \partial \alpha}'.e)|_{\tilde{\alpha}} + \frac{1}{T}(\frac{\partial f}{\partial \beta}'.\frac{\partial f}{\partial \alpha})|_{\tilde{\alpha}}$$

We can write (E.11) as,

(E.12) $$K = T^{-1/2}(\frac{\partial f}{\partial \beta}'.e)|_{\tilde{\alpha}} + B\sqrt{T}(\hat{\alpha}-\alpha)$$

Substitute (E.12) into (E.10),

(E.13) $$\sqrt{T}(\hat{\beta}-\beta) = A^{-1}[T^{-1/2}(\frac{\partial f}{\partial \beta}'.e)|_{\tilde{\alpha}} + B\sqrt{T}(\hat{\alpha}-\alpha)]$$

The criterion function to estimate α by nonlinear least squares is,

(E.14) $$S(\alpha) = \sum_{t=1}^{T} (p_{qt}^{r}-g_t(\alpha))^2$$

The first order conditions for the minimum are, (E.15) $$-2\sum_{t=1}^{T}(\frac{\partial g_t}{\partial \alpha}.v_t)|_{\hat{\alpha}} = 0$$

Divide both sides of the equation (E.15) by -2,

(E.16) $$\sum_{t=1}^{T}(\frac{\partial g_t}{\partial \alpha}.v_t)|_{\hat{\alpha}} = 0$$

The above equation can be written in matrix form as,

(E.17) $$(\frac{\partial g}{\partial \alpha}'.v)|_{\hat{\alpha}} = 0$$

where, $\frac{\partial g}{\partial \alpha}$ is a (TxZ) matrix and v is a (Tx1) vector. T denotes the number of observations and Z denotes the number of estimated parameters.

Following the central limit theorem,

(E.18) $$T^{-1/2}\frac{\partial g}{\partial \alpha}'.v = 0$$

Following the mean-value theorem, we can write (E.18)

(E.19) $$T^{-1/2}\frac{\partial g}{\partial \alpha}'.v = T^{-1/2}(\frac{\partial g}{\partial \alpha}'.v)|_{\hat{\alpha}} + [\frac{1}{T}(\frac{\partial^2 g}{\partial \alpha^2}'.v)|_{\bar{\alpha}} + \frac{1}{T}(\frac{\partial g}{\partial \alpha}'.\frac{\partial v}{\partial \alpha})|_{\bar{\alpha}}]\sqrt{T}(\alpha-\hat{\alpha})$$

where $\frac{\partial v}{\partial \alpha}|_{\bar{\alpha}} = -\frac{\partial g}{\partial \alpha}|_{\bar{\alpha}}$. The mean value of α, $\bar{\alpha}$, is a value between α and the estimate of α, $\hat{\alpha}$.Note that in equation (E.19) $T^{-1/2}\frac{\partial g}{\partial \alpha}.v|_{\hat{\alpha}} = 0$. This result comes from (E.17). We can write equation (E.19) as,

(E.20) $$T^{-1/2}\frac{\partial g}{\partial \alpha}'.v = [-\frac{1}{T}(\frac{\partial^2 g}{\partial \alpha^2}'.v)|_{\bar{\alpha}} + \frac{1}{T}(\frac{\partial g}{\partial \alpha}'.\frac{\partial g}{\partial \alpha})|_{\bar{\alpha}}]\sqrt{T}(\hat{\alpha}-\alpha)$$

Define,

$$C = -\frac{1}{T}\frac{\partial^2 g'}{\partial \alpha^2}.\nu|_{\hat{\alpha}} + \frac{1}{T}\frac{\partial g'}{\partial \alpha}.\frac{\partial g}{\partial \alpha}|_{\hat{\alpha}}$$

Then we can write (E.20) as,

(E.21) $$\sqrt{T}(\hat{\alpha}-\alpha) = C^{-1}. (T^{-1/2}\frac{\partial g'}{\partial \alpha}.\nu)$$

Substitute (E.21) into (E.13),

(E.22) $$\sqrt{T}(\hat{\beta}-\beta) = A^{-1}.[T^{-1/2}(\frac{\partial f'}{\partial \beta}.e)|_{\hat{\alpha}} + B.\ C^{-1}.(T^{-1/2}\frac{\partial g'}{\partial \alpha}.\nu)$$

In order to find the expected value of (E.22), we need to have the expected values for A, B and C.

