2006

DEMAND AND SUPPLY MODEL FOR THE U.S. SKI/WAKEBOARD BOAT MARKET

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ABSTRACT OF THESIS

DEMAND AND SUPPLY MODEL FOR THE U.S. SKI/WAKEBOARD BOAT MARKET

A simultaneous demand and supply model for the U.S. ski/wakeboard boat market is estimated by three-stage least squares and iterated three-stage least squares methods using publicly available data. The model is used to test if, and to what extent, certain factors impact the annual quantity of new ski/wakeboard boats demanded and supplied. Statistical analysis suggests that the model does a good job of explaining the annual quantity of new ski/wakeboard boats demanded and supplied. The findings are most immediately beneficial to manufacturers and dealers. Dealers can use the results to better forecast demand which in turn will lead to more efficient production planning for manufacturers.

KEYWORDS: Simultaneous Equations, Three-Stage Least Squares, Demand And Supply Model, Ski Boat Industry, Recreational Boating

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September 7, 2006

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THESIS

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The Graduate School

University of Kentucky

2006

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THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture
at the University of Kentucky.

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2006

ACKNOWLEDGENTS

I would like to acknowledge and communicate my sincere appreciation for the assistance provided by several individuals while completing my Master's thesis. Dr. David Freshwater has served as Director of Thesis and is also Director of Graduate Studies. He has offered many valuable suggestions through discussion and literal review. His knowledge and insight into the recreational boating industry is largely responsible for the final direction this thesis has taken by focusing on ski/wakeboard boats. I also greatly appreciate the willingness of Dr. David L. Debertin and Dr. Carl Dillon to serve as members on my thesis committee and am grateful for their suggestions and input. I want to extend my thanks to Dr. Leigh Maynard for providing counsel with respect to data collection and econometric methods.

Chris Wingo at MasterCraft, Reed Claiborne at Skiers Choice, Inc. and Scott Coots at Malibu Boats all provided excellent plant tours which allowed me to better understand the ski/wakeboard boat industry. This understanding and the details they provided added significantly to the quality of this thesis.

Finally, the continual love and support of my wife Alicia has made it possible for me to be successful in my pursuit of a graduate degree. Her patience and the sacrifices she has made are very much appreciated.

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Chapter One

Introduction

Background

Over the last century recreational boating has advanced from a sport for only the wealthy to a sport available to many Americans. Joseph Choate's 1957 article *Recreational Boating: America's Family Sport* examined the course of the recreational boating industry in the first half of the twentieth century. The real beginning was when the National Association of Engine and Boat Manufacturers, an industry trade association, formed in 1904. At the time, there were only 15,000 recreational boats on the water in America. The arrival of the roaring twenties witnessed an explosion in the number of recreational boats. By the end of the 1920's there were an estimated 1.5 million recreational boats in use. A big reason for the growth in popularity of recreational boating during that decade was C. Waterman's development of the outboard motor, with Ole and Bess Evinrude further popularizing an affordable version. During the great depression and through World War II the boating industry entered a different environment. Few Americans had the ability to spend as they once had, and manufacturers shifted to producing less expensive boats for fishing and cruising. After World War II, Americans again exhibited a strong preference for the sport. By 1957 "recreational boating had come to be called the nation's top family sport" (Choate, p. 109).

The popularity among American families has varied over the years and most people would consider a recreational powerboat a luxury item. More recently, a recession shortly after 2000 resulted in a large segment of the boating population quitting the sport, however, that trend has reversed again. Approximately $435.4 million of inboard runabout boats, also known as ski/wakeboard boats, were sold in the United States in 2004. Ski/wakeboard boat manufacturers are constantly attempting to predict cyclical shifts in order to accurately predict demand for their products.

The purpose of this article is to present a demand-supply model, for the portion of the U.S. recreational powerboat market which includes new ski/wakeboard boats, to better understand the factors that affect the demand and supply of these boats. This group of powerboats is a distinct category of boats exhibiting consistent product characteristics over recent years. The size, general style and methods of manufacturing ski/wakeboard boats have changed very little since the 1970's, relative to other types of recreational boats. Thus, using this segment of the U.S. recreational powerboat market will increase the likelihood that the product being modeled is homogeneous across time periods. The total annual stock of ski/wakeboard boats is equal to the starting stock of boats plus gross additions to the stock of ski/wakeboard boats less the quantity that is scrapped. Gross additions to the stock of boats is equal to new boat sales. Of the factors that affect the total stock, new boat sales exhibits the most variation and is the most responsive to changing economic conditions. Thus, new ski/wakeboard boat sales on an annual basis is used to model the demand and supply of these boats. The model will be used to test the null hypotheses listed below.

H_1: The elasticity of income for new ski/wakeboard boats is equal to or less than one.

H_2: An increase in the real average annual price per gallon of gasoline at the pump is not associated with a decrease in the quantity of new ski/wakeboard boats demanded.

H_3: An increase in the current prime interest rate is not associated with a decrease in the quantity of new ski/wakeboard boats demanded.

H_4: An increase in the return for the S&P 500 stock index is not associated with an increase in the quantity of new ski/wakeboard boats demanded.

H_5: The production of wakeboard boats is not associated with an increase in the quantity of new ski/wakeboard boats demanded.

The hypothesis tests listed above are focused on the factors that are believed to impact the quantity demanded of new ski/wakeboard boats and will reveal those factors that are significant. The results of these tests and the parameter estimates will be of greatest interest to manufacturers when forecasting. Forecasts for future levels of per capita income, gasoline, interest rates and the stock market are provided on a regular basis by many sources and can be substituted into the model to predict the impact on the demand for ski/wakeboard boats. Also, a likely benefit of the model to manufacturers will be a better understanding of the marginal impacts. Manufacturers will have an estimate of the marginal impact that a change in one of these factors will have on demand. Rather than attempting to forecast precise future demand levels, manufacturers will probably use the model to predict annual variations in demand and then adjust forecasts in a relative manner.

Information provided by such a demand-supply model will also be valuable to U.S. dealers of ski/wakeboard boats. A better understanding of the association between the factors that drive demand and the annual quantity of new ski/wakeboard boats demanded will enable dealers to make better forecasts, thereby allowing manufacturers to adjust production and set future price levels accordingly. Currently, dealers estimate demand for the upcoming season and place orders with the manufacturer. Manufacturers such as MasterCraft rely on dealers to provide estimates of the number of boats they will need to meet future demand. Thus, dealers bear the risk of excess supply since all boats produced by the manufacturer have been sold prior to production (Wingo). Improved accuracy in forecasting demand should reduce the risk to dealers in terms of holding excess inventory in down years. The model could also be useful when considering the impact of policy changes on the ski/wakeboard boat market. Policy implications however are not a focus of this paper.

A shift in preferences appears to have taken place in recent years within the ski/wakeboard boat industry. This shift in preferences has been from traditional types of skiing to wakeboarding. The total quantity of ski/wakeboard boats cannot be divided into sub-categories due to data limitations. The model presented is naïve in this respect as it only allows for an intercept shift due to the introduction of specifically designed wakeboard boats in 1998. The last hypothesis test listed tests for evidence that the introduction of wakeboard boats has been positively associated with the demand for new ski/wakeboard boats. The introduction of wakeboard boats has been a revolutionary change for the ski boat industry. Research in this area possesses the most potential for valuable findings but is beyond the scope of this thesis.

After discussions during plant tours with several leading manufacturers it does not appear as though ski/wakeboard boat manufacturers have performed any analysis whereby a demand-supply model has been estimated. It is also unlikely that similar research has been performed by market research firms and no literature was located that estimated a simultaneous demand-supply model for the ski/wakeboard segment of the boating industry. Even further, it has not been possible to find literature where a demand-supply model for the recreational boating industry in general has been estimated. The industry is reminiscent of the early twentieth century beer industry where market research was highly guarded and W. S. Gossett, an employee of Guiness Brewery, had to publish his statistical achievements under the pseudonym “Student” (Griffiths, Hill and Judge, p. 141).

This thesis is composed of six main parts. The first part of the thesis consists of an introduction, which includes a background discussion, industry analysis and literature review.

The theoretical framework is described in part two. The data to be used for the analysis, including summary statistics, is outlined in part three. In the fourth part the model and methods of estimation are presented. In part five, the results are presented, including all hypothesis tests. Finally, the thesis is concluded and possible areas for further research are suggested.

Industry Structure

Ralph Samuelson was documented as the first person to water ski successfully (Water Ski Milestones). Since his accomplishment in 1922 the sport has grown in popularity, along with recreational boating, and today includes types of water skiing, such as, barefoot, boards, hydrofoils, jumping, tricks and slalom. As a result, a demand for boats which are specifically designed for water skiing and/or wakeboarding, often at a competitive level, has materialized. There are two basic boat styles produced. First, traditional water ski boats are built to create as little wake as possible. This design is used primarily for slalom and barefoot skiing. On the other hand, wakeboard boats are built to create a large wake, in order to allow for jumps and tricks. Some manufacturers begin with the hull design of a traditional ski boat and utilize ballasts or hydraulic plates to "enhance" wake characteristics. The hull designs of most wakeboard boats are generally larger and more accommodating to families, but maintain characteristics that produce wakes which are suitable for competition skiing and/or wakeboarding.

Until recent years the "traditional" ski boat hull design was the primary product produced by manufacturers. However, starting in the mid 1990's wakeboarding experienced an explosion in popularity and has surpassed traditional styles of water skiing. In 1998 most manufacturers began offering an alternative line of boats specifically designed for wakeboarding, rather than just offering wake enhancement equipment on existing lines. Wakeboarding requires large wakes. Naturally, larger, heavier boats provide better conditions for wakeboarding. Thus, the introduction of wakeboard boats has likely led to an increase in the average size of boats in this segment. Ski/wakeboard boats currently being produced range in size from 19 feet in length to approximately 24 feet in length, compared to the typical 19 foot ski boat of the 1970's.

The ski/wakeboard boat segment consists of a small group of privately owned manufacturers. There are publicly traded companies within the recreational boat building industry, the largest of which is Brunswick Marine. None of the publicly traded companies currently produce ski/wakeboard boats. Sea Ray, a division of Brunswick Marine, produced a ski boat for a short period during the 1990's but quickly abandoned the pursuit. The lack of relative volume is one possible reason larger manufacturers have not attempted a more serious attempt to enter the ski/wakeboard boat market.

