PRICE DIFFERENCES IN A DURABLE PRODUCTS SECONDARY MARKET:

A HEDONIC PRICE ANALYSIS

A Dissertation

by

ROLAND JOHN FUMASI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Chair of Committee,	James W. Richardson
Co-Chair of Committee,	Henry L. Bryant
Committee Members,	Oral Capps, Jr.
	Michael T. Longnecker
Head of Department,	C. Parr Rosson III

August 2013

Major Subject: Agricultural Economics

ABSTRACT

Secondary markets have not historically possessed the characteristics necessary for market power to emerge, or effective product differentiation to be implemented. The potential effects of these characteristics on primary – secondary market interaction is generally not considered. The law of one price is expected to hold in secondary markets. By applying the hedonic technique to producer theory, and integrating the durability of the product directly into the profit maximizing conditions, potential differences in implicit prices between customer segments in the used bucket truck market are estimated.

Applying weighted least squares to the hedonic equation, parameters were estimated to indicate whether differences in hedonic prices exist between customer segments in the secondary, utility construction equipment market. The hedonic approach accounted for differences in price due to physical characteristics, while underlying supply and demand conditions were accounted for using indicator variables for time. Estimated differences in the effects of physical characteristics on price, between industries, were identified using interaction terms. Results of the econometric estimation indicate that differences in physical product characteristics do not fully account for differences in price between customer segments in the secondary bucket truck market.

If the law of one price can be violated in a secondary market, this could indicate market power. Future research on primary – secondary market interaction should consider the potential effects, if such market power does indeed exist.

DEDICATION

To Angel, Mary, and Ava

ACKNOWLEDGEMENTS

My Co-Chairs, Drs. James Richardson and Henry Bryant, deserve many thanks for continued guidance, confidence, and persistence, even at times of standstill on my part. I am very thankful for the ongoing support of my committee members, Drs. Oral Capps and Michael Longnecker. Further, I thank Drs. James Richardson and Joe Outlaw for providing me the opportunity to join the AFPC team, and develop the skills and experience necessary to complete this endeavor.

Thanks to George and Sarah McMahon for allowing me the flexibility and providing the support needed to successfully execute this dissertation, while still maintaining a “normal” life. I further thank George McMahon for the fact that I only once, questioned my commitment to this project. Thank you George, for the five minute conversation that will have such a positive impact on the lives of my children, and their future generations.

I thank all of my colleagues, family, and friends for always being positive and supportive. You all provided me the energy that it took to get this done.

Most importantly, thank you to my dear wife, Angel, and my wonderful children, Mary and Ava. All that I do, I do for you. Thank you for your understanding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Secondary (used) durable goods markets have been frequently studied based on their potential effects on market power and price discrimination in the primary market (e.g. Coase 1972; Anderson and Ginsburgh 1994; Kumar 2002; and Esteban and Shum 2007). As if only through their impact on the primary market do they play any significant role in determining economic outcomes. In the past, this assumption is not surprising. Twenty years ago, researchers would find it difficult to identify any semblance of market concentration or product differentiation in a typical used, durable goods market. The used automobile market, perhaps the most widely studied and organized used durable goods market, historically existed as tens of thousands of small, independent dealerships, scattered throughout every town, city, and rural outpost in the United States. Used car dealerships served their local markets with little, if any, expectation of product differentiation between dealers. Search costs associated with venturing outside the local market were assumed high, and rightfully so (Anderson and Ginsburgh 1994). Barriers to entry were low, requiring little relative capital or technical expertise when compared to new car dealers.

While many attributes of used durable markets, including the used car market, still exist today, the internet seems to have begun to change the market landscape. Sites such as www.eBay.com, www.AutoTrader.com and www.CommercialTruckTrader.com bring together the availability of thousands of used vehicles from every corner of the country. Consumers are no longer confined to limiting their search costs by staying local, as they can quickly search a nationwide/worldwide inventory of used cars and other durables (Diekmann et al 2008). Hosting a website and charging a fee to bring together many sellers, who each name their own price, does not constitute market concentration or power in the used car market itself, it is simply a case of potential market power in the internet space, i.e. Perhaps www.AutoTrader.com can charge higher fees than competitive websites. However, the internet has logically lessened the differential search costs between new and used markets (Clemons et al 2002). While this could potentially shift some buyers, depending on preferences, away from the new market and into the used, it says nothing about gaining market power *within* the used market itself. This may require something that is potentially lacking in the used car market, product differentiation between sellers (Corts 1998).

If one, or a few, sellers of a used durable good could distinguish their product from competing products in the marketplace, then perhaps they could charge a premium price, even perhaps capture consumer surplus where differentials in price do not necessarily match differences in marginal cost (Corts 1998). This could be challenging, as one would expect, for example that producing a higher quality, used product may necessarily require higher input costs. If producing a truly, higher quality, differentiated product required a relatively high degree of technical expertise and capital investment, then while marginal costs are expected to increase, so to are potential barriers to entry.

Let us imagine a used durable goods dealer who purchases product from sources in various geographic regions throughout the country, as not to limit the availability of raw materials. The dealer then pays to transport the used durables back to a central repair facility, in which well-trained technicians are required to completely refurbish the product. Let us further assume that the consistent level of quality produced is significantly higher than other dealers in the industry. Imagine that the average unit purchased by the dealer has a considerable acquisition cost, well above the cost of an average used car. Assume that each unit purchased is relatively large, weighing between 10,000 and 40,000 pounds, so that the land and repair facility required by the dealer is significant. Assume that the product serves a specific, business to business, niche, so that the expertise and human capital cost required to purchase, transport, repair, and sell the product is relatively high. Lastly, assume that the firm has a high cost, but dominating marketing presence in the industry, such that it is capable of product differentiation in the marketplace. If these assumptions are true, then we might expect that significant barriers to entry and product differentiation exist, which are both traditionally associated with the potential ability to exert market power (Borenstein 1985).

If it is also possible that heterogeneous customer groups, with differing demand elasticities are easily identified, and that arbitrage is unlikely, then perhaps a supplier has the ability to charge different prices depending on the individual market (Pigou 1932). If serving different market segments requires unique physical characteristics of the product for each market, then the market(s) is actually made up of "different" products, not differentiated ones.

If the niche industry described above was an integral part of a more basic industry that affects every consumer's daily life, then perhaps it is worth economic study. Not only could it be important from a consumer welfare perspective, but it may be important from the perspective of the application of economic theory. Theories of market power and primary – secondary market interaction, do not typically account for product differentiation between sellers in the secondary market. If ongoing research in these areas continues to focus only on potential market power in the primary market, then that is understandable. The current project lends itself to those endeavors, because if market power and product differentiation exist in secondary markets, then there is likely to be some effect on the primary market. Conventional theorists may desire to take this potential effect into account, and adjust the assumptions used to relate secondary markets to primary ones. This project does not attempt to put forth a new addition to theory, but only seeks to empirically identify whether such a secondary market exists. To this end, we look at the utility industry.