The expected value for A is:

$$E(A) = E[\frac{1}{T}(\frac{\partial f'}{\partial \beta}.\frac{\partial f}{\partial \beta})|_{\hat{\beta}}]$$

The expected value for B is:

$$E(B) = E[\frac{1}{T}\frac{\partial f}{\partial \beta}|_{\hat{\beta}}'.\frac{\partial f}{\partial \alpha}|_{\hat{\alpha}}]$$

The expected value for C is:

$$E(C) = E[\frac{1}{T}(\frac{\partial g'}{\partial \alpha}.\frac{\partial g}{\partial \alpha})|_{\hat{\alpha}}]$$

Note that the expected values of the first terms in A, B and C equal to zero since the expected values of the error terms are defined to be equal to zero (i.e., E(e)=0 and E(ν)=0).

Define,

$$r_t = (\frac{\partial f_t}{\partial \beta} * e_t)'|_{\hat{\alpha}} + B.\ C^{-1}.(\frac{\partial g_t}{\partial \alpha} * v_t)'$$

where, * denotes element-by-element multiplication.

(E.22) can be written as,

(E.23) $$\sqrt{T}(\hat{\beta} - \beta) = A^{-1}\ T^{-1/2} \sum_{t=1}^{T} r_t$$

(E.24) $$E[T(\hat{\beta} - \beta)^2] = E[A^{-1}\ T^{-1} \sum_{t=1}^{T} r_t r_t'\ A^{-1}]$$

(E.25) $$E[T(\hat{\beta} - \beta)^2] = (\frac{1}{T}(\frac{\partial f_t}{\partial \beta}' . \frac{\partial f_t}{\partial \beta})|_{\beta})^{-1} T^{-1} \sum_{t=1}^{T} E(r_t r_t')(\frac{1}{T}(\frac{\partial f_t}{\partial \beta}' . \frac{\partial f_t}{\partial \beta})|_{\beta})^{-1}$$

(E.26) $$E[(\hat{\beta} - \beta)^2] = [(\frac{\partial f_t}{\partial \beta}' . \frac{\partial f_t}{\partial \beta})|_{\beta}]^{-1} \sum_{t=1}^{T} E(r_t r_t')[(\frac{\partial f_t}{\partial \beta}' . \frac{\partial f_t}{\partial \beta})|_{\beta}]^{-1}$$

The above equation is the asymptotic covariance matrix. Since in practice, we cannot evaluate the matrices defined in (E.26) at β and α, we evaluate them at $\hat{\beta}$ and $\hat{\alpha}$. We can write (E.26) as:

(E.27) $$E[(\hat{\beta} - \beta)^2] = [(\frac{\partial f_t}{\partial \beta}' . \frac{\partial f_t}{\partial \beta})|_{\hat{\beta}})^{-1} \sum_{t=1}^{T} E(r_t r_t')((\frac{\partial f_t}{\partial \beta}' . \frac{\partial f_t}{\partial \beta})|_{\hat{\beta}}]^{-1}$$

where,

$$r_t = (\frac{\partial f_t}{\partial \beta} * e_t)'|_{\hat\beta} + B.\ C^{-1}.(\frac{\partial g_t}{\partial \alpha} * v_t)'|_{\hat\alpha}$$

and,

$$E(B) = E[\frac{1}{T}(\frac{\partial f_t}{\partial \beta}'|_{\hat\beta}.\frac{\partial f_t}{\partial \alpha})|_{\hat\alpha}]$$

$$E(C) = E[\frac{1}{T}\frac{\partial g_t}{\partial \alpha}'\frac{\partial g_t}{\partial \alpha}|_{\hat\alpha}]$$

To estimate (E.27), we need to define matrices $\frac{\partial f_t}{\partial \beta}|_{\hat\beta}$, $\frac{\partial f_t}{\partial \alpha}|_{\hat\alpha}$ and $\frac{\partial g_t}{\partial \alpha}|_{\hat\alpha}$. We also need to define $e_t|_{\hat\beta}$ and $v_t|_{\hat\alpha}$ in r_t. $e_t|_{\hat\beta}$ is the estimated residuals from the demand equation with instrument for the price variable. $v_t|_{\hat\alpha}$ is the estimated residuals from the equation to estimate the fitted values for the price variable.