The total market for inboard runabout boats shipped consisted of only 11,600 units in 2004, all of which were new ski/wakeboard boats (NMMA). Statistical Surveys Inc. located in Grand Rapids, Michigan provides detailed statistical reports for the marine industry. These reports include units shipped each year by company and type of boat. According to Statistical Surveys Inc., there were 11,313 new ski/wakeboard boats shipped in 2004 based on boat registration data from 46 states, which represented 97% of the U.S. market of ski/wakeboard boats. After adjusting this estimate to account for 100% of the market, a total of 11,662 (11,313/0.97) new ski/wakeboard boats are estimated to have been shipped. This is close to the rounded estimate of 11,600 units shipped provided by the National Marine Manufacturers Association. This represented a 7.1% increase over the number of boats shipped in 2003. Table 1.1 details the market share by manufacturer for 2004 (Statistical Surveys). In 2004, Malibu was the leading manufacturer in terms of units shipped with 24.8% market share. MasterCraft, the leader in terms of units for many years, followed in second place with 20.63% market share. Skier's Choice manufactures the Supra and Moomba brands in the same plant on the same production line. If these brands are considered together then Skier's Choice is the third largest manufacturer just ahead of Correct Craft with each having a market share of 13.5% and 13.25%, respectively. The top four manufacturers account for nearly 75% of the ski/wakeboard boats produced and sold in the U.S. each year. Of notable interest is the fact that the production facilities for Malibu, MasterCraft and Skier's Choice are all within approximately 20 miles of each other in east Tennessee. It is not uncommon for employees at one manufacturer to have prior employment experience at one of the other manufacturers (Claiborne, Wingo).

Table 1.1: Market share by company for the ski/wakeboard boat market

	2004		
Company	**Retail Sales**	**Market Share**	**Change from 2003**
Malibu	2,806	24.80%	10.60%
MasterCraft	2,334	20.63%	-5.47%
Correct Craft	1,499	13.25%	0.87%
Centurion	1,062	9.39%	9.26%
Moomba	1,027	9.08%	19.84%
Tige	852	7.53%	24.74%
Supra	500	4.42%	-0.20%
Sanger	404	3.57%	16.43%
Ski Supreme	251	2.22%	27.41%
MB Sports	242	2.14%	13.62%
Calabria	232	2.05%	27.47%
Gekko	53	0.47%	6.00%
Other	51	0.45%	-25.00%
TOTAL	11,313	100.00%	7.11%

Source: Statistical Surveys Inc.

Malibu Boats is a privately owned company which was started in 1982 and allows for employee ownership. The company believes that allowing employees to have a financial interest in the success of the company is critical to its continued growth. The corporate office is in

Merced, California with production facilities located in Tennessee, California and Australia. It is the only ski boat company with production facilities near both U.S. coasts, and has 110 dealers throughout the U.S., Canada and Mexico. The Malibu brand consists of four lines of boats which are the Response, Sunsetter, Ride and Wakesetter. Malibu boat hulls are mostly hand laid fiberglass, however, chopped fiberglass is used in the construction of the hull/floor/stringer system. Malibu is also experimenting with injection processes. Currently, swim platforms are produced using an injection mold technology which yields a lighter product. During a plant tour, it was reported that this technology is being tested for use in hull production and in the future Malibu may also produce hulls using this injection technology (Coots).

MasterCraft is a privately owned company which was started in 1968 and currently has approximately 600 employees at its only facility in Vonore, Tennessee. MasterCraft boats are sold at over 100 dealers. The company currently plans to produce well over 3,000 ski/wakeboard boats this year (Wingo). The MasterCraft brand consists of four lines of boats which are the Prostar, X-Series, Maristar and Saltwater Series. MasterCraft boat hulls are 100% hand laid fiberglass. Chopped fiberglass is not used in the construction of the hull/floor/stringer system. MasterCraft utilizes Six Sigma strategies to increase efficiency and product quality. A typical buyer of a MasterCraft ski/wakeboard boat is between 40 and 45 years of age, has an annual income over $100,000 per year and is meticulous in nature (Wingo).

Skier's Choice is also a privately owned company and was started in 1980. The company currently employs approximately 600 employees at its only facility in Maryville, Tennessee. Skier's Choice builds the Supra and Moomba brands at the same facility on the same production line. The Supra brand consists of the Comp, Sunsport, Launch and Gravity lines. Supra notes on its website that in 1983 it was the first manufacturer to offer an open bow inboard boat. The

Moomba brand was introduced in 1991 and consists of the Outback and Mobius lines. Skier's Choice considers the Moomba brand to be value oriented. While both brands are built on the same production line, the real difference is in the accessories and options available. Supra and Moomba boat hulls are 100% hand laid fiberglass. Chopped fiberglass is not used in the construction of the hull/floor/stringer system.

Correct Craft is a privately owned company which was started in 1925 under the name Florida Variety Boat Company by W.C. Meloon. The company was renamed the Pine Castle Boat and Construction Company in 1930. Mr. Meloon made the final name change in 1936 settling on Correct Craft. Today the company continues to be located in Orlando, Florida and builds four lines of boats. These lines include, the Air, Crossover, Family Recreation and Ski. Correct Craft boat hulls are hand laid fiberglass.

Literature Review

One of the earliest attempts to address the relationship between supply and demand was by E. J. Working in 1927. He noted that "statistical demand curves must be interpreted in the light of the nature of the original data and of the methods of analysis used" (Working, 234). He stressed the importance of answers to four questions when interpreting demand curves: 1) is the supply or demand curve more variable 2) what market do the price and quantity data refer 3) to what extent are all other things held equal and 4) are the shifting of the supply and demand curves correlated or random (Working, 234). For example, the reason for narrowing the segment of powerboats to be analyzed to inboard runabout boats results directly from considering question 3.

In attempts to address these issues, estimation methods evolved beyond the ordinary least squares method of estimation. Zellner and Theil developed the three-stage least squares method of estimation, an improvement upon two-stage least squares, yielding more efficient parameter estimates when there are equations that are over-identified (Zellner and Theil, p. 54). Articles that followed compared various methods of estimation with respect to efficiency and computational difficulties. For example, Albert Madansky's article *On the Efficiency of Three-Stage Least-Squares* in 1964 presented a comparison between the two-stage least squares and three-stage least squares methods of estimation when estimating a system of simultaneous linear equations. Madansky showed that three-stage least squares estimation "yields estimates which are asymptotically at least as efficient as two-stage least-squares estimates" (Madansky, p. 54-55). In 1964 Kmenta and Gilbert performed a Monte Carlo experiment to examine the small sample properties of 5 alternative estimators of seemingly unrelated regressions. They claim Zellner's two-stage procedure performs as well on average as the maximum likelihood estimator and is likely preferred to the maximum likelihood estimator since it is considerably less time consuming to perform (Kmenta and Gilbert, p. 1199). However, there has been a drastic reduction in the cost of computing power over recent years. These advances in computational capabilities allow for the calculation and comparison of estimation results using several methods of estimation without more difficulty for the researcher. The presentation of estimation methods has evolved with concise illustrations in texts such as *Learning and Practicing Econometrics* (Griffiths, Hill and Judge). Much of my notation and computational methods will follow those presented in *Learning and Practicing Econometrics*.

Access to research for the ski/wakeboard boat industry is extremely limited. My search in academic journals only provided a few articles where simultaneous equation models are utilized to model aggregate demand and supply for a specific product. The research process for this analysis is expected to be most similar to that of Epple and McCallum (2004) who estimated a simultaneous equation model using annual U.S. time series data for 1960-1999 for chicken. The purpose of their article was to present and estimate a simultaneous equation model using actual data that yielded results where there was significant evidence that the signs of all parameter estimates were in a direction that agreed with economic theory (Epple and McCallum, p. 2). Their review of econometrics textbooks illustrates the absence of such examples. The model proposed here will be similar in complexity and the methods pursued in estimating a simultaneous equation model for the ski/wakeboard boat industry will also be similar to those utilized by Epple and McCallum. But, rather than using ordinary least squares or two-stage least squares methods of estimation, three-stage least squares and iterated three-stage least squares methods of estimation will be utilized. Willett and French used three-stage least squares when estimating a dynamic econometric model of the U.S. beekeeping industry in 1991 and Lin estimated a supply and demand model for world oil using three-stage least squares (Willett and French; Lin).

Chapter Two

Theoretical Framework

The economic model of the demand and supply for new ski/wakeboard boats in the U.S. represents a series of static equilibriums. Economic theory suggests that the demand for new ski/wakeboard boats is a function of the price of ski/wakeboard boats, prices of complements and substitutes and consumers' incomes. The annual quantity demanded of these types of boats is proposed to be a function of the real average sale price, real U.S. per capita income, size of U.S. civilian labor force, real average annual per gallon gasoline price at the pump, average annual prime interest rate, annual return for the S&P 500 and a dummy variable representing the introduction of wakeboard boats. The price of new ski/wakeboard boats is expected to be negatively associated with the quantity demanded each year. Chris Wingo of MasterCraft believes most new ski/wakeboard boat purchases are financed rather than being outright cash purchases. Therefore, the average annual prime interest rate is included in the model to account for the fact that the interest rate is a component of the purchase price.

Real per capita income, the size of the civilian labor force and the annual return for the S&P 500 stock index are included to capture the total purchasing power of consumers. Increases in per capita income and the size of the civilian labor force result in an increase in the number of dollars available to purchase these boats. The inclusion of the unemployment rate or substitution of the number of employed individuals for the size of the civilian labor force may improve the power of the model and could be considered in future research. Over 10 percent of MasterCraft owners are CEOs, about 30 percent own their own company and 23 percent occupy a managerial position (Star). These percentages illustrate the affluent nature of ski/wakeboard boat owners. Such affluent individuals are likely to own stocks or stock mutual funds. The performance of these investments is a good measurement of the increase in wealth and discretionary dollars. The annual return for the S&P 500 index is included as an indicator of this wealth effect.

The price of gasoline at the pump is the primary complement to ski/wakeboard boats. Gasoline is required for the operation of ski/wakeboard boats. Other complements, such as the price of trucks which are used to pull a boat, may be considered in future research.

As discussed above, there was a shift in preferences throughout the 1990's toward wakeboarding. This is captured in the model by including a dummy variable equal to one for the years 1998 and later, the years in which wakeboard boats have been in production. Between 1973 and 1997 the largest change in the quantity sold from year to year was 1,700 units, a 23% increase. With the introduction of wakeboard boats in 1998, the quantity of ski/wakeboard boats sold jumped by 4,800 units, or 78.7%, from 1997 to 1998. The largest year-to-year shift after 1998 was a decrease of 2,500 units from 2000 to 2001, an 18.4% decrease. The dummy variable is an intercept shifter which will account for the jump in the quantity of new ski/wakeboard boats sold due to the introduction of wakeboard boats.