The utility industry in the United States, including electric power, land-line telecommunications, cellular communications, and fiber optic communications, requires continual infrastructure buildup and maintenance. The electric utility infrastructure in the U.S. and the rest of the industrialized world was built between 60 and 80 years ago. Much of this infrastructure is outdated, and with the continuing increase in demand for power each year, the grid cannot safely and reliably manage the loads of today and tomorrow without significant upgrades. It is estimated that $41 billion will be invested globally in the electrical transmission and distribution infrastructure through 2015 (Fisher 2010). By 2030, the electric utility industry will need to make a total infrastructure investment of $1.5 to $2.0 trillion (Chupka et al 2008).

In addition to scheduled infrastructure upgrades, existing infrastructure such as land-line telecommunications and electric utility lines, can be partially destroyed on an annual basis due to extreme weather and other natural disasters (earthquakes on the west coast, hurricanes in southeastern and gulf states, tornadoes and ice storms in the plains, and blizzards in the north).

Construction and maintenance of utility infrastructure requires the use of a specialized type of equipment known as a bucket truck. Bucket trucks consist of a hydraulic lifting system known as an aerial device, which is mounted onto a truck. Aerial devices can also be mounted onto other types of vehicles such as vans or tracked carriers. Bucket trucks are designed to lift personnel into the air to perform work. Some bucket trucks are also equipped with a material handling winch at the boom tip that is designed to lift materials and supplies.

Utility construction equipment, such as bucket trucks, serves the critical needs of the electric utility and telecommunications industries. Industry segments that purchase bucket trucks include: investor owned utilities, telecommunications companies, power cooperatives and municipal power agencies, as well as electric utility and telecommunications contractors specializing in the construction and maintenance of transmission and distribution power lines and telecommunications infrastructure. The estimated annual value of U.S. utility construction equipment sales is $1.5 billion (Edington 2012). Each of the customer segments above require specific attributes to be present in the equipment they purchase. For example, the electric utility transmission segment will typically buy insulated bucket trucks with a minimum working height of 70 feet. The electric utility distribution segment buys insulated bucket trucks with lower working heights. The telecommunications segment typically purchases non-insulated bucket trucks with working heights of 43 feet or less. Although some bucket truck buyers operate in more than one segment, due to the specifications needed by each segment, equipment cannot practically be transferred from one segment's fleet to another (Edington 2012).

Four U.S. Original Equipment Manufacturers (OEMs) produce 98% of the utility construction equipment sold in North America. Altec produces an estimated 65%, Terex adds an additional 20%, while ETI and Versalift produce the remaining 13% (Edington 2012). Unlike the automobile industry, bucket truck manufacturers do not have a comprehensive dealer network. New bucket trucks are not manufactured in mass, and then shipped to dealer sales lots; dealer lots do not exist. Bucket trucks are typically ordered, per specification, directly from the OEM.

OEM equipment is sold/leased/rented to many large utility entities and municipalities. Large utility organizations use their own personnel and their new(er) utility equipment fleets for standard, daily maintenance of infrastructure. However, the actual construction/rebuilding of utility infrastructure is done by contractors, many of whom buy used utility construction equipment. Estimated annual U.S. sales of used utility construction equipment is $200 million (Edington 2012).

Like the market for *new* utility construction equipment, the *used* market is also dominated by a relatively small number of firms who serve the end-user. Seven used equipment sources account for 80% of used utility construction equipment sales to end-users across North America. These seven firms tend to have nationwide and/or global customer bases. Three of these large suppliers are either wholly or partially owned/controlled by an OEM. The other four have close business relationships with other OEMs. The remaining 20% of used utility construction equipment sales are made by hundreds of small dealers that tend to serve more localized markets (Edington 2012).

In the used market there is a high degree of variation in the quality of the product being sold. Many sellers acquire the used equipment, transport it back to their location, and sell it “as-is where-is” to end-users without performing any type of service to the vehicle. At the other end of the spectrum is Utility Fleet Sales, which is one of the seven large suppliers. Utility Fleet Sales completely inspects, services, and reconditions all major components, and sells a product that is guaranteed to work. Most firms, serving the end-user, offer a product that is somewhere in between, and is at least cleaned and partially serviced. Due to the high level of variation in product quality, and intensive marketing efforts by firms offering a higher quality product, a level of product differentiation is believed to exist. This is evidenced by the fact that Utility Fleet Sales continues to gain market share, although its prices tend to be as high as other firms. It is estimated that Utility Fleet Sales has a current U.S. market share of 15%, but is expected to have a 45% market share by 2020. The completely reconditioned, ready-to-work, remanufactured utility construction equipment offered by Utility Fleet Sales is quickly becoming the industry standard among end-users (Edington 2012).

Note that the industry data and information sources cited in the previous pages are estimates made by industry experts. The reason that more scientific conclusions and hard data do not currently exist may be due to the fact that the utility construction equipment industry has only existed, in its current state, for approximately a decade, and the largest participating firms in the industry are privately held, so published data does not exist.

Prior to the early 2000's, Altec and the other utility construction equipment OEMs *sold* product outright to end-users. True leases were rare. End-users, who bought new equipment, would continue to utilize the equipment purchased until it had no useful life remaining. End-users who could not economically justify purchasing new equipment would rent equipment. Rental companies would continue to keep units in their rental fleets until the units had no useful life remaining. Equipment would be sold at auction for scrap metal and spare parts (Edington 2012).

In the late 90's, Altec moved to an equipment leasing/rental business model, and other OEMs quickly followed suit. Hendel and Lizzeri (2002) and Waldman (2003) examine the role of leasing in durable goods markets. They demonstrate the economic advantages that exist when firms with market power rent/lease new equipment as opposed to outright selling. In our context, Altec's move toward almost always renting/leasing equipment to the retail market demonstrates that firm's potential recognition of the increased profitability that the theorists suggest.

In the years that followed, Altec began buying other OEMs and immediately ceased production of the purchased product lines. Hence, creating a higher level of market concentration and power. These acquisitions left only Altec, Terex, ETI, and Versalift as the dominant suppliers in the market (Edington 2012).

Since 2005, the structure of the market for used utility construction equipment has continued to change rapidly, based on economic opportunities. Savvy individuals had the foresight to recognize the glut of higher quality, five to six year old, used equipment that would exist annually due to the industry's change to the leasing/rental model. They also recognized the lack of a dealer network in place to deal with the resale of off-lease equipment.

Only over the past eight years have companies such as NUECO, JJ Kane, and Utility Fleet Sales begun to flourish. These firms have rapidly created a viable market, and a profitable distribution infrastructure to sell late-model, off-lease utility construction equipment to end-users. Distribution channels and intra-industry alliances continue to change and form as this thesis is being written. Simply put, the used utility construction equipment industry is brand new. Through aggressive marketing strategies and comprehensive industry knowledge, firms such as Utility Fleet Sales have helped end-users recognize the availability and the economic benefits associated with purchasing this late-model, off-lease equipment, thus actually creating demand (Edington 2012).

Due to the relative youth of the industry and the fact that the primary participating firms are privately held, published data and analysis do not currently exist. This is unfortunate, considering the importance of utility construction equipment in ensuring that our global utility infrastructure remains reliable and up-to-date.