In defining $\frac{\partial f_t}{\partial \beta}|_{\hat\beta}$, $\frac{\partial f_t}{\partial \alpha}|_{\hat\alpha}$ and $\frac{\partial f_t}{\partial \alpha}|_{\hat\alpha}$, we should first write out the demand equation with the instrument for the price variable and the equation to estimate the fitted values for the price variable.

Demand equation with instrument for the price variable:

(E.28) $$f_t(\beta,\alpha) = \Delta_{12}q_t^r = \beta_0+\beta_1\Delta_{12}\hat{p}_{st}^r+\Delta_{12}f_t^r+(1+\phi L^1)(1+\Phi L^{12})e_t$$

We can rewrite (E.28) as,

(E.29) $$f_t = \Delta_{12}q_t^r = \beta_0+\beta_1\Delta_{12}\hat{p}_t^r+\Delta_{12}f_t^r+\phi e_{t-1}+\Phi e_{t-12}+\phi\Phi e_{t-13}+e_t$$

The equation to estimate the fitted values for the price variable in (E.28) is,

(E.30) $$p_t^r = g_t(\alpha) = \alpha_0+\alpha_1 p_{yt}^r+\alpha_2 h_t^n+\alpha_3 m_t^r+\alpha_4 f_t^r+v_t$$

Substitute the estimate of (E.30) into (E.29),

$$f_t = \Delta_{12}q_t^r = \beta_0+\beta_1\Delta_{12}(\hat{\alpha}_0+\hat{\alpha}_1p_{yt}^r+\hat{\alpha}_2h_t^n+\hat{\alpha}_3m_t^r+\hat{\alpha}_4f_t^r)$$

(E.31)

$$+\Delta_{12}f_t^r+\phi e_{t-1}+\Phi e_{t-12}+\phi\Phi e_{t-13}+e_t$$

Define,

$$\frac{\partial f_t}{\partial \beta}|_{\hat{\beta}} = \begin{bmatrix} 1 & \Delta_{12}\hat{p}_{qt}^r & \Delta_{12}f_t^r & \hat{e}_{t-1}+\Phi\hat{e}_{t-13} & \hat{e}_{t-12}+\phi\hat{e}_{t-13} \\ . & . & . & . & . \\ . & . & . & . & . \\ 1 & \Delta_{12}\hat{p}_{qT}^r & \Delta_{12}f_T^r & \hat{e}_{T-1}+\Phi\hat{e}_{T-13} & \hat{e}_{T-12}+\phi\hat{e}_{T-13} \end{bmatrix}$$

$$\frac{\partial g_t}{\partial \alpha}|_{\hat{\alpha}} = \begin{bmatrix} 1 & p_{yt}^r & m_t^r & h_t^n & f_t^r \\ . & . & . & . & . \\ . & . & . & . & . \\ 1 & p_{yT}^r & m_T^r & h_T^n & f_T^r \end{bmatrix}$$

$$\frac{\partial f_t}{\partial \alpha}|_{\hat{\alpha}} = \begin{bmatrix} 0 & \beta_1\Delta_{12}p_{yt}^r & \beta_1\Delta_{12}m_t^r & \beta_1\Delta_{12}h_t^n & \beta_1\Delta_{12}f_t^r \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & \beta_1\Delta_{12}p_{yT}^r & \beta_1\Delta_{12}m_T^r & \beta_1\Delta_{12}h_T^n & \beta_1\Delta_{12}f_T^r \end{bmatrix}$$

To estimate (E.27), we substitute matrices, $\frac{\partial f_t}{\partial \beta}|_{\hat{\beta}}$, $\frac{\partial f_t}{\partial \alpha}|_{\hat{\alpha}}$ and $\frac{\partial g_t}{\partial \alpha}|\hat{\alpha}$ and the vectors $\hat{e}_r...\hat{e}_T$, $\hat{\vartheta}_r...\hat{\vartheta}_T$in (E.27).(E.27) is calculated by using GAUSS program version 2.1 for personal computers. This calculation is applied to the demand equation with instrument for the price variable that is reported in Table 4.2 in Chapter IV.