The proposed demand equation does not account for the prices of substitutes. The most relevant substitute for a new boat is a used boat. There are three sources where the annual price of new and used boats for the past 35 years could be attained. NADA, BUC Research and ABOS Marine produce regular publications listing valuations for the marine industry. BUC Research will not allow access to the archives of their publications and ABOS Marine did not return telephone calls. The NADA was willing to pull this data for a fee, however, the cost to purchase the data drastically exceeds the resources for this project. It is believed that such information could increase the explanatory power of the model significantly and provide great value to manufacturers. The average spread each year between the price of a new boat and a three year old boat of the same model could be used as an indicator of the relative tightness of the ski/wakeboard boat market. A narrowing of this spread indicates that demand is increasing for this segment of boats and would likely be associated with an increase in new ski/wakeboard boats sold. As this spread widens, manufacturers should interpret this as a signal that demand is weakening. The price spread could prove valuable with respect to setting production schedules and lead to gains in market share and increased profitability.

Economic theory suggests that supply will be a function of the price of the good, prices of inputs in production and improvements in production technology. The annual quantity supplied of new ski/wakeboard boats is believed to be a function of the real average sale price, real cost of inputs in production such as synthetic rubber/synthetic fiberglass, industrial electricity power, labor and inboard engines and a manufacturing productivity trend. The inboard engine is the largest physical input in production in terms of cost. The cost of inboard engines is not available for this time period. Excluding the cost of inboard engines, changes in the cost of primary inputs are accounted for in the model. The cost structure of producing new ski/wakeboard boats has not changed dramatically over the time period of this analysis. Technological improvements have been made in the production of ski/wakeboard boats and are modeled by a linear trend variable. During plant tours it appeared as though the gains from technological improvements consisted more of product quality/consistency gains and a reduction in material waste, rather than a savings in labor usage. While computers afford some gains in labor requirements, the real advantage is in reducing excess materials. According to Chris Wingo of MasterCraft, the average size of ski/wakeboard boats has increased over the years but the labor required to produce larger boats has also increased, since they are still hand made just as they were 30 years ago (Wingo).

Chapter Three

Data

The data set used for the analysis of the new ski/wakeboard boat segment was compiled from several sources and includes the variables that are believed to explain the quantity of new ski/wakeboard boats demanded and supplied. It is an annual data set which covers the years 1970 through 2004. The natural log of all variables will be used in the model, except for the S&P 500 annual return and the wakeboard dummy variables. These variables are not converted to logarithmic form due to zero and negative values for several observations. This is taken into account when interpreting results. The complete data set prior to taking natural logarithms is included in Appendix A. Variable details are provided in Table 3.1 where descriptions are presented for the variables in their original form. Also, each variable is identified as either discrete or continuous and the *a priori* expected signs of the coefficients are given. For example, it is expected that a rise in the real average annual per gallon price of gasoline at the pump is associated with a decrease in the quantity of new ski/wakeboard boats demanded on average. Next, summary statistics are provided for all variables before taking natural logarithms in Table 3.2, and after taking natural logarithms in Table 3.3. Finally, correlation coefficients before taking natural logarithms are provided in Table 3.4, and after taking natural logarithms in Table 3.5. Statistical analyses were conducted using *Stata* software.

Table 3.1: Details of all variables in the model before taking natural logarithms

Variable	Description	Type	Expected Sign
Demand Equation			
ln*qty**	Quantity of new ski/wakeboard boats sold annually	Discrete	N/A
ln*price**	Real average price of new ski/wakeboard boats	Continuous	-
ln*income*	U.S. per capita income (constant 2004 $)	Continuous	+
ln*labor*	U.S. civilian labor force over age 16 in thousands	Continuous	+
ln*gas*	Average annual per gallon price of gasoline at the pump (constant 2005 $)	Continuous	-
ln*prime*	Average annual prime interest rate	Continuous	-
stock	Total annual return for the S&P 500	Continuous	+
wake	Dummy variable for years wakeboard boats have been produced	Discrete	+
Supply Equation			
ln*qty**	Quantity of new ski/wakeboard boats sold annually	Discrete	N/A
ln*price**	Real average price of new ski/wakeboard boats	Continuous	+
ln*fiber*	Annual PPI for synthetic rubber/synthetic fiberglass (constant 1982 $)	Continuous	-
ln*electric*	Annual PPI for industrial electric power (constant 1982 $)	Continuous	-
ln*wage*	Social Security Administration's national average wage index	Continuous	-
ln*trend*	Linear trend variable	Discrete	+

Table 3.2: Summary statistics of all variables used before taking natural logarithms

Variable	N	Mean	Std. Dev.	Minimum	Maximum
qty[*]	32	6581.56	3125.61	2900.00	13600.00
price[*]	32	15300.86	11183.08	1976.14	40945.24
income	32	19641.75	3087.41	14894.00	24511.00
labor	32	121011.53	17291.22	89429.00	147401.00
gas	32	1.80	0.44	1.22	2.92
prime	32	9.05	3.16	4.12	18.87
stock	32	12.68	17.96	-26.51	37.57
wake	32	0.22	0.42	0.00	1.00
fiber	32	111.45	34.35	37.70	170.60
electric	32	105.49	34.92	28.00	147.20
wage	32	20236.26	8538.58	7580.16	35648.55
trend	32	19.50	9.38	4.00	35.00

Table 3.3: Summary statistics of all variables used after taking natural logarithms

Variable	N	Mean	Std. Dev.	Minimum	Maximum
ln*qty*[*]	32	11.22	2.03	8.07	14.59
ln*price*[*]	32	9.32	0.89	7.59	10.62
ln*income*	32	9.86	0.16	9.61	10.13
ln*labor*	32	11.69	0.15	11.40	11.90
ln*gas*	32	0.56	0.23	0.20	1.07
ln*prime*	32	2.15	0.34	1.42	2.94
stock	32	12.68	17.96	-26.51	37.57
wake	32	0.22	0.42	0.00	1.00
ln*fiber*	32	4.66	0.37	3.63	5.14
ln*electric*	32	4.58	0.44	3.33	4.99
ln*wage*	32	9.82	0.46	8.93	10.48
ln*trend*	32	2.82	0.60	1.39	3.56

Table 3.4 Correlation coefficients for all variables in the model before taking natural logarithms

	qty	*price*	*income*	*labor*	*gas*	*prime*	*stock*	*wake*	*fiber*	*electric*	*wage*	*trend*
*qty**	1.0000											
*price**	0.8761	1.0000										
income	0.9202	0.9318	1.0000									
labor	0.8662	0.9377	0.9784	1.0000								
gas	-0.6260	-0.5167	-0.6400	-0.5880	1.0000							
prime	-0.5314	-0.5538	-0.4710	-0.4499	0.7475	1.0000						
stock	-0.0598	-0.0494	0.0320	0.0782	0.0058	0.0701	1.0000					
wake	0.8558	0.8163	0.7576	0.6887	-0.3295	-0.4310	-0.1825	1.0000				
fiber	0.8171	0.9087	0.9428	0.9867	-0.5073	-0.3665	0.1598	0.6269	1.0000			
electric	0.7256	0.8295	0.8848	0.9504	-0.5100	-0.3247	0.1764	0.4970	0.9690	1.0000		
wage	0.8989	0.9692	0.9807	0.9886	-0.5819	-0.4986	0.0232	0.7710	0.9657	0.9049	1.0000	
trend	0.8769	0.9528	0.9796	0.9967	-0.6064	-0.4940	0.0644	0.7164	0.9789	0.9307	0.9955	1.0000

Table 3.5 Correlation coefficients for all variables in the model after taking natural logarithms

	ln*qty*	ln*price*	ln*income*	ln*labor*	ln*gas*	ln*prime*	*stock*	*wake*	ln*fiber*	ln*electric*	ln*wage*	ln*trend*
ln*qty**	1.0000											
ln*price**	0.9740	1.0000										
ln*income*	0.9995	0.9708	1.0000									
ln*labor*	0.9879	0.9916	0.9849	1.0000								
ln*gas*	-0.6415	-0.5775	-0.6475	-0.6126	1.0000							
ln*prime*	-0.5468	-0.4387	-0.5518	-0.4615	0.6035	1.0000						
stock	0.0573	0.0979	0.0465	0.1037	-0.0167	0.1050	1.0000					
wake	0.7188	0.6311	0.7216	0.6509	-0.3464	-0.5105	-0.1825	1.0000				
ln*fiber*	0.9260	0.9691	0.9178	0.9674	-0.4822	-0.3190	0.2296	0.5305	1.0000			
ln*electric*	0.8632	0.9413	0.8546	0.9263	-0.4534	-0.2475	0.2378	0.4165	0.9788	1.0000		
ln*wage*	0.9881	0.9925	0.9856	0.9987	-0.6076	-0.4563	0.1017	0.6584	0.9669	0.9271	1.0000	
ln*trend*	0.9599	0.9863	0.9544	0.9907	-0.5813	-0.3999	0.1657	0.5749	0.9880	0.9660	0.9889	1.0000

Demand Variables

Addressing the importance of the four questions outlined above with respect to statistical demand curves, the demand curve is believed to be more variable since ski/wakeboard boats are not perishable and because of a shift in preferences due to the introduction of wakeboard boats. The quantity sold varies more due to shifts in demand than supply. The supply curve is more likely to approximate the marginal cost of production. Second, the quantity and price data refer to the U.S. market for new inboard runabout boats, as classified by the National Marine Manufacturers Association, sold each year. Third is the consideration as to what extent all other things are held constant. The quantity of new ski/wakeboard boats sold each year is believed to be a function of the real average price of these boats, per capita income, size of the labor force, real price of gasoline, average prime interest rate, annual return for the S&P 500 and change in preferences toward wakeboard boats, with all other factors held constant. Changes in preferences toward wakeboard boats are identified with a dummy variable. The primary input required to use a ski/wakeboard boat, a complementary good, is gasoline. The average purchase price and interest rate measure the cost to purchase a new ski/wakeboard boat. However, the prices of other types of boats are not held constant. Finally, shifts in the demand and supply curves are believed to be correlated through per capita income and the wage index. The relationship between these variables is not believed to have changed across time periods. Thus, the correlation is not expected to cause a statistical problem.