The secondary utility construction equipment market appears to fit the description that was described above: One in which relatively few dominant suppliers exist, and product differentiation may be present. It is an essential part of an industry that provides the utilities that every consumer relies upon. Customers should self-select the specific type of equipment they purchase based on equipment attributes that match the type of work they perform. Further, the market does not appear to possess the characteristics of a highly contestable market. Barriers to entry, or at least barriers to scale appear likely. A relatively high level of specialized industry expertise, training, and human capital are required to effectively purchase, transport, recondition, and sell the product. Raw materials (used equipment and parts) are relatively expensive. Significant scale requires significant investment in land, buildings, shop equipment, and other inputs. At least one large competitor appears to be producing a truly differentiated, higher quality product. Operational efficiency and marketing dominance appear to be present, and coupled with product differentiation, could, theoretically, be leading to significant price differences between market segments, even after differences in product characteristics are controlled for.

Economic Problem

Is there evidence of price differences between customer segments in the secondary utility construction equipment market, which are not due to differences in physical product characteristics?

Hypothesis

Differences in price between customer segments are primarily due to differences in physical product characteristics, but these characteristics do not fully account for differences in price.

Objectives

1. Identify the most suitable theoretical framework for the problem at hand.
2. Determine the appropriate empirical model for estimation.
3. Determine the most appropriate statistical technique to estimate parameters.
4. Validate the model both statistically and for applied accuracy.

5. Conduct appropriate statistical tests to reach a conclusion about the research hypothesis.

Significance of the Study

Economists have for decades, and continue to put forth theoretical work on how the existence of secondary markets impacts primary (new) markets. The primary focus of the work has been on how the secondary market impacts the durable goods monopolist's and/or oligopolist's ability to exercise market power in the primary market. The justification for many market power studies is related to consumer welfare outcomes, which is certainly meaningful. Oligopolistic settings, or product differentiation, leading to monopolistic competition, are typically studied as a primary market phenomenon. What seems to be missing in past studies of primary – secondary market interaction is any recognition of potential market power or product differentiation in the secondary market, which should, theoretically, impact the primary market and thus have an impact on consumer welfare. This is somewhat understandable, because in the past there has been little evidence to suggest that any secondary market represented a suitable environment for market power or product differentiation to exist.

In true, traditional, scientific fashion, something potentially different has been witnessed in the marketplace (nature) that perhaps warrants further explanation; the recent development of a secondary market in which it appears that a relatively high degree of market power and product differentiation could exist. Furthermore, the market witnessed is crucial to the everyday, common existence of each and every individual living in developed and developing countries world-wide, because it is crucial in providing the electric utility and communications infrastructure that people rely upon.

If the current study shows that differences in used bucket truck prices cannot be fully accounted for by differences in physical product characteristics, then perhaps future research on primary – secondary market interaction should attempt to account for potential market power and/or product differentiation in secondary markets. At the very least, future researchers may more easily identify real-world environments in which such a phenomenon might exist. If the current study finds no evidence that "the law of one price" has been violated, in such a seemingly "inviting environment", then it has at least given further scientific justification to past and future research for continuing to ignore the possibility in secondary markets.

Outline of the Study

Chapter two reviews the relevant theoretical and empirical literature. Chapter three develops the specific methods used to accomplish said objectives. The specific data applied to the methods are presented in Chapter four. Chapter five provides a detailed description of the results for the methods employed, and a formal test of the research hypothesis. The thesis concludes with a summary, along with conclusions that can be drawn from the research results, and recommendations for future research.

CHAPTER II

REVIEW OF LITERATURE

The purposes of this chapter are: 1) to present the concepts that tie together; price differences, product differentiation, market power, secondary markets, hedonic pricing, and utility construction equipment, 2) to review the economic theory and empirical techniques that pertain to this research, and 3) to outline the justification for the chosen method.

Market Power, Product Differentiation, and Differences in Price

It was Arthur Pigou (1932) who introduced the concept and taxonomy of the discriminating monopoly, and put forth the conditions under which the law of one price could be, and was, violated. While Pigou's original definitions and taxonomies used to describe the economic principle(s) underlying price differences have been challenged and/or expanded upon by authors such as Robinson (1933), Machlup (1955), and Coase (1972), his basic principles still underlie the concepts studied today.

Pigou's basis for the existence of price discrimination is founded in the idea of a potential market with only one, monopolistic, firm. He recognized that even in a monopolistic environment, price discrimination would not be possible unless certain, underlying conditions were met. The critical condition being that no one unit of a good could take the place of any other unit. Hence, no one unit sold in one market could be transferred to another, and no one unit of demand could be transferred to another market.

Thus, the idea of the "no arbitrage" condition for effective price discrimination was put forth.

Pigou also described three degrees of discriminating power. The first degree involves charging a different price for each unit sold (bought). The firm extracts from each purchaser their maximum willingness to pay for each and every unit traded. A case of what is typically called "perfect" price discrimination, in which *all* the consumer surplus, associated with a perfectly competitive market, is transferred to the firm. Pigou explains that this first degree is highly unlikely to ever exist, because it involves complete market segmentation in which every consumer's willingness to pay must somehow be uncovered. Second degree discrimination exists when a firm charges n different prices, and is typically associated with volume discounts, i.e. large volume buyers pay less for each unit. Pigou finds it highly unlikely that even second degree discrimination can exist in the long-run, because it eventually leads to arbitrage.

Pigou's contention was that, in real life only third degree price discrimination is actually found. Third degree discrimination exists when the seller can segment the market into n different customer groups, based on relevant differentiating characteristics. Assuming that the no arbitrage condition can be enforced by some mechanism. It is evident that most economists share Pigou's contention, to some degree, as the overwhelming volume of price discrimination literature has primarily focused on third degree discrimination only. Pigou, like Robinson (1933) was primarily concerned with welfare economics, and how non-competitive markets affected optimal, societal outcomes.

Joan Robinson (1933) introduced the concept of monopsony, and its price discriminating effects on the labor force. Unlike Pigou, who more generally introduces the idea that differing demand elasticities is what makes third degree price discrimination possible, Robinson concentrates on and details how differing elasticities are the root cause for discriminating behavior. Price discrimination occurs when a monopsonist will buy from each source of supply in a way that allows for the marginal cost to equal the total marginal utility of the whole amount purchased. The advantage for a monopsonist comes from the differences in the elasticities of supply from various sources. According to the author's theory, once lured into monopsonistic systems, the supply of labor increases over time, and cannot respond appropriately to declines in wages. She claims that this lack of responsiveness, inelasticity, leads to overall lower wages and higher unemployment. It is Robinson's thorough treatment of identifying differing elasticities as a means of price discrimination, which has continued to permeate the price discrimination literature through today. Third degree price discrimination can only exist with a downward sloping demand curve, in which there would exist consumer surplus in a competitive environment. With no economic surplus, there would not exist anything for the monopolist or monopsonist to gain in a less competitive setting.

Following Pigou (1932) and Robinson (1933), literature on price discrimination began to make its way into different fields of economics and was applied to various issues; rate-making problems in Transportation and Public Utilities; antitrust problems in Industrial Organization; unfair competition issues in Marketing; dumping in International Trade; basing-point and delivered price problems in Government Control of Business; and problems of output determination in Pure Economic Theory (Machlup

1955). In 1955, Fritz Machlup attempted to bring some of the separate studies together into a more comprehensive framework, and tie in the concept of product differentiation.