APPENDIX F

EXPECTED VALUE OF THE CHANGE IN APPLE SALES ASSOCIATED WITH HEALTH RISK INFORMATION

APPENDIX F

EXPECTED VALUE OF THE CHANGE IN APPLE SALES ASSOCIATED WITH HEALTH RISK INFORMATION

Let $q(p_t, f_t^0)$ be the individual demand function for apples when health risk is not present in the market and let $q(p_t, f_t^1)$ be the demand function for apples when health risk is present in the market. Here, p_t is the apple price, f_t^0 is the absence of the reported risk, and f_t^1 is the presence of the reported risk at time t. These demand functions are demonstrated in Figure 1.

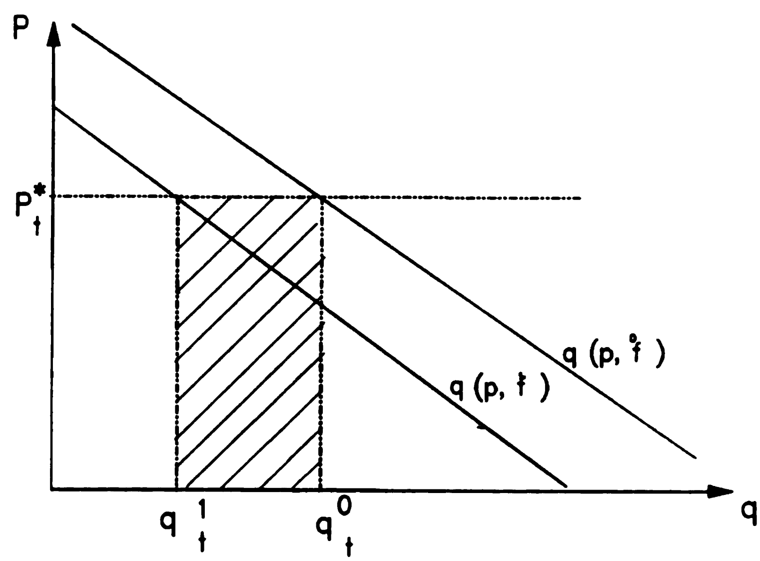

Figure F.1. Change in Apple Sales Asociated With Health-Risk Information

Here, q_t^0 denotes per capita quantity of apples demanded when risk is not present, q_t^1 denotes per capita quantity of apples demanded when risk is present. p_t^* is the retail price of apples at time t.

The change in per capita apple purchases at time t is,

(F.1) $$\Delta q_t = q_t^1 - q_t^0$$

The expected value of the change in per capita apple purchases at time t is obtained by taking the expectation of (F.1):

(F.2) $$E(\Delta q_t) = E(q_t^0) - E(q_t^1)$$

The expected value of the change in per capita apple sales at time t is obtained by multplying (F.2) by price of apples at time t, p_t^*. This gives an estimate of the value of the shaded area in Figure F.1. The total value of the change in apple sales is obtained by multipliying the change in per capita apple sales with the population at time t.

In this study, the demand function for apples is specified as log-linear. The following equation is the individual demand function for apples that is specified in this study when health risk is present in the market. Note that the variables are seasonally differenced since the dependent variable in the demand equation is nonstationary.

(F.3) $$\begin{aligned}\ln q_t^1 - \ln q_{t-12}^1 &= \beta_0 + \beta_1(\ln p_t - \ln p_{t-12}) \\ &\quad + \beta_2(f_t^1 - f_{t-12}^1) + \phi\epsilon_{t-1} + \Phi\epsilon_{t-12} + \phi\Phi\epsilon_{t-13} + \epsilon_t\end{aligned}$$

where β_0, β_1, β_2, ϕ and Φ are the regression coefficients and ϵ_t is the random error term. Here, ϕ and Φ are the seasonal ARIMA coefficients.