The annual number of inboard runabout boats sold, and their average sale price each year, is available for the years 1970 – 2004 on the website for the National Marine Manufacturers Association (Domestic Shipment). The number of inboard runabout boats sold is assumed to equal the quantity of new ski/wakeboard boats demanded for that year. This is a reasonable assumption since the description "inboard runabout" is merely a more technical description of a ski/wakeboard boat. Ski/wakeboard boats are generally the only type of runabout boats built with an inboard motor design. Wakeboard boats were included in the inboard runabout boat category upon their introduction in 1998. The average sale price each year for inboard runabout boats is also available for the years 1970 – 2004 on the website for the National Marine Manufacturers Association and is indexed using the GDP implicit price deflator. This is believed to be a reasonable instrument to transform the average sale price variable into real dollars. The GDP deflator has a correlation coefficient over 0.99 with the PPI index for boat building. However, the PPI index for boat building, which would be a preferred instrument, is not available for all years. Real per capita income for the United States in constant 2004 dollars for the years 1970 through 2004 is available on the U.S. Census Bureau website (Historical Income). This data was compiled by the U.S. Census Bureau as part of the 2004 Current Population Survey. The total U.S. civilian labor force in thousands for the years 1970 through 2004 is available from the Bureau of Labor Statistics website (Employment Status). The total civilian labor force includes those individuals 16 years of age or older who are able to work. Both employed and unemployed individuals are included. The performance of the stock market is represented by the annual return for the S&P 500 index. These returns are provided by most mutual fund companies and were compiled for this project using the Dodge & Cox Funds website (Stock Fund Annual Returns). The Board of Governors of the Federal Reserve System provides historical interest rates. The average annual prime interest rate as recorded by the Federal Reserve is used (Selected Interest Rates). The real average annual per gallon gasoline pump price in constant 2005 dollars as provided by the Department of Energy, Energy Information Administration is used to represent the price of gasoline for consumers (Historical

Gas Prices). The dummy variable $wake_t$ is created to account for the years in which wakeboard boats have been produced. It is equal to one for the years 1998 through 2005 and is equal to zero for all prior years.

Supply Variables

The variables believed to be relevant in explaining the quantity of new ski/wakeboard boats supplied each year include: the real average sale price, real price level for inputs in the production process and a trend variable representing improvements in manufacturing productivity. The first material used in powerboat production is synthetic rubber/synthetic fiberglass. The annual producer price index in constant 1982 dollars for synthetic rubber/synthetic fiberglass is also available on the Bureau of Labor Statistics website (PPI-Chem. and allied prods.). The annual producer price index for synthetic rubber/synthetic fiberglass does not include data for 1970, but will not cause a problem since data for the years 1970 through 1972 will be dropped for reasons discussed below. The annual producer price index in constant 1982 dollars for industrial electric power can also be downloaded from the Bureau of Labor Statistics website (PPI-Ind. Electric Power). The national average wage index in real terms produced by the Social Security Administration is used as the price of labor (Automatic Increases). A preferred wage index for the price of labor is the employment cost index for U.S. manufacturing employees provided by the Bureau of Labor Statistics, however, this index does not provide complete data prior to 1976 (Employment Cost Index – Man.). The correlation coefficient between the national average wage index and the employment cost index is 0.9965. Thus, it is believed the national average wage index available on the Social Security Administration website is a good measure of the price of labor for the boat manufacturing industry. Finally, a linear trend variable is included to account for improvements in manufacturing productivity.

According to Table 3.2, the producer price indices for synthetic rubber/synthetic fiberglass and industrial electric power in constant 1982 dollars increased in comparable magnitude. The average annual wage employers paid employees for 1973 through 2004 was $20,236 and increased from $7,580 in 1973 to $35,648 in 2004. Similarly, the U.S. per capita income in 2004 dollars averaged $19,641 for the same period and increased from $14,894 in 1973 to $24,511 in 2004. The average price for gasoline at the pump was $1.796 per gallon. The average prime interest rate was 9.05 percent and ranged from a minimum of 4.12 percent in 2003 to a maximum of 18.87 percent in 1981. The average annual return for the S&P 500 was 12.68 percent.

After initial review of the data set and summary statistics, there are four possible limitations. First, the data set consists of annual observations covering 35 years. The small sample size could present difficulties with respect to degrees of freedom. Second, as shown in Table 3.4 and Table 3.5 the data set may suffer from multicollinearity among the price indices for synthetic rubber/synthetic fiberglass, industrial electric power and wages. The correlation coefficient between the wage index and the industrial electric power index is over 0.90. The correlation coefficients between each of these indices and the index for synthetic rubber/synthetic fiberglass are over 0.96. This may result in large standard errors. One possible alternative that can be considered if multicollinearity appears, is to construct a single index for the inputs of production. Third, the classification of inboard runabout boats seems to have changed between 1972 and 1973. After reviewing the data set for inboard runabout boats and other categories of boats, the recorded quantity of inboard runabout boats sold in each of these years is exactly the same as the quantity of inboard cruisers sold. These two categories of boats appear to have been recorded jointly prior to 1973. Therefore, the years 1970 through 1972 are deleted leaving 32 observations for the years 1973 through 2004. Finally, the data set is a time series, therefore serial correlation among the errors may need to be addressed.

Chapter Four

Model and Methods

The model and methods are developed in this section. To start, the structural form of the economic model is presented. Second, the model is transformed into a statistical model that allows for estimation. Then identifiability for each equation within the statistical model is determined. Next, the reduced form of the statistical model is derived. The final presentation in the Model and Methods section presents the estimator used and its properties.

Structural Form of the Economic Model

The structural form of the linear, in parameters, economic model is represented by equations (1), (2) and (3).

$$(1) \qquad \ln qty^{*}_{d,t} = \beta_0 + \beta_1 \ln price^{*}_{t} + \beta_2 \ln income_t + \beta_3 \ln labor_t + \beta_4 \ln gas_t + \beta_5 \ln prime_t + \beta_6 stock_t + \beta_7 wake_t$$

$$(2) \qquad \ln qty^{*}_{s,t} = \alpha_0 + \alpha_1 \ln price^{*}_{t} + \alpha_2 \ln fiber_t + \alpha_3 \ln electric_t + \alpha_4 \ln wage_t + \alpha_5 \ln trend_t$$

$$(3) \qquad \ln qty^{*}_{d,t} = \ln qty^{*}_{s,t} = \ln qty^{*}_{t}$$

where t = 1, 2, …, 32 and * identifies endogenous variables which are equal across equations.

Quantity and price are jointly determined and are considered endogenous variables within the model. In the presence of a static equilibrium, $\ln qty^{*}_{t}$ and $\ln price^{*}_{t}$ are the endogenous variables, and all other variables are determined outside the system and are considered exogenous variables. The economic model consists of two behavioral equations and one identity equation (3) which ensures market clearing.

Structural Form of the Statistical Model

Transitioning to a statistical model, the behavioral relation modeled above does not explain all market movements without error. Thus, these errors are represented in the statistical model by including random unknown error terms e_t and v_t that are assumed to be independent and normally distributed random variables with a mean zero and variance σ_e^2 and σ_v^2, respectively. Also, all variables, except the variables representing the S&P 500 return and wakeboard boat production years, are converted to natural logarithmic form. These modifications to the economic model yield the following structural form of the statistical model:

(4) $$\ln qty_{d,t}^{*} = \beta_0 + \beta_1 \ln price_t^{*} + \beta_2 \ln income_t + \beta_3 \ln labor_t + \beta_4 \ln gas_t$$

$$+ \beta_5 \ln prime_t + \beta_6 stock_t + \beta_7 wake_t + e_t$$

(5) $$\ln qty_{s,t}^{*} = \alpha_0 + \alpha_1 \ln price_t^{*} + \alpha_2 \ln fiber_t + \alpha_3 \ln electric_t + \alpha_4 \ln wage_t$$

$$+ \alpha_5 \ln trend_t + v_t$$

(6) $$\ln qty_{d,t}^{*} = \ln qty_{s,t}^{*} = \ln qty_t^{*}$$

(7) and $e_t \sim N(0, \sigma_e^2)$, $v_t \sim N(0, \sigma_v^2)$

where t = 1, 2, …, 32.

A concern with the statistical model is that the error terms e_t and v_t are contemporaneously correlated across equations. In the presence of contemporaneously correlated error terms across equations, estimates for the parameters of the model will not be efficient if estimated by ordinary least squares (OLS). Accordingly, alternative methods of estimation are used to obtain more efficient parameter estimates. All exogenous variables are assumed to be uncorrelated with the error term in their respective equation.

Identification

The next step is to check the identification of each equation within the statistical model. Let g* equal the number of endogenous variables in the i^{th} equation, k* equal the number of exogenous variables in the i^{th} equation and K equal the total number of exogenous variables in all equations within the model. There are 10 exogenous variables in the model which results in K equal to 10. Equation (4) contains 2 endogenous variables ($\ln qty^*_{d,t}$, $\ln price^*_t$) and 6 exogenous variables ($\ln income_t$, $\ln labor_t$, $\ln gas_t$, $\ln prime_t$, $stock_t$, and $wake_t$) resulting in g_1* equal to 2 and k_1* equal to 6. Equation (5) contains 2 endogenous variables ($\ln qty^*_{s,t}$, $\ln price^*_t$) and 4 exogenous variables ($\ln fiber_t$, $\ln electric_t$, $\ln wage_t$, and $\ln trend_t$) resulting in g_2* equal to 2 and k_2* equal to 4. Equation (4) modeling quantity demanded is overidentified since $(g_1^*+k_1^*-1) = 7$ is less than K = 10 and equation (5) modeling quantity supplied is overidentified since $(g_2^*+k_2^*-1) = 5$ is less than K = 10 (Griffiths, Hill and Judge, p. 605-606). Neither equation is underidentified, thus, consistent estimation of the parameters is possible.

Reduced Form of the Statistical Model

The structural form of the statistical model consists of three equations and two endogenous variables. Since there are more equations than variables, the three equations in structural form can be used to solve for $\ln qty_t^*$ and $\ln price_t^*$ in terms of the exogenous variables. Solving equation (4) for $\ln price_t^*$, substituting the result into equation (5) and solving for $\ln qty_t^*$ yields the reduced form equation for quantity $\ln qty_t^*$. Similarly, solving equation (4) for $\ln price_t^*$, substituting equation (5) into equation (4) and solving for $\ln price_t^*$ yields the reduced form equation for the natural logarithm of the real average sale price $\ln price_t^*$. The resulting reduced form equations (8) and (9), where the jointly determined endogenous random variables are expressed as linear functions of the exogenous variables in the system, are:

(8) $$\ln qty_t^* = \pi_{11} + \pi_{12} \ln fiber_t + \pi_{13} \ln electric_t + \pi_{14} \ln wage_t + \pi_{15} \ln trend_t + \pi_{16} \ln income_t + \pi_{17} \ln labor_t + \pi_{18} \ln gas_t + \pi_{19} \ln prime_t + \pi_{110} stock_t + \pi_{111} wake_t + \pi_{112}$$

where
$$\pi_{11} = \frac{\alpha_0 - \frac{\alpha_1\beta_0}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{14} = \frac{\alpha_4}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{17} = -\frac{\frac{\alpha_1\beta_3}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{110} = -\frac{\frac{\alpha_1\beta_6}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}}$$

$$\pi_{12} = \frac{\alpha_2}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{15} = \frac{\alpha_5}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{18} = -\frac{\frac{\alpha_1\beta_4}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{111} = -\frac{\frac{\alpha_1\beta_7}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}}$$

$$\pi_{13} = \frac{\alpha_3}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{16} = -\frac{\frac{\alpha_1\beta_2}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{19} = -\frac{\frac{\alpha_1\beta_5}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{112} = \frac{v - \frac{\alpha_1 e}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}}$$