Machlup's paper focused on the taxonomy, descriptions, and functional definitions associated with different forms and purposes of price discrimination. The first thing he attempted was a more comprehensive definition of price discrimination in general: "The practice of a firm or group of firms selling or leasing at prices disproportionate to the marginal costs of the products sold or leased, or of buying or hiring at prices disproportionate to the marginal productivities of the factors bought or hired" (Machlup 1955). Machlup's definition does not include any reference to homogeneous products, indeed this is explicitly purposeful in his paper. He points out that products need not be homogeneous and in fact certain types of price discrimination rely heavily on differentiated products. Machlup also reminds us, as do his predecessors, that at least some degree of market power is what makes price discrimination possible. Machlup then classifies different types of price discrimination based on its purpose and based on the technique used. Here we focus only on those classifications most relevant to the work at hand.

He distinguishes between three main classes of technique: Personal, Group, and Product. While he acknowledges that the classes are not mutually exclusive, his discussion winds together different classes in a way that require some unwinding here, to be useful in the current setting. Under the classification of Personal or Individual price discrimination, he takes great care and gives clear examples of what seem to be more precisely categorized as product discrimination. He points to discrimination based on the type of work the product is put to and the degree of quality that a product possesses.

He then discusses product use again under the Group discrimination heading. Product use and quality are most certainly a function of the specific attributes contained in the product. Machlup defines Product discrimination as a setting in which customers choose freely among different products and/or product qualities at different prices. Again, a setting which depends on the individual product characteristics. This is but one example, where Machlup's work seems to create a “jigsaw puzzle” of pieces that are not easily arranged into a clear picture of price discrimination (Papandreou 1955). Machlup's discussion helps to make three points that are important to the current endeavor: First, it is difficult to unwind the concepts of price discrimination and product differentiation, in any setting in which product differentiation is present. This is a point that Coase seems to make in his evaluation of Machlup's work. In Coase's words, “A more serious objection to my argument might be that, if accepted, it would result in the problem of price discrimination being swallowed up in the general monopoly pricing problem. This is so. And I approve of it” (Coase 1955).

Secondly, Machlup believed, at the time, that his “get the most out of each group” classification (a technique that he lists under the Group Discrimination heading) was something rarely seen in manufactured products. He points to four reasons: 1) Discrimination in industrial pricing is almost always under suspicion of being unlawful. 2) It is difficult to divide the market into distinct user groups. 3) It is difficult to discover, because of so many differences in production costs. 4) Having a high degree of market power is not easily achieved in manufacturing. However, if we take Machlup's classifications as partially arbitrary, and more descriptive than functional, which he himself admits, then we can re-class the manufacturing scenario into one of product discrimination and/or differentiation, and fairly easily dispose of three of the four reasons given above.

First, while discrimination that is intended to hamper competition is generally considered unlawful, product differentiation, and thus differential pricing, is not. This makes unlawful price discrimination more difficult to identify in the presence of product differentiation. Secondly, in a setting of product differentiation for specific uses, it is not difficult to divide the market into distinct groups of users. In fact, as Machlup points out, users will self select. Machlup's fourth reason, that a high degree of market power is not easily obtained in manufacturing, is easily disposed of today regardless of how the discrimination is classified. In fact, most of the price discrimination literature, since 1955, as well as the general market power literature, has focused around durable goods. Machlup seems to have overlooked the potential high barriers to entry in many manufacturing settings. Although, in Machlup's defense, it could be that Machlup's intent has either been misunderstood or misconstrued. As far as Machlup's third reason above; using a product discrimination setting at least points to identifying a product's objective characteristics, which may allow insights, not on absolute production costs, but at least on the expected direction of production cost differentials. A point which was eluded to by Coase in his comments to Machlup's paper, "...dealing with a multiproduct firm, it would appear to be an undue simplification not to take into account explicitly that the costs of and the demands for the various products will often be interrelated" (Coase 1955). The third point that can be gleaned from Machlup's work, which is critical to the current project, is the need to identify, quantify, and value a specific product's observable characteristics.

Borenstein (1985) showed analytically that even in highly competitive markets, price discrimination could exist when there is product heterogeneity, and that free-entry alone does not necessarily hinder discriminatory pricing. As examples, he points to industries such as magazine subscriptions and hotel rates. Reduced subscription rates for students or "kids stay free" promotions in hotels are certainly cases in which sales prices are different although marginal costs are not. Borenstein claims that it is the heterogeneity between brands that makes this possible. He uses a spatial model of monopolistic competition to show that sorting customers based on brand preference can be a stronger sorting mechanism than differences between basic product characteristics. According to Borenstein, sorting based on strength of brand preference is not present in earlier models of price discrimination. His work stresses a concept that has been accepted in the literature since. Brand constitutes a form of product differentiation for certain purchasers, just as other measurable characteristics do.

However, Borenstein's model assumes that products differ in only one dimension, brand, and therefore he can, and does, assume that marginal costs are equal between brands. When applying Borenstein's work to empirical cases, this becomes a "slippery slope," because differentiated products may vary in many dimensions, including differences in physical characteristics, which may likely mean differences in marginal costs. In an empirical setting, the researcher must account for differences in price, which are due to differences in physical characteristics, otherwise the effect of brand, while potentially important, may be overstated.

Borenstein's model also allows for the possibility that a consumer does not purchase the product at all. This is a fair possibility in consumer markets for non-necessity items such as hotels or magazine subscriptions. However, in markets for goods that are necessities, and in which no reasonable substitute exists, the possibility of not purchasing quickly diminishes. As is the case of the current endeavor. This research deals with a market for a product, bucket trucks, that is a required business asset for completing certain projects. Unless the purchaser forgoes a particular revenue stream or goes out of business entirely, if his/her company needs a bucket truck, then they will purchase or lease one. As long as the marginal cost of owning (leasing) is no greater than the marginal revenue received from putting the asset to work, then some purchasing (leasing) transaction should take place. It is perhaps fair to assume that there is a portion of bucket truck demand (within a certain price range) that is perfectly inelastic. An assumption that is far from the case of a purely competitive scenario.

Anderson and De Palma (1988) mathematically (not empirically) show the importance of accounting for interaction effects between cross-sections that potentially account for price differences, and measurable product characteristics. Their model is developed in a spatial (geographic) context, but also accounts for the heterogeneity of products based on characteristics. Their work is included here, because their mathematical model shows that interaction effects between location and product characteristics should be considered. They recognize that consumers in different geographic locations may exhibit differences in marginal willingness to pay for certain product characteristics. They showed that minimum differentiation occurs in geographic space when there is a high degree of heterogeneity in characteristic space. When there is little differentiation in characteristic space, the market solution involves a high degree of dispersion in the spatial dimension. While this research does not account for a geographic dimension, it accounts for other non-continuous cross-sections that may interact with product characteristic variables. Anderson and De Palma's work remind us that parallelism between cross-sections should not necessarily be assumed. Interaction effects should be tested for.