(F.3) can be written as,

(F.4) $$\begin{aligned}\ln q_t^1 &= \ln q_{t-12}^1 + \beta_0 + \beta_1(\ln p_t - \ln p_{t-12}) \\ &\quad + \beta_2(f_t^1 - f_{t-12}^1) + \phi\epsilon_{t-1} + \Phi\epsilon_{t-12} + \phi\Phi\epsilon_{t-13} + \epsilon_t\end{aligned}$$

where,

$$\ln q_t^1 \sim N(\mu, \sigma^2)$$

$$\epsilon_t \sim N(0, \sigma^2)$$

(F.4) can be written as,

(F.5) $$q_t^1 = q_{t-12}^1 \, p_t^{\beta_1} \, p_{t-12}^{-\beta_1} \, e^{\beta_0 + \beta_2 (f_t^1 - f_{t-12}^1)} \, e^{c} \, e^{\epsilon_t}$$

where,

$$c = \phi \epsilon_{t-1} + \Phi \epsilon_{t-12} + \phi \Phi \epsilon_{t-13}$$

and

$$q_t^1 \sim lognormal(e^{\mu + \sigma^2/2}, e^{2\mu + \sigma^2}(e^{\sigma^2} - 1))$$

$$e^{\epsilon_t} \sim lognormal(e^{\sigma^2/2}, e^{\sigma^2}(e^{\sigma^2} - 1))$$

The expected value of individual demand for apples when risk is present in the market is,

(F.6) $$E(q_t^1) = e^{\hat{\ln q}_t^1 + \hat{\sigma}^2/2}$$

where, $\hat{\ln q}_t^1$ is the estimate of $\hat{\ln q}_t^1$ and $\hat{\sigma}$ is the estimate of σ which are obtained by estimating equation (F.4).

(F.6) can be written as,

(F.7) $$E(q_t^1) = e^{\hat{\ln q}_{t-12}^1 + \hat{\beta}_0 + \hat{\beta}_1(\ln p_t - \ln p_{t-12}) + \hat{\beta}_2(f_t^1 - f_{t-12}^1) + \hat{c} + \hat{\sigma}^2/2}$$

where, $\hat{\beta}_0$, $\hat{\beta}_1$, $\hat{\beta}_1$ are the estimates of the regression parameters from equation (F.4) and $\hat{c}$ is the estimate of c. The expected value of individual demand for apples when risk is not present in the market is identical to (F.7) with the exclusion of $\hat{\beta}_2(f_t^1 - f_{t-12}^1)$:

(F.8)
$$E(q_t^0) = e^{\ln \hat{q}_{t-12}^0 + \hat{\beta}_0 + \hat{\beta}_1(\ln p_t^i - \ln p_{t-12}) + \hat{c} + \hat{\sigma}^2/2}$$

The expected value of the change in per capita purchases is obtained by subtracting (F.7) from (F.8), (G.8):

(F.9)
$$E(\Delta q_t) = e^{\hat{\beta}_0 + \hat{\beta}_1(\ln p_t - \ln p_{t-12}) + \hat{c} + \hat{\sigma}^2/2}$$
$$*[e^{\ln \hat{q}_{t-12}} - e^{\ln \hat{q}_{t-12} + \hat{\beta}_2(f_t - f_{t-12})}]$$

APPENDIX G

EXPECTED VALUE OF THE CHANGE IN THE CONSUMER SURPLUS ASSOCIATED WITH HEALTH-RISK INFORMATION

APPENDIX G

EXPECTED VALUE OF THE CHANGE IN THE CONSUMER SURPLUS ASSOCIATED WITH HEALTH-RISK INFORMATION

Let $q(p_t, f_t^0)$ be the individual demand function for apples when health risk is not present in the market and let $q(p_t, f_t^1)$ be the individual demand function for apples when health-risk is present in the market. Here, p_t is the apple price, f_t^0 is the absence of the reported risk and f_t^1 is the presence of the reported risk at time t. These demand functions are demonstrated in Figure G.1.