(9) $$\ln price_t^* = \pi_{21} + \pi_{22} \ln income_t + \pi_{23} \ln labor_t + \pi_{24} \ln gas_t + \pi_{25} \ln prime_t + \pi_{26} stock_t + \pi_{27} wake_t + \pi_{28} \ln fiber_t + \pi_{29} \ln electric_t + \pi_{210} \ln wage_t + \pi_{211} \ln trend_t + \pi_{212}$$

where
$$\pi_{21} = \frac{\frac{\alpha_0}{\beta_1} - \frac{\beta_0}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{24} = -\frac{\frac{\beta_4}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{27} = -\frac{\frac{\beta_7}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{210} = \frac{\frac{\alpha_4}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}}$$

$$\pi_{22} = -\frac{\frac{\beta_2}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{25} = -\frac{\frac{\beta_5}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{28} = \frac{\frac{\alpha_2}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{211} = \frac{\frac{\alpha_5}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}}$$

$$\pi_{23} = -\frac{\frac{\beta_3}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{26} = -\frac{\frac{\beta_6}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{29} = \frac{\frac{\alpha_3}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}} \qquad \pi_{212} = \frac{\frac{v}{\beta_1} - \frac{e}{\beta_1}}{1-\frac{\alpha_1}{\beta_1}}$$

The reduced form parameters, π's, are functions of the structural form parameters. The reduced form of the statistical model allows for the direct interpretation of the impact that a change in an exogenous variable will have on an endogenous variable accounting for the joint determination of quantity and real average sale price. Direct estimation of the reduced form parameters using ordinary least squares will produce asymptotically consistent estimates if π_{112} and π_{212} are not correlated with any of the exogenous independent variables, as is assumed here. However, using the reduced form parameter estimates to then derive parameter estimates for the structural coefficients, also know as the indirect least squares method (ILS), will not provide unique estimates of the structural parameters since equations (4) and (5) are overidentified. For example, given the reduced form coefficients calculated above the structural coefficient for real average price, $\ln price_t^*$, would have four possible solutions:

$$\beta_1 = \frac{\pi_{12}}{\pi_{28}} \quad \text{or} \quad \beta_1 = \frac{\pi_{13}}{\pi_{29}} \quad \text{or} \quad \beta_1 = \frac{\pi_{14}}{\pi_{210}} \quad \text{or} \quad \beta_1 = \frac{\pi_{15}}{\pi_{211}}.$$

Therefore, the structural form of the statistical model is estimated simultaneously yielding consistent and efficient estimates which are then used to calculate unique reduced form coefficients. The unique parameter estimate for $\ln price_t^*$ obtained by simultaneous estimation will be compared to the four estimates resulting from using the indirect least squares method.

Method of Estimation

Estimating the demand equation (4) and the supply equation (5) separately using OLS would produce biased and inconsistent parameter estimates due to endogeneity bias. The standard errors would also be inconsistent (Greene, p. 396). Given that both equations are overidentified estimation by indirect least squares would not yield unique estimates of the structural parameters as illustrated above. Neither equation is underidentified so simultaneous estimation of the parameters is possible.

The two-stage least squares (2SLS) method of estimation allows for simultaneous estimation. This method would produce parameter estimates that are biased but consistent and standard errors that are also consistent (Greene, p. 398-399). However, to get even more efficient parameter estimates another method of estimation is utilized.

There is information in the errors of each equation which helps to explain some of the variation in the other equation. Estimating these equations as a system accounts for the likelihood that contemporaneous correlation between the errors across equations is not zero. Such a framework is a variation of seemingly unrelated regressions and it further improves efficiency while increasing degrees of freedom. This leads to the more efficient estimation method three-stage least squares (3SLS), which also would produce biased, but asymptotically consistent, parameter estimates and consistent standard errors (Greene, p. 407). Further, three-stage least squares method of estimation is more efficient than two-stage least squares since both equations are overidentified (Zellner and Theil, p. 58).

Another estimator which is utilized and results presented is iterated three-stage least squares (iterated 3SLS). Iterated three-stage least squares estimates are biased but consistent, although, do not approach the maximum likelihood estimator or improve the asymptotic efficiency (Greene, p. 406). Standard errors are also consistent in large samples.

Maximum likelihood estimates do not possess advantages in asymptotic properties over estimates obtained using three-stage least squares (Greene, p. 407; Kmenta and Gilbert, p. 1199). Both three-stage least squares and iterated three-stage least squares methods of estimation are used to estimate the demand and supply equations simultaneously and allow for a comparison of results.

Chapter Five

Results

Before testing for serial correlation, parameter estimates, obtained by estimating the structural form of the statistical model using both 3SLS and iterated 3SLS are presented. Second, since the data set is a time series, hypothesis tests are conducted to determine if there is evidence of serial correlation among the errors of each equation. The data is transformed to correct for serial correlation where necessary. Third, results from estimating the structural form of the statistical model using the transformed data are presented and the explanatory power of the model is discussed. The hypothesis tests outlined in the introduction are carried out. Last, the final parameter estimates for the structural form of the statistical model are then used to calculate unique parameter estimates for the reduced form equations. As data becomes available for the 2005 production year the quantity demanded and average sale price predicted by the model will be compared to the actual quantity demanded and average sale price experienced for 2005.

Table 5.1 presents the parameter estimates, standard errors and whether each variable is significant when testing at the 10%, 5% or 1% level of significance, before testing for serial correlation. Parameter estimates are consistent across estimation methods with very little change in values. All analyses of signs and magnitude are reserved until after conducting hypothesis tests for serial correlation and, if necessary, transforming the data.

Table 5.1: Estimation results before correcting for serial correlation

	Three-Stage Least Squares Estimation Results			Iterated Three-Stage Least Squares Estimation Results		
	Coefficient	Std. Error	Sig.	Coefficient	Std. Error	Sig.
Demand Equation						
Dependent variable:	$\ln qty^{*}_{d,t}$			$\ln qty^{*}_{d,t}$		
intercept	-125.4200	5.3280	***	-125.5026	5.3349	***
$\ln price^{*}_{t}$	-0.1309	0.0798		-0.1318	0.0800	*
$\ln income$	10.3085	0.4036	***	10.2724	0.4039	***
$\ln labor$	3.1076	0.6848	***	3.1454	0.6856	***
$\ln gas$	0.0770	0.0489		0.0716	0.0489	
$\ln prime$	-0.0824	0.0316	***	-0.0787	0.0316	**
stock	0.0005	0.0004		0.0005	0.0004	
wake	0.0558	0.0301	*	0.0592	0.0301	**
AIC = -6.0345				AIC = -6.0313		
Supply Equation						
Dependent variable:	$\ln qty^{*}_{s,t}$			$\ln qty^{*}_{s,t}$		
intercept	-21.4779	5.7910	***	-21.5078	5.7730	***
$\ln price^{*}_{t}$	0.7949	0.3143	**	0.7869	0.3133	**
$\ln fiber$	0.4608	0.4559		0.4022	0.4546	
$\ln electric$	-2.8112	0.3738	***	-2.7844	0.3725	***
$\ln wage$	3.2923	0.8396	***	3.3152	0.8368	***
$\ln trend$	1.3089	0.5541	**	1.3194	0.5527	**
AIC = -3.9911				AIC = -3.9936		

*** Indicates there is significant evidence that the coefficient is different from zero when testing at the 1% level of significance.

** Indicates there is significant evidence that the coefficient is different from zero when testing at the 5% level of significance.

* Indicates there is significant evidence that the coefficient is different from zero when testing at the 10% level of significance.

Note: Coefficients with perverse signs are in bold.

Hypothesis Tests for Serial Correlation

There is reason to suspect serial correlation among the errors of each equation since the analysis uses a sample of time series observations. If serial correlation among the errors exists and is ignored, the estimator will not be efficient and the reported covariance matrix will be biased. Thus, the standard errors and inference would not be valid. Using the errors e_t and v_t from the iterated 3SLS estimation above, the estimated values for serial correlation among the errors of the demand equation ρ_1 and the supply equation ρ_2 can be obtained by estimating equations (10) and (11) by OLS.

(10) $e_t = \rho_1 e_{t-1} + \mu_t$ Demand Equation

(11) $v_t = \rho_2 v_{t-1} + \tau_t$ Supply Equation

where μ_t and τ_t are both independent with constant variances σ^2_μ and σ^2_τ, respectively. Estimating equations (10) and (11) by OLS yields estimates for ρ_1 and ρ_2 which agree with the hypothesis tests for serial correlation using the Durbin-Watson statistic.

Durbin-Watson statistics, when estimating the equations simultaneously before any transformation is performed on the data, are provided by computer software. Table 5.2 summarizes the results from testing the null hypotheses that the errors in both the demand equation and supply equation are not correlated over time. All hypothesis tests are conducted at the 5% level of significance. Considering the demand equation first, with the null hypothesis that ρ_1 is equal to zero and the alternative hypothesis that ρ_1 is greater than zero, the null hypothesis that ρ_1 is equal to zero for the demand equation is inconclusive. Also for the demand equation, with the null hypothesis that ρ_1 is equal to zero and the alternative hypothesis that ρ_1 is less than zero, the null hypothesis that ρ_1 is equal to zero is not rejected. For the supply equation the first null hypothesis is that ρ_2 is equal to zero and the alternative hypothesis is that ρ_2 is greater than zero. Since the Durbin-Watson statistic (0.8399) for the supply equation is less than the lower bound d_L (1.109) the null hypothesis that ρ_2 is equal to zero for the supply equation is rejected. Thus, there is significant evidence that positive serial correlation exists among the errors of the supply equation. The first-order serial correlation among the errors of the supply equation is estimated to be 0.557947. Finally, the second null hypothesis tested for the supply equation is that ρ_2 is equal to zero with the alternative hypothesis is that ρ_2 is less than zero. The null hypothesis is not rejected.

Table 5.2: Summary of serial correlation hypothesis testing results

			Before Transformation	After Transformation
Demand Equation				
		DW:	1.8006	1.6811
T:	32	H_O: $\rho = 0$, H_A: $\rho > 0$	Inconclusive	Inconclusive
K:	8	H_O: $\rho = 0$, H_A: $\rho < 0$	Fail to reject H_O	Fail to reject H_O
d_L:	0.972			
d_U:	2.004			
Supply Equation				
		DW:	0.8399	1.6480
T:	32	H_O: $\rho = 0$, H_A: $\rho > 0$	Reject H_O	Inconclusive
K:	6	H_O: $\rho = 0$, H_A: $\rho < 0$	Fail to reject H_O	Fail to reject H_O
d_L:	1.109			
d_U:	1.819			

Note: All Durbin-Watson statistics are calculated from estimates using iterated 3SLS.