Anderson and Ginsburgh (1994) develop a theory of how the existence of secondary (used) markets may effect how a monopolist implements price discrimination. They show that a monopolist can extract maximum rents in the presence of a secondary market by controlling the quality of their product such that it is either “worthless” in the secondary market or is “as good as new” in the secondary market. Unlike previous research, they indicate that if the secondary market is competitive then the monopolist does not necessarily have an incentive to kill-off the secondary market, because the monopolist essentially uses the secondary market as a sorting mechanism (consumers self-select), by which to achieve a form of indirect price discrimination.

Previous research had distinguished two effects that secondary markets have on monopolists: 1) Secondary markets increase the willingness to pay for new products, because the purchaser has a viable market in which to dispose of the product later. 2) Secondary markets decrease the price that monopolists can charge for new products, because their own used product is competing with the new product. Anderson and Ginsburgh essentially attempt to untangle these two opposing influences. They also point out that previous models of secondary markets have concentrated on either the “lemon problem” (asymmetric information), or optimal durability of the monopolist's product. They cite various papers in which the lemon problem need not hold.

Anderson and Ginsburgh also make two assumptions that are relevant to discuss in the context of the current research. First, they introduce the assumption that consumers have heterogeneous preferences and therefore differing valuations of new and used products. Secondly, they assume (as is typically assumed) that only buyers in secondary markets incur transaction costs. The current endeavor attempts to partially strengthen their first assumption, one of heterogeneous buyers in the used market, but completely dismisses their second assumption in the current market context.

In the bucket truck market, sales are business to business transactions, in which income producing assets are being purchased. There are clear, observable, different markets into which used bucket trucks are sold. Bucket trucks with certain observable characteristics are sold into each market. For example, electric utility contractors exclusively purchase insulated bucket trucks, while telecommunications contractors purchase non-insulated units. While heterogeneity of preferences between new and used products is the essence of the Anderson and Ginsburgh assumption, the current project is concerned primarily with the secondary market. The idea of heterogeneous preferences for certain product characteristics *within* the used market is focused upon.

Anderson and Ginsburgh assume that only secondary market purchasers incur transaction costs. In the traditional context of durable goods markets, which existed twenty-five years ago, this assumption may be reasonable. For example, purchasing a new car involved going to the dealership(s) of choice and deciding which car to purchase, or simply picking up the phone and ordering the exact car desired. Purchasing a used automobile involved scouring numerous, small used car dealers, or classified advertisements, until the consumer may/may not have found the brand, style, and quality of choice. Gathering information about used car options required a significant investment of time. Imagine attempting to purchase other types of used durables; refrigerators or furniture, before the world-wide web was readily available.

The assumption of only having transaction costs in the secondary market is not valid in the current research. First, today the internet is alive and well. In the context of the automobile example, a purchaser can search sites such as www.AutoTrader.com, sort available products based on numerous characteristics, and instantly search a nationwide market. Utility construction equipment options available on the internet are vast. The industry uses sophisticated websites with various search criteria options, full sets of photographs, and video for each item (e.g., www.UtilityFleetSales.com). Additionally, aggregation sites such as www.CommercialTruckTrader.com, list available bucket trucks from many dealerships around the country. The internet has seemingly driven down the search costs associated with used durables, however in the bucket truck market, specifically, there is a potentially more significant reason that the Anderson and Ginsburgh assumption cannot be made; production time.

Unlike new, consumer automobiles, new bucket trucks are not produced by the tens of thousands and shipped to a plethora of dealers to sit on sales lots. New bucket trucks are typically ordered to specification from the manufacturer, and then must be produced. As of the time of this writing, a new bucket truck could take from six to twelve months to receive, once the order is placed and a deposit is made, depending on the specifications of the unit (Fumasi 2013). This can create a significant cost to the purchaser in the form of lost revenue, while they must wait for the unit. This can be mitigated by proper management of the purchasing cycle, however this management is not without cost. Additionally, contractors (who constitute a large portion of used bucket truck purchasers) typically bid for contracts. If the contract is awarded to them, they must typically expand their fleet rapidly. They are not likely to have a considerable excess bucket truck capacity, which sits idle until the next contract becomes available. This reality makes perfect management of the purchasing cycle very unlikely.

The concept of production times for manufactured-to-order products creates a unique opportunity and secondary market, which has vastly different characteristics than traditional, consumer durable markets studied. If the secondary market can offer buyers a close substitute for new, without the wait time, and at a lower acquisition cost, then the traditional assumption that manufacturers of durable goods are competing with themselves in future periods becomes more powerful than ever. If secondary dealers can also significantly lower a buyers' search costs by using the internet, then the secondary market may indeed exhibit lower overall “search” costs than the new market. As is the case with www.AutoTrader.com in the consumer auto market, this phenomenon becomes a more realistic possibility as the used bucket truck market becomes more centralized and/or large, preferred suppliers emerge.

In 1989, Thomas Holmes published a paper that was closely related to the Borenstein (1985) work. Like Borenstein, Holmes distinguishes between a buyer's choice not to buy at all, from that based on the tendency to buy from a different supplier. The primary difference is that Borenstein relied on simulations, while Holmes employed analytical methods. Holmes shows that the price elasticity of demand that a firm faces in the market can be expressed as the sum of two parts: the overall industry-demand elasticity and the cross-price elasticity between competing suppliers. The paper is included in this review to again point out the common type of market that has been assumed in past research; an assumption that does not generally hold in the current context. Like Borenstein (1985), Holmes assumes the market is one for a non-necessity good, for which the consumer may choose to not buy at all. As discussed above, this is not a valid assumption in the utility construction market. Contractors bid on contracts. Once the contract is awarded, they will typically need to add trucks to their fleet to complete the contract on time and on budget. Not buying, and thus not fulfilling the contract, is not typically a viable business option.

Stavins (1996) empirically finds that price differences in the airline market become more common as the market becomes more competitive. Stavins empirically tests the theoretical findings of Borenstein (1985) and Holmes (1989), that price discrimination may increase with less market concentration.

Stavins uses a reduced-form, hedonic regression model for parameter estimation. Her model takes into account measurable airline ticket characteristics. She also uses interaction terms to allow price discrimination to vary with market concentration (she uses a Herfindahl index to measure concentration). However, because a group of her primary independent variables (ticket restrictions) were highly correlated, she included only one of the ticket restrictions at a time in her estimation. It is possible that this procedure may have resulted in biased parameter estimates. While the use of a hedonic model, with interaction terms, is an appropriate method for the problem at hand, dropping theoretically important variables from the estimating equation to minimize collinearity issues will be avoided.

Corts (1998) theoretically shows that it is possible for third-degree price discrimination in an oligopoly setting to actually lead to lower prices for all consumers. This is because the price discrimination can actually lead to all out price competition, which makes firms worse-off, so firms avoid using price discriminating tactics. Corts uses game theory to demonstrate the conditions under which different types of equilibria can be reached. For effective price discrimination to be carried out there must be some existent asymmetry in which different firms rank different consumers as their "strong," primary market. In this case price discrimination can be a symmetric best-response for the firms. Product differentiation makes this possible, because then it becomes more likely that each firm will have a different "strong" market. Corts' primary objective is to demonstrate that price symmetry is not necessarily the same thing as best-response symmetry, but that price symmetry is a necessary condition for effective, common price discrimination. However, a uniform price equilibrium can be reached when a firm makes a credible commitment not to discriminate.