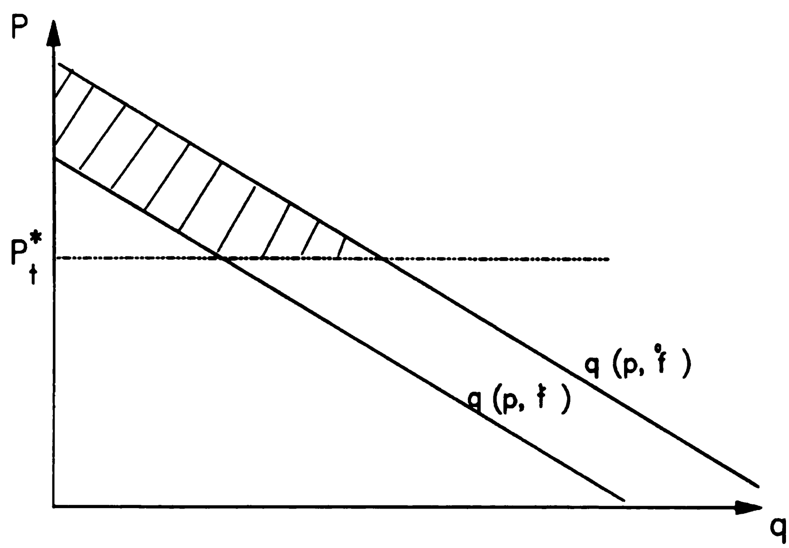

Figure G.1. Change in Consumer Surplus Associated with Health-Risk Information

The consumer surplus is the area under the demand curve above the price that the consumer pays for the good. The consumer surplus for the demand curve when health-risk is present in the market is, (G.1) $$CS_t^1=\int_{p_t^*}^{\infty} q(p_t,f_t^1)dp_t$$

The consumer surplus for the demand curve when health-risk is not present in the market is,

(G.2) $$CS_t^0=\int_{p_t^*}^{\infty} q(p_t,f_t^0)dp_t$$

The change in consumer surplus is the difference between (G.1) and (G.2).

(G.3) $$\Delta CS_t=CS_t^0-CS_t^1$$

The expected value of the change in consumer surplus is obtained by taking the expectation of (G.3)

Demand function for apples when health risk is present in the market is identical to the demand equation presented in Appendix F (Equation F.5).

The consumer surplus when health risk is present in the market is,

(G.4)
$$CS_t^1 = \int_{p^*}^{\infty} q_t^1 dp_t$$
$$= \int_{p^*}^{\infty} (q_{t-12}^1\, p_t^{\beta_1}\, p_{t-12}^{-\beta_1}\, e^{\beta_0+\beta_2(f_t^1-f_{t-12}^1)}\, e^{c+\epsilon_t})\, dp_t$$

(G.5) $$CS_t^1 = q_{t-12}^1 p_{t-12}^{-\beta_1} e^{\beta_0+\beta_2(f_t^1-f_{t-12}^1)} e^{c+\epsilon_t} \frac{p_t^{\beta_1+1}}{\beta_1+1}\Big|_{p^*}^{\infty}$$

where,

$$c = \phi\epsilon_{t-1}+\Phi\epsilon_{t-12}+\phi\Phi\epsilon_{t-13}$$

and

(G.5) is infinity for $\beta_1 \geq -1$. Therefore, the consumer surplus should be calculated conditional that the own price elasticity of apples is greater than unity.

$$q_t^1 \sim lognormal(e^{\mu+\sigma^2/2}, e^{2\mu+\sigma^2}(e^{\sigma^2}-1))$$

$$e^{\epsilon_t} \sim lognormal(e^{\sigma^2/2}, (e^{\sigma^2}-1))$$

If $\beta_1 > -1$, then the consumer surplus when the health risk is present in the market is,

(G.6)
$$CS_t^1 = -q_{t-12}^1 p_{t-12}^{-\beta_1} e^{\beta_0+\beta_2(f_t^1-f_{t-12}^1)} e^{c+\epsilon_t} \left(\frac{p_t^{*\beta_1+1}}{\beta_1+1}\right)$$