Given the evidence of positive serial correlation among the errors within the supply equation the data is transformed using the Prais-Winsten method to get a feasible generalized least squares estimator (Griffiths, Hill and Judge, p. 523-524; Kenkel, p. 796-797). All observations for the dependent variable, independent variables and the intercept are transformed in a manner, such that, $x_t - \rho_2 x_{t-1}$, where x_t represents a vector of all variables in the model including the dependent variable and intercept term. In order to prevent losing an observation, the first observation is transformed by the process $\sqrt{1-\rho_2^2}\,x_1$ where x_1 again represents a row vector of all variables in the model but only for the first observation. The estimated value of ρ_2 equal to 0.557947 is used in the data transformation. The structural form of the statistical model is estimated again by 3SLS and iterated 3SLS using the transformed data. Once more, a test for serial correlation among the errors in both the demand and supply equation is conducted. One concern is the effect of using the estimated value of ρ_2 from the initial supply equation to transform the exogenous variables also included in the demand equation. Specifically, the concern is whether this will induce serial correlation among the errors of the demand equation.

Again, Table 5.2 summarizes the findings for testing the same four null hypotheses as before the transformation. Evaluating the demand equation first, the null hypothesis that ρ_1 is equal to zero is inconclusive when the alternative hypothesis is that ρ_1 is greater than zero. The null hypothesis that ρ_2 is equal to zero, when the alternative hypothesis is that ρ_2 is less than zero, is not rejected. There is no significant evidence to support the claim that there is either positive or negative serial correlation among the errors of the demand equation. For the supply equation after the data transformation, a test of the null hypothesis that ρ_2 is equal to zero when the alternative hypothesis is that ρ_2 is greater than zero is now inconclusive. And finally, the null hypothesis that ρ_2 is equal to zero is not rejected when the alternative hypothesis is that ρ_2 is less than zero. The data transformation appears to be justified. There is no longer significant evidence that positive serial correlation exists among the errors for the supply equation. Given the results of the hypothesis tests for serial correlation among the errors after transforming the data, it is believed that estimation of the structural form of the statistical model will now produce a covariance matrix that can be utilized to conduct valid hypothesis tests. The results from iterated 3SLS are used for all remaining analyses and hypothesis tests are conducted at a 5% level of significance.

Estimation Results After Data Transformation

Again parameter estimates are consistent across estimation methods with very little change in coefficient values from one method to another. Corresponding standard errors are nearly identical across estimation methods. Table 5.3 presents the parameter estimates, standard errors and indicated levels of significance obtained by estimating the structural form of the statistical model by 3SLS and iterated 3SLS methods after transforming the data. The resulting estimated equations are:

$$\text{(12)} \quad \ln qty^{*}_{d,t} = -122.049 - 0.032 \ln price^{*}_{t} + 9.407 \ln income_{t} + 3.501 \ln labor_{t} + 0.096 \ln gas_{t} + 0.091 \ln prime_{t} + 0.0003 stock_{t} + 0.070 wake_{t} + e_{t}$$

$$\text{(13)} \quad \ln qty^{*}_{s,t} = -21.934 + 0.746 \ln price^{*}_{t} + 0.247 \ln fiber_{t} - 2.588 \ln electric_{t} + 3.389 \ln wage_{t} + 1.288 \ln trend_{t} + v_{t}$$

The Akaike information criterion (AIC) is used to assess the power of the model. Similar to $\overline{R}^2$, the AIC measure involves a trade-off between minimizing the sum of squared errors and restraining any increase in the number of independent variables (Griffiths, Hill and Judge, p. 343). The AIC calculations are provided in Table 5.4 and the AIC statistics are also provided in Table 5.1 and Table 5.3 with regression results. The AIC statistics for both the demand and supply equations are smaller after correcting for serial correlation. The decrease in these statistics supports the claim above that the data transformation was justified.

Table 5.3: Estimation results after correcting for serial correlation

Three-Stage Least Squares Estimation Results				Iterated Three-Stage Least Squares Estimation Results			
	Coefficient	Std. Error	Sig.		Coefficient	Std. Error	Sig.
Demand Equation				**Demand Equation**			
	Dependent variable:	$\ln qty^{*}_{d,t}$			Dependent variable:	$\ln qty^{*}_{d,t}$	
intercept	-122.1053	6.0934	***	*intercept*	-122.0488	6.0922	***
$\ln price^{*}_{t}$	-0.0324	0.0955		$\ln price^{*}_{t}$	-0.0321	0.0955	
ln*income*	9.3895	0.4873	***	ln*income*	9.4074	0.4871	***
ln*labor*	3.5209	0.8013	***	ln*labor*	3.5010	0.8011	***
ln*gas*	0.0932	0.0584		ln*gas*	0.0958	0.0583	*
ln*prime*	-0.0887	0.0396	**	ln*prime*	-0.0910	0.0395	**
stock	0.0003	0.0003		*stock*	0.0003	0.0003	
wake	0.0714	0.0362	**	*wake*	0.0704	0.0362	*
AIC = -6.1783				AIC = -6.1782			
Supply Equation				**Supply Equation**			
	Dependent variable:	$\ln qty^{*}_{s,t}$			Dependent variable:	$\ln qty^{*}_{s,t}$	
intercept	-22.0064	6.0227	***	*intercept*	-21.9342	6.0442	***
$\ln price^{*}_{t}$	0.7409	0.2943	**	$\ln price^{*}_{t}$	0.7463	0.2953	**
ln*fiber*	0.2128	0.4281		ln*fiber*	0.2473	0.4296	
ln*electric*	-2.5650	0.4530	***	ln*electric*	-2.5884	0.4545	***
ln*wage*	3.4070	0.8288	***	ln*wage*	3.3887	0.8316	***
ln*trend*	1.2871	0.6225	**	ln*trend*	1.2884	0.6249	**
AIC = -4.4438				AIC = -4.4385			

*** Indicates there is significant evidence that the coefficient is different from zero when testing at the 1% level of significance.

** Indicates there is significant evidence that the coefficient is different from zero when testing at the 5% level of significance.

* Indicates there is significant evidence that the coefficient is different from zero when testing at the 10% level of significance.

Table 5.4: Comparison of AIC test statistics for all scenarios

Akaike Information Criterion - Before Data Transformation

$$AIC_i = \ln(SSE_i/T) + (2K_i/T)$$

		3SLS		Iterated 3SLS
Demand				
	SSE_1 =	0.0543	SSE_3 =	0.0546
	K_1 =	8	K_3 =	8
	T =	32	T =	32
	AIC_1 =	-6.0345	AIC_3 =	-6.0313
Supply				
	SSE_2 =	0.4159	SSE_4 =	0.4165
	K_2 =	6	K_4 =	6
	T =	32	T =	32
	AIC_2 =	-3.9911	AIC_4 =	-3.9936

Akaike Information Criterion - After Data Transformation

		3SLS		Iterated 3SLS
Demand				
	SSE_5 =	0.0462	SSE_7 =	0.0465
	K_5 =	8	K_7 =	8
	T =	32	T =	32
	AIC_5 =	-6.1783	AIC_7 =	-6.1782
Supply				
	SSE_6 =	0.2888	SSE_8 =	0.2986
	K_6 =	6	K_8 =	6
	T =	32	T =	32
	AIC_6 =	-4.4438	AIC_8 =	-4.4385

All signs are in the expected direction except the coefficients for the real average price of gas at the pump, real cost of synthetic rubber/synthetic fiberglass and real cost of labor. However, when testing at the 5% level of significance there is no significant evidence that the coefficients for the real average price of gas at the pump and real cost of synthetic rubber/synthetic fiberglass are different than zero on average, therefore, no attempt is made to explain their perverse signs. The real cost of labor does not exhibit a sign in the expected direction. The quantity of new ski/wakeboard boats demanded is expected to decrease as the cost of labor increases. A possible explanation for this is the high correlation between the wage index in the supply equation and real per capita income in the demand equation. These variables in natural log form have a correlation coefficient equal to 0.9856.

Demand Equation Results

In the demand equation, the sign of the coefficient for the real average price of new ski/wakeboard boats is in the direction which agrees with economic theory. However, there is no statistical evidence that this coefficient is different from zero on average. The unique parameter estimate for $lnprice_t$ using the iterated 3SLS estimator is equal to -0.0321 compared to the four values that would be obtained using the indirect least squares method:

$$\beta_1 = \frac{\pi_{12}}{\pi_{28}} = 0.5730 \qquad \beta_1 = \frac{\pi_{13}}{\pi_{29}} = 0.0222$$

$$\beta_1 = \frac{\pi_{14}}{\pi_{210}} = -0.3789 \qquad \beta_1 = \frac{\pi_{15}}{\pi_{211}} = 0.6805\,.$$

The unique estimate obtained by iterated 3SLS for the coefficient of $\ln price_t^*$ in the demand equation, β_1 equal to -0.0321, is approximately in the middle of the range of parameter estimates obtained by the indirect least squares method. However, given the statistical evidence using both indirect least squares and iterated 3SLS, the null hypothesis, that β_1 is equal to zero on average, is not rejected. While indirect least squares is a consistent estimator, it does not provide unique parameter estimates and is not efficient. Iterated 3SLS is asymptotically efficient and is a preferred estimator. Again, in the demand equation there is no significant evidence that the coefficient for $\ln price_t^*$ is different than zero on average.

There is significant statistical evidence that the coefficients for the variables representing, real per capita income, size of the labor force and average annual prime interest rate are different from zero on average. It is estimated that a 1 percent increase in the size of the labor force is associated with a 3.5 percent increase in the quantity of new ski/wakeboard boats demanded each year. Also in agreement with expectations, an increase in either real per capita income or the size of the labor force is associated with an increase in the quantity demanded on average. A 1 percent increase in real per capita income is associated with a 9.4 percent increase in the quantity demanded. A test of the null hypothesis that the elasticity of income for new ski/wakeboard boats is equal to or less than one is rejected when the alternative hypothesis is that the elasticity of income is greater than one. This a one tailed test where (9.41 – 1) / 0.49 = 17.16 is greater than the approximate critical value of 1.697. Therefore, there is significant evidence when testing at the 5% level of significance that the elasticity of income is greater than one on average. This evidence supports the theory that new ski/wakeboard boats are luxury items.

Second, the null hypothesis that an increase in the real average annual per gallon price of gasoline at the pump is not associated with a decrease in the quantity of new ski/wakeboard boats demanded is not rejected. There is no significant evidence that an increase in the real average annual price per gallon of gasoline at the pump is associated with a decrease in the quantity of new ski/wakeboard boats demanded on average.