Corts admits that conditions on demand that generate the various regimes he displays remain elusive. He explains that a more complete characterization of demand conditions that generate the results is needed and would further our understanding. Perhaps the idea of a uniform price condition is best illustrated by the project at hand, because it is a business to business setting in which purchases are made on more objective criteria than consumer markets, i.e. profit maximization. Additionally, it is possible that a secondary market has much closer to a continuous range of product quality offered by each firm. For example, a purchaser can select a unit from a broad spectrum of different mileage characteristics, but the units are otherwise the same. Corts points out that if each firm has such a diverse product offering, based on perceived product quality, then no price discrimination is necessary. One could argue that a well-stocked used dealer has a much more diverse product offering than a new dealer, with numerous brands and a much larger variation in product quality and pricing.

Kumar (2002) examines the optimal dynamic price and product quality strategy for a durable goods monopolist in the presence of a secondary market. Like Anderson and Ginsburgh, Kumar finds that a durable goods monopolist can benefit by the existence of a secondary market. This occurs when the durable goods monopolist properly controls the quality of its product, so that the profit maximizing obsolescence path is reached. However, what is also relevant to the current problem, is that Kumar finds that the resale trading frequency and the price discount for used products depends on the strategic quality obsolescence in the new good market.

Bucket trucks are designed to lift personnel into the air, sometimes reaching heights of over 120 feet. Hence, due to safety, the construction of the aerial device is such that the primary structural components of the unit are "overbuilt." That is to say that the primary steel and fiberglass components of the device are constructed so that they will typically far outlast the truck chassis itself. Additionally, many of the most widely used aerial device technologies in new equipment have not significantly changed for decades (Edington 2012). Other durable goods markets have a much more robust rate of technological obsolescence than does the bucket truck market. This creates an opportunity for skilled and efficient operators, who have the expertise to cost-effectively refurbish the product. If done thoroughly, and perhaps even remounting the aerial device onto a new chassis, the secondary product can effectively be "like new." Thus the price discount for used product is minimized, and the resale trading frequency may likely increase, as the remanufactured product takes more customers from the primary market.

Recall that price discrimination is generally defined as price differences that cannot be fully explained by differences in costs. Clerides (2004) focuses on the cost-side of this definition. He explains that the literature goes to great length to control for potential sources of cost variation, but still most studies conclude that price discrimination exists. He argues that the possible reason for this is that some sources of cost variation are not being accounted for. He points out that conventional acceptance that price variation, which cannot be explained by cost differences, constitutes price discrimination, has not been thoroughly formalized, especially in a setting of differentiated products.

Clerides explores the two common ways that researchers typically compare costs in the price discrimination research: 1) Price-cost margins (absolute differences) and 2) Price-cost markups (percentage differences). Clerides uses empirical data and hedonic analysis to compare the two methods. He finds that each method gives a very different result regarding rejecting the hypothesis of no price discrimination, when applied to the same set of data.

Liu and Serfes (2005) use a game-theoretic framework to show that price discrimination can lead to a Nash equilibrium in which a firm who produces a higher quality product can extract consumer surplus, while the lower quality firm is less profitable. They explore the effect of how changing the cost of acquiring consumer information affects the equilibrium outcome. Unlike Corts (1998), who assumes that consumers can be segmented into two groups, Liu and Serfes assume that consumers can be segmented into more than two groups with different demand elasticities. Liu and Serfes indicate that if the fixed cost of acquiring consumer information is below a certain threshold, then in the unique Nash equilibrium only the high quality firm acquires the information and price discriminates. They further show that the high quality firm always benefits from acquiring information. The low quality firm's best response is to credibly commit not to price discriminate. The equilibrium profit of the high quality firm monotonically increases as the precision of the consumer information improves, within a range. If the cost of acquiring more precise information becomes too high, then neither firm purchases the information.

While the Liu and Serfes results may not be entirely intuitive, the general explanation is as follows. If the low quality firm acquires information and uses it to charge discriminatory prices, they price themselves out of the market in every period except the first. If the initial, low quality prices are discriminatory, but still lower than the high quality firm's prices, the high quality firm meets those prices in the second period, and the lower quality firm still has zero demand for its product. This illustrates the importance of true, product differentiation, in which one firm's product is actually of higher quality, and that quality is made known to buyers. Once consumers recognize the quality difference in the first period, the low quality firm has no chance of exercising price discrimination. Getting this result relies on the assumption that consumers have perfect information in the first, and subsequent periods. Realistically, only once a consumer purchases each type of product and compares quality, will they have the information necessary for the Liu and Serfes outcome. In the real world, this may take time, which may allow the low quality firm to charge discriminating prices for more than one period. They will do so as long as the benefit gained from new, first-time buyers in each period is greater than the loss associated with the customers from the previous periods who are lost.

In the current setting, the precision by which customers are segmented, and the cost of acquiring such information are both relatively low. Based on the Liu and Serfes outcome, it is expected that high quality firms may be acquiring the information. However, as described above, purchasers do not posses perfect information in the real world. Hence, it is expected that lower quality bucket truck firms are also acquiring the information and may be exercising some level of price discrimination. This outcome is expected to diminish over time, as more purchasers have the opportunity to distinguish between the differing levels of quality. Thus, the long-run result should be consistent with the Liu and Serfes outcome. Regardless of the industry, the Liu and Serfes result is plausible as a *long-run* equilibrium.

Household Production Theory and Hedonic Price Analysis

Machlup (1955) points out the need to account for a specific product's observable characteristics, when attempting to identify differences in price. The most widely used tool to accomplish this task in empirical studies is the hedonic technique.

According to Nerlove (1995), hedonic price analysis has its origins in Agricultural Economics with Frederick V. Waugh (1928). Waugh's purpose was to determine consumers' relative valuations of certain characteristics of asparagus, and to estimate the buyer's marginal willingness to pay for each attribute.

In 1961, Griliches recognized the failure of the major price indices to fully account for changes in product quality over time. His goal was to estimate implicit (shadow) prices for certain quality changes in automobiles over time, and use those estimated shadow prices to correct the price indices. His general reasoning is in his recognition that durable goods are sold in many varieties/models, and that the qualities those models possess over time is always changing.

Griliches uses a semi-log hedonic equation that regresses price on measurable values of automobile characteristics, some being continuous variables and some being indicator variables to account for either the presence, or lack thereof, of particular traits. He then introduces an indicator variable for specific time periods, which allows him to estimate the average change in the group over time. Griliches then uses his regression results to adjust price indices for quality change.

Griliches recognized certain limitations in his work. First, he applies list price data to his model, but recognizes that list prices may not accurately reflect transaction prices. He also applies his model to used cars, however the range of data used is only for used cars between six months and one year of age. For the current project, actual transaction prices on used equipment, spanning at least twenty years of age, are available. However, perhaps most importantly to the current research, Griliches points out that measurable characteristics such as length and weight are only proxies for the things that consumers ultimately value, i.e. comfort.