The expected value of the consumer surplus when risk information is present in the market is obtained by taking the expected value of (G.6):

$$E(CS_t^1) = E[-q_{t-12}^1 p_{t-12}^{-\beta_1} e^{\beta_0+\beta_2(f_t^1-f_{t-12}^1)} e^{c+\epsilon_t}\left(\frac{p_t^{*\beta_1+1}}{\beta_1+1}\right)]$$

(G.7)
$$= -q_{t-12}^1 p_{t-12}^{-\beta_1} e^{\beta_0+\beta_2(f_t^1-f_{t-12}^1)} e^{c} \frac{p_t^{*\beta_1+1}}{\beta_1+1} E(e^{\epsilon_t})$$

$$= -q_{t-12}^1 p_{t-12}^{-\beta_1} e^{\beta_0+\beta_2(f_t^1-f_{t-12}^1)} e^{c} \frac{p_t^{*\beta_1+1}}{\beta_1+1} e^{\hat{\sigma}^2/2}$$

The expected value of the consumer surplus when risk information is not present in the market is:

(G.8)
$$E(CS_t^0) = -\dot{q}_{t-12}^0 p_{t-12}^{-\beta_1} e^{\beta_0} e^{c} \frac{p_t^{*\beta_1+1}}{\beta_1+1} e^{\hat{\sigma}^2/2}$$

The expected value of the change in consumer suplus is thus:

(G.9)
$$E(CS_t^0) - E(CS_t^1) = p_{t-12}^{\beta_1} e^{\beta_0} e^{c}$$

$$\frac{p_t^{*\beta_1+1}}{\beta_1+1} e^{\hat{\sigma}^2/2}[-q_{t-12}^0 + q_{t-12}^1 e^{\beta_2(f_t-f_{t-12})}]$$

BIBLIOGRAPHY

BIBLIOGRAPHY

"After Scare, Suit by Apple Farmers." The New York Times, 29 November 1990, A22.

Baumes, Harry S. Jr. and Roger K. Conway. An Econometric Model of the U.S Apple Market. ERS Staff Report No: AGES850110. Washington, D.C.: United States Department of Agriculture, Economic Research Service, 1985.

Box, George E.P. and Gwilym M. Jenkins. Time Series Analysis Forecasting and Control. San Francisco: Holden Day, 1976.

Buxton, Boyd. "Economic Impact of Consumer Health Concerns About Alar on Apples." Fruit and Tree Nuts Situation and Outlook Yearbook TFS-250, United States Department of Agriculture, Economic Research Service (August 1989): 85-88.

Caswell, Julie A. ed. Economics of Food Safety. New York: Elseiver Science Publishing Co., 1991.

Chiang, Alpha C. Fundamental Methods of Mathematical Economics. 3rd ed., New York: McGraw Hill Book Company, 1984.

Choi, Kwan E. and Helen H. Jensen. "Modelling the Effect of Risk on Food Demand." In Economics of Food Safety, edited by Julie Caswell, New York: Elseiver Science Publishing Co., 1991.

City of New York, Department of Consumer Affairs. Market Basket Report. New York, January 1980 - July 1991.

Dalymple, Dana. "Economic Aspects of Apple Marketing in the United States." Ph.D. diss., Michigan State University, 1962.

Deaton, Angus and John Muellbauer. Economics and Consumer Behavior. Cambridge: Cambridge University Press, 1980.

Eom, Young Sook. "Pesticide Residues and Averting Behavior." Raleigh: North Carolina State University, Division of Economics and Business, February 1991, [photocopy].

Fisher, A., L.G. Chestnut, and D.M. Violette. "The Value of Reducing Risks of Death: A Note on New Evidence." Journal of Policy Analysis and Management 8(1) (1989): 88-100.

GAUSS System Version 2.1 for IBM PC-XT-AT-PS/2 & Compatibles. Aptech Systems Inc., Kent, Washington.

Gibson, Richard. "Apples With Alar Frightened Grocers More Than Buyers." The Wall Street Journal, 7 August 1989, B3.

Gold, Allan. "Company Ends Use of Apple Chemical." The New York Times, 18 October 1989, A18.

Guyton, William Preston. "Consumer Response to Risk Information: A Case Study of the Impact of Alar Scare on New York City Fresh Apple Demand." M.S. Thesis, Michigan State University, 1990.