Next, a 10 percent increase in the level of the average prime interest rate, not a one unit increase when measured as a percentage, is estimated to be associated with a 0.9 percent decrease in the quantity of new ski/wakeboard boats demanded on average. The null hypothesis that an increase in the current prime interest rate is not associated with a decrease in the quantity demanded is rejected. There is significant evidence that an increase in the average prime interest rate is associated with a decrease in the quantity of new ski/wakeboard boats demanded.

The fourth null hypothesis to be tested is that an increase in the annual return for the S&P 500 stock index is not associated with an increase in the quantity of new ski/wakeboard boats demanded. This null hypothesis is not rejected since there is no significant evidence that an increase in the annual return for the S&P 500 index is associated with an increase in the quantity of new ski/wakeboard boats demanded on average.

Finally, the null hypothesis that the introduction of wakeboard boats is not associated with an increase in the total quantity demanded of new ski/wakeboard boats is not rejected when testing at the 5% level of significance. Despite failing to reject the null hypothesis at the 5% level of significance, there is some evidence that the introduction of wakeboard boats is associated with an increase in the quantity demanded given the p-value of 0.052. Also, the null hypothesis is rejected at the 5% level of significance when using the 3SLS estimator. This evidence supports the argument that preferences have shifted away from traditional ski boats toward wakeboard boats.

Supply Equation Results

Evaluating the supply equation, there is significant evidence that the coefficients for all variables except synthetic rubber/synthetic fiberglass are different than zero on average, holding all other variables constant. However, there is no significant evidence that the coefficient for synthetic rubber/synthetic fiberglass is different than zero on average. It is estimated that a 10 percent increase in the real average price of a ski/wakeboard boat is associated with a 7.5 percent increase in the quantity supplied each year. This agrees with expectations and seems reasonable in magnitude. A 1 percent increase in the real cost of industrial electricity is associated with a 2.6% decrease in the quantity of boats supplied on average and agrees with expectations. On the other hand, the association of a 1 percent increase in the real cost of labor with a 3.4% increase in the quantity of boats supplied does not agree with expectations. As mentioned previously, this outcome is likely due to the extreme correlation between the wage index and per capita income in the demand equation. Lastly, there is significant evidence that new production technologies are associated with an increase in the quantity of ski/wakeboard boats supplied. Thus, the null hypothesis that new production technologies are not associated with an increase in the quantity of ski/wakeboard boats supplied is rejected.

Estimated Reduced Form Equations

The unique parameter estimates obtained from iterated 3SLS are substituted into the reduced form coefficient formulas provided on page 27 to calculate values for the coefficients of the reduced form equations. The unique parameter estimates used for these calculations and the calculated reduced form coefficients are summarized in Table 5.5 and yield the following reduced form equations:

$$\begin{aligned}(14)\quad \ln qty_t^* &= -117.9202 + 0.0102 \ln fiber_t - 0.1067 \ln electric_t + 0.1397 \ln wage_t \\ &\quad + 0.0531 \ln trend_t + 9.0195 \ln income_t + 3.3566 \ln labor_t + 0.0918 \ln gas_t \\ &\quad - 0.0872 \ln prime_t + 0.0003 stock_t + 0.0675 wake_t + \pi_{112}\end{aligned}$$

$$\begin{aligned}(15)\quad \ln price_t^* &= -128.6159 + 12.0856 \ln income_t + 4.4977 \ln labor_t + 0.1231 \ln gas_t \\ &\quad - 0.1169 \ln prime_t + 0.0004 stock_t + 0.0904 wake_t - 0.3177 \ln fiber_t \\ &\quad + 3.3253 \ln electric_t - 4.3534 \ln wage_t - 1.6552 \ln trend_t + \pi_{212}\end{aligned}$$

Table 5.5: Coefficients of the reduced form equations

Iterated Three-Stage Least Squares Estimation Results

	Coefficient	Std. Error	Sig.
Demand Equation			
	Dependent variable:	$\ln qty^*_{d,t}$	
intercept	-122.0488	6.0922	***
$\ln price^*_t$	-0.0321	0.0955	
ln*income*	9.4074	0.4871	***
ln*labor*	3.5010	0.8011	***
ln*gas*	0.0958	0.0583	*
ln*prime*	-0.0910	0.0395	**
stock	0.0003	0.0003	
wake	0.0704	0.0362	*
Supply Equation			
	Dependent variable:	$\ln qty^*_{s,t}$	
intercept	-21.9342	6.0442	***
$\ln price^*_t$	0.7463	0.2953	**
ln*fiber*	0.2473	0.4296	
ln*electric*	-2.5884	0.4545	***
ln*wage*	3.3887	0.8316	***
ln*trend*	1.2884	0.6249	**

Reduced Form Equation Coefficients

$\ln qty^*_t$		$\ln price^*_t$	
intercept	-117.9202	*intercept*	-128.6159
ln*income*	9.0195	ln*income*	12.0856
ln*labor*	3.3566	ln*labor*	4.4977
ln*gas*	0.0918	ln*gas*	0.1231
ln*prime*	-0.0872	ln*prime*	-0.1169
stock	0.0003	*stock*	0.0004
wake	0.0675	*wake*	0.0904
ln*fiber*	0.0102	ln*fiber*	-0.3177
ln*electric*	-0.1067	ln*electric*	3.3253
ln*wage*	0.1397	ln*wage*	-4.3534
ln*trend*	0.0531	ln*trend*	-1.6552

*** Indicates there is significant evidence that the coefficient is different from zero when testing at the 1% level of significance.
** Indicates there is significant evidence that the coefficient is different from zero when testing at the 5% level of significance.
* Indicates there is significant evidence that the coefficient is different from zero when testing at the 10% level of significance.

Direct interpretation of the impact that a change in an exogenous variable will have on an endogenous variable accounting for the joint determination of quantity and average sale price can now be made with equations (14) and (15). For example, it is estimated that a 1 percent increase in real per capita income will be associated with a 9 percent increase in the equilibrium level of the quantity of ski/wakeboard boats sold annually. Also, it is estimated that a 1 percent increase in real U.S. per capita income would be associated with a 12.1 percent increase in the equilibrium level of the real average sale price of new ski/wakeboard boats.

Chapter Six

Conclusion

The estimated demand-supply model does a good job of explaining the variation in the quantity of new ski/wakeboard boats demanded and supplied each year in the U.S. The model provides a valuable understanding of the impact on demand and supply of changes in specific economic factors. These estimated impacts can be used by manufacturers to more accurately forecast demand for their product and, as a result, to adjust production schedules to more efficiently meet demand. More accurate demand forecasts and improved production scheduling to better manage inventory levels should translate into higher profits and gains in market share.

From the hypothesis tests conducted, there is significant evidence that the elasticity of income for these boats is greater than one, which supports the belief that ski/wakeboard boats are luxury items. As consumers' incomes rise their discretionary funds increase as a percentage of income and the funds required for necessities decreases as a percentage of income. There is evidence that a 1 percent increase in income is associated with a greater than one percent increase in the demand for new ski/wakeboard boats. As per capita income rises consumers purchase more ski/wakeboard boats on average. There is no significant evidence that an increase in the real per gallon price of gasoline at the pump is associated with a drop in the quantity of new ski/wakeboard boats demanded, or that an increase in the annual return for the S&P 500 index is associated with an increase in the quantity of new ski/wakeboard boats demanded. Conversely, there is evidence that an increase in the prime interest rate is associated with a decrease in the quantity of new ski/wakeboard boats demanded. There is evidence that the introduction of wakeboard boats is associated with an increase in the quantity of new ski/wakeboard boats demanded.

Areas for future research are to improve the accuracy and scope of the model by including the prices of additional complements and substitutes, the price of inboard engines and the number of individuals employed. An alternative to more precisely account for the number of consumers would be to substitute the number of employed individuals for the size of the labor force. The model could also be extended to evaluate the effect of the introduction of wakeboard boats by separating ski and wakeboard boats into two separate groups for analysis. Did the preferences of traditional skiers change with the introduction of wakeboard boats or is there a new group of buyers? Further data is required with respect to the percentage of ski versus wakeboard boats produced each year in order to expand the model and address questions of this type.

Another approach altogether would be to analyze the total stock of ski/wakeboard boats rather than gross additions, as was done in this thesis. Additional data is required to estimate a scrap equation based on lagged sales that would allow for the total stock of ski/wakeboard boats to be analyzed.

Arguably the most valuable information to manufacturers and dealers would be the findings resulting from analyzing the spread between new and used ski/wakeboard boats. The spread between new and used prices is an immediate indicator of market conditions and could be utilized to capture market share and consumer surplus in good years and reduce risk in down years. This information could also be included in the model to account for the price of the nearest substitute.

Finally, are the ski/wakeboard boat manufacturers exerting market power and if so to what extent? At what point does it become feasible for larger companies such as Brunswick

Marine and Genmar Corporation to enter the ski/wakeboard boat market? These are a few areas for further research with respect to the ski/wakeboard boat market.