The vast majority of the hedonic literature is based on consumer products, in which the consumer derives utility from the measured characteristics in the model. Often times authors are forced to use proxies. For example, researchers can measure sugar content (brix) in fruit, but cannot objectively measure sweetness, which is likely the consumer's ultimate source of utility. In using hedonic models for consumer products, economists have an additional limitation: While they can estimate differences in willingness to pay, they cannot necessarily interpret the reasons for the absolute differences in magnitude. As an example, research may indicate that a consumer is willing to pay, on average, $3,000 more for a black car than a white car, ceteris paribus. But *why* is the difference equal to $3,000 and not $5,000? Research on automobiles commonly uses horsepower as an attribute in the hedonic model. Research finds that consumers are willing to pay more for something that will cost them more later, due to increased fuel usage. From a purely pecuniary perspective, how do economists justify this? They don't. Psychologists do. The issue lies in the fact that hedonic equations for consumer products are only one step removed from utility, a concept that is ordinal, not cardinal.

The current endeavor deals not with consumer products, but with income producing, business inputs. This has an advantage when interpreting "why" a specific attribute has a specific estimated shadow price. For example, if a bucket truck buyer is willing to pay $5,000 more for a unit that possesses a material handling winch, ceteris paribus, then perhaps it can be assumed that the buyer expects to gain at least $5,000 (not accounting for discounted value) in additional revenue over the life of the input. This is a more constructive interpretation than simply, "The buyer prefers a unit with a material handling winch, and is willing to pay $5,000 for it." The advantage here is based on the fact that productive inputs are two steps removed from utility. The business operator will ultimately gain utility when he spends the additional profit gained by use of the material handling winch, but the ultimate utility gained is not the focus here.

While the work of Waugh (1928) and Griliches (1961) demonstrates that hedonic modeling has been used in some form for many decades, current researchers sometimes credit the advent of household production theory with allowing for the development of the hedonic technique in its current state. Hedonic models are founded in the analysis of quality differences and choices between goods that differ in observable characteristics. Household production theory and the empirical implications created by it, are the foundations by which hedonic models were developed (Deaton & Muellbauer 1980).

Becker (1965) recognized that any and all non-working uses of time had two important components of cost, the direct, market price of the activity and the foregone value of the time used up during the activity, the indirect cost. Even sleeping typically possesses both components. A consumer spends the market prices on things such as a bed and a pillow, but also gives up the income that could have been earned if the time was spent working. Becker creates a general theoretical framework that enables researchers to treat the cost of time on the same footing as the cost of market goods.

Accomplishing this, required that Becker treat the household as a productive unit. As a producer, the household possesses a production function that allows it to combine market goods, i.e. beds and pillows, with time, to produce the final, utility producing commodity, sleep. Becker applied the general theory to determining how changes in income, earnings, and market prices, may affect how consumers allocate their time between work and non-work activities. The paper revealed that the traditional labor-leisure model was far more specific and restrictive than it needed to be, thus impeding broader empirical applications. Becker also found that previous results explaining the income and substitution effects due to changes in income, earnings, and market prices, were perhaps misguided. By accounting for the value of time in its entirety and treating the household as a productive unit, Becker's model opened the door for more accurately estimating how/why consumers change consumption habits and how/why they change their allocation of time between competing activities. Becker's work was the beginning of a new theory of choice.

In similar fashion as Becker (1965), Lancaster (1966) put forth the idea that conventional consumer theory (at the time) was vastly inadequate. Lancaster showed that the depth of results coming from consumer theory could be improved by recognizing that consumers do not gain utility from consuming a particular "good," they instead get utility from the specific, intrinsic attributes that the good possesses. He pointed out that "the objective nature of the goods-characteristics relationship plays a crucial role in the analysis and enables us to distinguish between objective and private reactions to such things as changes in relative prices." Lancaster included an explanation of how his model could effectively be used in durable goods markets by recognizing and using two types of dimensions in characteristic space; cross-section and time.

Household production theory was the framework used to explain consumer choice, given differing product characteristics. It did so by treating households as producers of final, utility bearing characteristics. Actual market goods were treated as inputs into this production process. Rosen (1974) diverges from this by imposing a market between buyers and sellers, where firms themselves tailor their goods to embody final characteristics desired by consumers.

Rosen (1974) clearly defined what is meant by hedonic prices. A class of differentiated products is completely described by a vector of objectively measured characteristics. Observed product prices and the specific amounts of characteristics associated with each good define a set of implicit or “hedonic” prices (Rosen 1974). Rosen's work took Lancaster's general theory of consumer behavior, and applied the use of hedonic prices in describing market equilibria. While previous work had illustrated that hedonic price differences are equalizing only at the margin and could identify neither supply nor demand, Rosen introduced a feasible econometric procedure that could accomplish this task in some cases. However, Rosen's work has still been faulted for not having the ability to distinguish between supply and demand, in a more general setting, thus giving rise to the “identification” problem.

Prior to Rosen's work, the literature dealing with quality variation had emphasized consumer behavior. Rosen's work was an attempt to identify properties of market equilibrium in a setting of quality variation. Rosen's paper ignores the possibility of secondary markets, which is an assumption that is not adequate here. However, Rosen does assume one thing that will be used; that each market good has a fixed, observable value of the characteristic vector. In other words, there exists a well-defined mapping from market good space to characteristic space. However, Rosen's model assumes that there are clearly defined quoted prices for identical bundles, and that consumers will purchase from the seller who offers the lowest price. These assumptions do not hold very well in the current project, but may within a range of characteristics.

Product offerings are seldom “identical” in used goods markets. Rosen's assumptions of zero arbitrage capabilities, and indivisibility are spot-on in the current context. Bundles cannot be untied and sellers cannot economically repackage existing products.

Witte et al (1979) applied Rosen's theory of implicit markets for characteristics of goods to the housing market. In an attempt to remedy the identification problem, they empirically estimate a joint envelope of a family of value functions and another family of offer functions, thus accounting for both demand-side and supply-side variables. Their multi-step procedure allowed them to solve for the price that made the quantity demanded and the quantity supplied of each characteristic equal, by treating the problem as if each characteristic has its own, separate market. The primary assumption used to accomplish this is the assumption of separability. Their results represent coefficients of an envelope function, which reflects both bids and offers. They admit that their general price results for the composite good, housing, are not readily interpretable, but that the model gives meaningful implicit marginal prices for good attributes. This could perhaps be the reason that their procedure has not been widely adopted in the empirical hedonic literature. Most researchers regress price (or log price) on a set of product characteristic values (or log values), and assume that either the market is in equilibrium or that supply is exogenous.

Deaton and Muellbauer (1980) offer a comprehensive look at consumer theory and demand estimation including the use of hedonic prices, which is based largely on the work of Rosen (1974) mentioned above. Deaton and Muellbauer refer to the intrinsic attributes that a product possesses as “specification variables.”