Greene, William H. Econometric Analysis. New York: Macmillan Publishing Co., 1990.

Halloran, John Mark. "Price Forecasting Model for Michigan Fresh Apples." M.S. Thesis, Michigan State University, 1981.

Hausman, J.A. "Specification Tests in Econometrics." Econometrica, 6(46) (November 1978): 1251-1271.

Hoehn, John and Douglas Kreiger. Methods for Valuing Environmental Change. Staff Paper no. 88-30. East Lansing: Michigan State University, Department of Agricultural Economics, 1988.

International Apple Institute. National and International Apple News. Mc. Lean, Virginia, January 1980 - July 1991.

Ippolitto, Pauline and Richard A. Ippolitto. "Measuring the Value of Life Saving From Consumer Reaction to New Information." Journal of Public Economics, 25 (1984): 53-. 81.

Judge, George G., W.E. Griffiths, R. Carter Hill, Helmut Lutkepohl, Tsoung-Chao Lee. Introduction to the Theory and Practice of Econometrics. 2d ed. New York: John Wiley and Sons, 1988.

Judge, George G., W.E. Griffiths, R. Carter Hill, Helmut Lutkepohl, Tsoung-Chao Lee. The Theory and Practice of Econometrics. 2d ed. New York: John Wiley and Sons, 1985.

Kennedy, Peter. A Guide to Econometrics. 2d ed. Cambridge: MIT Press, 1985.

Kmenta, Jan. Elements of Econometrics. 2d ed. New York: Macmillan Publishing Co., 1986.

New York City, Department of Consumer Affairs. Market Basket Report. New York.

O'Rourke, Desmond. "Anatomy of a Disaster." Agribusiness, 6 (5) (1991): 417-424.

PC RATS (Regression Analysis Time Series) Version 3.1, VAR Econometrics Inc., Evanston, Il.

Rescher, Nicholas. Risk: A Philosophical Introduction to the Theory of Risk Evaluation and Management. New York:University Press of America, 1983.

Sewell, Bradford H. and Robin M. Whyatt. "Intolerable Risk: Pesticides in Our Children's Food." Washington D.C.: Natural Resources Defense Council, 1989.

Smith, Mark, Eileen O. van Ravenswaay and Stanley R. Thompson. "Sales Loss Determination in Food Contamonation Incidents: An Application to Milk Bans in Hawaii." American Journal of Agricultural Economics, 70(3) (August 1988): 513-520.

State of New York, Department of Labor. Employment Review. New York, January 1980 - July 1991.

"U.S to Bail Out Apple Growers." Chicago Tribune, 9 July 1989, C22.

United States Department of Agriculture, Agricultural Marketing Service. Fresh Fruit and Vegetable Arrivals in Eastern Cities. Washington, D.C., January 1980 - July 1991.

United States Department of Agriculture, Agricultural Marketing Service. Fresh Fruit and Vegetable Shipments in the United States. Washington, D.C., January 1980 - July 1991.

United States Departmant of Commerce, Bureau of the Census. Current Population Reports. Series P25, Washington, D.C., 1978 - 1988.

United States Department of Commerce, Bureau of the Census. Summary Population and Housing Characteristics. CPH-1, 1990.

United States Department of Commerce, Bureau of Labor Statistics. CPI Detailed Report. Washington, D.C., January 1980 - July 1991.

van Ravenswaay, Eileen. "Consumer Perceptions of Health Risks in Food." In Increasing Understanding of Public Problems and Policies-1990. Oak Brook, Il: Farm Foundation, 1990.

van Ravenswaay, Eileen and John P. Hoehn. "The Impact of Health Risk on Food Demand: A Case Study of Alar and Apples." In Economics of Food Safety, edited by Julie A. Caswell, New York: Elseiver Science Publishing Co., 1991.

Willig, Robert D. "Consumer Surplus Without Apology." The American Economic Review, (September 1976): 589-597.

Wooldridge, Jeffrey M. "Regression-Based Inference in Linear Time Series Models with Incomplete Dynamics." East Lansing: Michigan State University Department of Economics, August 1989, [photocopy].