Appendix A: Data set used for the analysis

year	*qty*	*price*	*real_price*	*fiber*	*electric*	*wage*	*trend*	income	*labor*	*gas*	*prime*	*stock*	*gdp_def*	*wake*
1973	3200	6205.31	1976.1438	37.70	28.00	7580.16	4	15250	89429	1.68	8.03	-14.72	31.8460	0
1974	3200	6591.25	2289.1741	48.50	36.40	8030.76	5	14894	91949	2.05	10.81	-26.51	34.7305	0
1975	3700	7114.86	2703.0083	61.20	44.30	8630.92	6	14909	93774	2.05	7.86	37.32	37.9910	0
1976	4950	5318.18	2137.4438	63.30	47.90	9226.48	7	15426	96158	2.01	6.84	23.99	40.1913	0
1977	3430	8417.20	3597.6379	65.20	54.30	9779.44	8	15915	99008	1.97	6.83	-7.19	42.7415	0
1978	3730	8684.99	3972.1873	67.10	59.10	10556.03	9	17026	102250	1.86	9.06	6.38	45.7363	0
1979	4050	8680.00	4300.2021	74.90	64.50	11479.46	10	17282	104962	2.28	12.67	18.66	49.5415	0
1980	2900	10265.17	5547.6841	88.40	77.80	12513.46	11	16908	106940	2.91	15.26	32.38	54.0438	0
1981	2950	11740.00	6940.8350	98.10	89.20	13773.10	12	16824	108670	2.92	18.87	-5.25	59.1213	0
1982	3200	13000.00	8154.3149	100.00	100.00	14531.34	13	16828	110204	2.51	14.85	21.54	62.7255	0
1983	3900	12600.00	8214.2549	99.90	103.10	15239.24	14	17082	111550	2.33	10.79	22.58	65.1925	0
1984	4500	13368.00	9043.0840	102.10	108.40	16135.07	15	17869	113554	2.18	12.04	6.30	67.6473	0
1985	4500	15168.00	10573.3096	103.00	112.80	16822.51	16	18440	115461	2.09	9.93	31.78	69.7080	0
1986	5300	16126.98	11489.9092	102.00	114.50	17321.82	17	19190	117834	1.56	8.33	18.66	71.2465	0
1987	6600	16270.00	11907.6875	105.60	111.90	18426.51	18	19704	119865	1.54	8.21	5.26	73.1880	0
1988	7400	17650.00	13358.4023	115.30	112.60	19334.04	19	20135	121669	1.48	9.32	16.61	75.6850	0
1989	9100	19687.03	15464.5586	122.00	116.20	20099.55	20	20678	123869	1.53	10.87	31.67	78.5520	0
1990	7500	17680.00	14425.2441	122.80	119.60	21027.98	21	20162	125840	1.66	10.01	-3.12	81.5908	0
1991	6200	18780.97	15858.6025	124.50	128.10	21811.60	22	19770	126346	1.56	8.46	30.47	84.4398	0
1992	6400	18163.91	15689.9824	124.60	129.60	22935.42	23	19589	128105	1.49	6.25	7.61	86.3800	0
1993	6800	19602.94	17324.3438	126.80	130.60	23132.67	24	20310	129200	1.43	6.00	10.08	88.3763	0
1994	7200	19830.00	17897.2695	130.50	129.20	23753.53	25	20872	131056	1.40	7.15	1.32	90.2535	0
1995	6900	21400.00	19709.9883	140.60	130.80	24705.66	26	21204	132304	1.40	8.83	37.57	92.1028	0
1996	6000	21039.00	19744.4707	140.30	131.60	25913.90	27	21739	133943	1.47	8.27	22.96	93.8470	0
1997	6100	22362.00	21335.5840	141.50	130.80	27426.00	28	22582	136297	1.44	8.44	33.34	95.4100	0
1998	10900	23243.00	22422.0566	141.90	130.00	28861.44	29	23286	137673	1.22	8.35	28.57	96.4680	1
1999	12100	25490.00	24944.9609	141.90	128.90	30469.84	30	24074	139368	1.31	8.00	21.06	97.8618	1
2000	13600	26944.00	26943.1250	148.60	131.50	32154.82	31	24511	142583	1.66	9.23	-9.10	99.9968	1
2001	11100	31763.00	32524.9941	149.50	141.10	32921.92	32	24384	143734	1.55	6.91	-11.86	102.3990	1
2002	10500	37982.00	39571.6602	149.30	139.90	33252.09	33	23943	144863	1.44	4.67	-22.10	104.1853	1
2003	11100	36332.00	38620.0078	158.70	145.80	34064.95	34	23902	146510	1.63	4.12	28.67	106.2975	1
2004	11600	37533.00	40945.2383	170.60	147.20	35648.55	35	23848	147401	1.89	4.34	10.86	109.0913	1

Appendix B: Output from estimating the model using three stage least squares before correcting for serial correlation

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lnqty^*_d	32	8	0.0381	0.9996	88279.70	0.0000
lnqty^*_s	32	6	0.1127	0.9968	10057.96	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnqty^*_d						
ln$price^*$	-0.1309	0.0798	-1.64	0.101	-0.2874	0.0256
ln*income*	10.3085	0.4036	25.54	0.000	9.5174	11.0996
ln*labor*	3.1076	0.6848	4.54	0.000	1.7654	4.4498
ln*gas*	0.0770	0.0489	1.58	0.115	-0.0188	0.1728
ln*prime*	-0.0825	0.0316	-2.61	0.009	-0.1444	-0.0205
stock	0.0006	0.0004	1.34	0.180	-0.0003	0.0014
wake	0.0558	0.0301	1.85	0.064	-0.0032	0.1147
intercept	-125.4200	5.3280	-23.52	0.000	-135.8628	-114.9772
lnqty^*_s						
ln$price^*$	0.7949	0.3143	2.53	0.011	0.1789	1.4109
ln*fiber*	0.4608	0.4559	1.01	0.312	-0.4327	1.3542
ln*electric*	-2.8112	0.3738	-7.52	0.000	-3.5437	-2.0786
ln*wage*	3.2923	0.8396	3.92	0.000	1.6468	4.9378
ln*trend*	1.3089	0.5541	2.36	0.018	0.2229	2.3949
intercept	-21.4779	5.7910	-3.71	0.000	-32.8280	-10.1278

Endogenous variables: lnqty^* ln$price^*$

Exogenous variables: ln*income* ln*labor* ln*gas* ln*prime* *stock* *wake* ln*fiber* ln*electric* ln*wage* ln*trend*

Appendix C: Output from estimating the model using iterated three stage least squares before correcting for serial correlation

Iteration 30: tolerance = 7.548e-06
Iteration 31: tolerance = 5.867e-06
Iteration 32: tolerance = 4.560e-06
Iteration 33: tolerance = 3.544e-06
Iteration 34: tolerance = 2.754e-06
Iteration 35: tolerance = 2.141e-06
Iteration 36: tolerance = 1.664e-06
Iteration 37: tolerance = 1.293e-06
Iteration 38: tolerance = 1.005e-06
Iteration 39: tolerance = 7.811e-07

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
$\ln qty^*_d$	32	8	0.0382	0.9996	87951.93	0.0000
$\ln qty^*_s$	32	6	0.1126	0.9968	10092.47	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
$\ln qty^*_d$						
$\ln price^*$	-0.1318	0.0800	-1.65	0.099	-0.2885	0.0249
ln*income*	10.2724	0.4039	25.43	0.000	9.4808	11.0640
ln*labor*	3.1454	0.6856	4.59	0.000	1.8015	4.4892
ln*gas*	0.0716	0.0489	1.46	0.143	-0.0242	0.1675
ln*prime*	-0.0787	0.0316	-2.49	0.013	-0.1406	-0.0167
stock	0.0005	0.0004	1.28	0.201	-0.0003	0.0014
wake	0.0592	0.0301	1.97	0.049	0.0003	0.1181
intercept	-125.5026	5.3349	-23.52	0.000	-135.9588	-115.0463
$\ln qty^*_s$						
$\ln price^*$	0.7869	0.3133	2.51	0.012	0.1729	1.4010
ln*fiber*	0.4022	0.4546	0.88	0.376	-0.4887	1.2931
ln*electric*	-2.7844	0.3725	-7.47	0.000	-3.5146	-2.0543
ln*wage*	3.3152	0.8368	3.96	0.000	1.6751	4.9553
ln*trend*	1.3194	0.5528	2.39	0.017	0.2362	2.4026
intercept	-21.5078	5.7730	-3.73	0.000	-32.8226	-10.1929

Endogenous variables: $\ln qty^*$ $\ln price^*$
Exogenous variables: ln*income* ln*labor* ln*gas* ln*prime* *stock* *wake* ln*fiber* ln*electric* ln*wage* ln*trend*

Appendix D: Output from estimating the model using three stage least squares after correcting for serial correlation

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
ln*qty*$^*_d$	32	8	0.0355	1.0000	700319.15	0.0000
ln*qty*$^*_s$	32	6	0.0899	0.9997	109412.41	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln*qty*$^*_d$						
ln*price**	-0.0324	0.0955	-0.34	0.734	-0.2197	0.1548
ln*income*	9.3895	0.4873	19.27	0.000	8.4344	10.3447
ln*labor*	3.5209	0.8013	4.39	0.000	1.9504	5.0914
ln*gas*	0.0932	0.0584	1.60	0.115	-0.0210	0.2076
ln*prime*	-0.0887	0.0396	-2.24	0.025	-0.1663	-0.0111
stock	0.0003	0.0003	0.89	0.376	-0.0004	0.0009
wake	0.0714	0.0362	1.97	0.049	-0.0004	0.1424
intercept	-122.1053	6.0934	-20.04	0.000	-134.0481	-110.1625
ln*qty*$^*_s$						
ln*price**	0.7409	0.2943	2.52	0.012	0.1641	1.3177
ln*fiber*	0.2128	0.4281	0.50	0.619	-0.6263	1.0519
ln*electric*	-2.5650	0.4530	-5.66	0.000	-3.4527	-1.6772
ln*wage*	3.4070	0.8288	4.11	0.000	1.7827	5.0314
ln*trend*	1.2871	0.6225	2.07	0.039	0.0670	2.5072
intercept	-22.0064	6.0227	-3.65	0.000	-33.8107	-10.2021

Endogenous variables: ln*qty** ln*price**
Exogenous variables: ln*income* ln*labor* ln*gas* ln*prime* *stock* *wake* ln*fiber* ln*electric* ln*wage* ln*trend*

Appendix E: Output from estimating the model using iterated three stage least squares after correcting for serial correlation

```
Iteration 12:  tolerance =  .00007426
Iteration 13:  tolerance =  .00004495
Iteration 14:  tolerance =  .00002721
Iteration 15:  tolerance =  .00001647
Iteration 16:  tolerance =  9.970e-06
Iteration 17:  tolerance =  6.035e-06
Iteration 18:  tolerance =  3.653e-06
Iteration 19:  tolerance =  2.211e-06
Iteration 20:  tolerance =  1.338e-06
Iteration 21:  tolerance =  8.103e-07
```

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
lnqty^*_d	32	8	0.0355	1.0000	700443.84	0.0000
lnqty^*_s	32	6	0.0901	0.9997	108503.64	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
ln$qty^*_{d,}$						
ln$price^*$	-0.0321	0.0955	-0.34	0.737	-0.2193	0.1552
ln*income*	9.4074	0.4871	19.31	0.000	8.4527	10.3620
ln*labor*	3.5010	0.8011	4.37	0.000	1.9309	5.0711
ln*gas*	0.0958	0.0583	1.64	0.100	-0.0185	0.2101
ln*prime*	-0.0910	0.0395	-2.30	0.021	-0.1685	-0.0135
stock	0.0003	0.0003	0.92	0.358	-0.0003	0.0009
wake	0.0704	0.0362	1.94	0.052	-0.0005	0.1413
intercept	-122.0488	6.0922	-20.03	0.000	-133.9894	-110.1082
lnqty^*_s						
ln$price^*$	0.7463	0.2953	2.53	0.012	0.1674	1.3252
ln*fiber*	0.2473	0.4296	0.58	0.565	-0.5947	1.0894
ln*electric*	-2.5884	0.4545	-5.70	0.000	-3.4792	-1.6977
ln*wage*	3.3887	0.8316	4.07	0.000	1.7588	5.0187
ln*trend*	1.2884	0.6249	2.06	0.039	0.0637	2.5131
intercept	-21.9342	6.0442	-3.63	0.000	-33.7806	-10.0878

Endogenous variables: lnqty^* ln$price^*$
Exogenous variables: ln*income* ln*labor* ln*gas* ln*prime* *stock* *wake* ln*fiber* ln*electric* ln*wage* ln*trend*

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