According to Deaton and Muellbauer, the approach given when dealing with different varieties of goods is to introduce quality parameters, and through them, specification variables, directly into the utility function. The quality parameter for each good is assumed to be a function of the specification variables. They describe setting up the empirical specification so the intercept gives the price of some reference variety in each time period and can serve as a measure of the general price level for all the varieties of a good.

Mertens and Ginsburgh (1985) sought to find the primary determinants of price differences in the European automobile market. Their endeavor is perhaps more similar to the current work than any other work discussed here. Their hypothesis was that if they could control for technical differences and product differentiation based on brand, then any additional differences in price between countries in which the auto was sold, would suggest market power. They introduce the microeconomic framework leading to the econometric model, and then use a semi-log specification of a hedonic price equation to estimate parameters. Their results indicate that consumer brand preference is significant in determining price, but that prices between countries still have significant differences even after brand and technical differences are accounted for.

The empirical methods used by Mertens and Ginsburgh began with individual regressions for each country in an attempt to find a common set of technical automobile characteristics that was important to consumers in every country under study. Mertens and Ginsburgh used ANCOVA to test for equal slopes (parallelism) across countries, and found that they could not reject the hypothesis of parallelism. Mertens and Ginsburgh chose to keep all of the original variables that were included, based on regression results. However, if they hadn't decided to keep all the variables that theory suggested, then they could have potentially thrown out a variable that was important to most countries, but not all. Thus resulting in a specification error for most countries, and less accurate results of marginal effects. Perhaps it is more prudent to let theory and industry expertise guide the choice of included variables, and use an empirical specification that will pick up differences in slopes across cross-sections. Some interaction terms may be found insignificant, which can also be valuable information. In fact, it is the potential differences in slope across the cross sections that is of the very essence in solving the problem at hand.

Bresnahan (1987) applied hedonic methods to the used U.S. automobile industry. In 1992, Purohit used hedonic pricing to model the relationship between new and used automobile markets. These works furthered, the original work of Griliches (1961) for the use of hedonic models in the used vehicle markets.

In 1989, Palmquist expanded on the work of Witte et al and used both bid and offer functions in a hedonic setting. His purpose was to develop a model of the derived demand for differentiated factors of production, specifically agricultural land. He recognized that while it was common to treat land as a homogeneous factor of production, each parcel of land actually has a bundle of important characteristics that varies between tracts. The price for which the land rents to an agricultural producer depends on the land's characteristics. The price that a farmer is willing to pay to rent any particular piece of land is a function of the expected profits to the farmer, which the land's characteristics partially determine. Palmquist's work is one of few examples, in which hedonic analysis is applied to a productive input market. Like Palmquist's work, the current project is dealing with a heterogeneous factor of production, and, like Palmquist, it is expected that price is a function of expected profit, which is partially determined by the input's characteristics.

Berry (1994) continued the use of hedonic pricing models to estimate supply and demand for differentiated products in imperfect markets. He extended the use of hedonic pricing to discrete-choice models, both logit and probit. His application illustrated the potential flexibility of hedonic pricing theory. In 1999, Berry et al extended the previous work by applying hedonic, discrete-choice modeling to evaluating trade policy in the automobile industry.

Nerlove (1995) diverged from the previous hedonic literature. He did not regress price, as the dependent variable, on a vector of quality attributes, as was standard in previous work. Instead, he treated quantity sold as the dependent variable and regressed on price and quality attributes. He justified the reduced form by assuming that prices and attribute contents could be taken as exogenous to the market under study, the Swedish wine consumer. His estimates of shadow prices are shown to differ greatly from those obtained from using the more standard method of treating price of the market good as the dependent variable. Nerlove pointed out that the general issue with standard, price-dependent, hedonic models is that they have an inherent "identification" problem. Just as in the case of ordinary (not hedonic) demand analysis, using data on prices and quantities creates this issue.

However, Nerlove reminds us that if supply is exogenously determined, then the identification problem may be avoided in hedonic settings, just as it can be in non-hedonic settings, under the same assumption. According to Nerlove, both Shultz (1938), and Court and Griliches (1961), show that if the quantity supplied shifts exogenously, independently of the shifts in the demand function, a regression of price on quantity will estimate the price elasticity of demand. Nerlove relies on this idea, because he assumes that the different varieties of wine in the Swedish market are determined by world supply and demand considerations and are therefore exogenous to the Swedish consumers of wine, because Swedish consumers constitute such a small part of the overall world market.

In 1999, Goldberg and Verboven studied price differences in the European car market. They attempted to explain the large and persistent differences in like car pricing between different countries. Their model accounted for policy differences, namely import quotas, changes in price over time, and specific product attributes. The model used different countries for cross-sectioning. Using a semi-log, hedonic equation, with intercept shifters for cross-sectioning and other mutually exclusive, categorical variables, they were able to account for pricing differences not associated with physical product characteristics. This work is another example of the precedent for using hedonic models to identify price differences in durable goods markets.

<u>Hedonic Price Analysis In Input Markets</u>

As has been pointed out in the previous section, the use of hedonic analysis has been primarily used in consumer goods markets. More recent work in the Agricultural Economics literature includes two papers in which hedonic price equations are applied to production input markets. The Review of Literature ends with a treatment of those two works, as the current endeavor is also concerned, not with consumer products, but with applying the hedonic technique to income producing inputs.

Rudstrom (2004) estimates the implicit values of quality and packaging characteristics associated with dairy quality (high quality) hay. Specifically, she assesses the importance of nutritional quality, bale size, and bale type in determining the market price of dairy quality hay. She recognizes that the price paid for a production input, such as hay, should be a function of its characteristics, which impact the yield of final outputs. She applies a hedonic pricing model, which allows for estimation of the implicit prices of these output yielding characteristics.

Rudstrom clearly and eloquently provides a theoretical backdrop, which justifies the use of the hedonic method in input markets. Her backdrop is derived using basic producer theory, specifically, derived input demand. She then applies continuous variables such as crude protein and relative feed value, which directly impact the quantity of milk produced by dairy cows, to her hedonic model. She includes indicator variables for various bale types and sizes. Rudstrom also includes indicator variables for the hay cutting, i.e. first-cutting of the season versus second, third, or fourth-cutting of the season. The use of these indicators could have had potentially undesirable results in the Rudstrom work.

Nutrient qualities in hay, such as crude protein and relative feed value, are typically found to be a function of the cutting. Hence, perhaps there is a significant correlation between the cutting indicator variables and the other explanatory variables in the model. Rudstrom makes no mention of testing for collinearity. If, in fact, degrading collinearity was present in her model, then estimated variances would have been high, and her parameter estimates and hypothesis tests may be somewhat unreliable. In the current work, great care will be taken to test for collinearity among independent variables.

The collinearity issue aside, Rudstrom's work presents a logical and theoretically sound approach to using hedonic analysis in input markets. Rudstrom's theoretical backdrop is used here as justification for using a hedonic model. Additionally, Rudstrom's organization and presentation of results, specifically her use of marginal values and price flexibilities, appear intuitive and relevant to the problem at hand, thus will be followed when appropriate.

Vanek et al (2008) use a hedonic model to estimate the implicit value of heritable traits (Expected Progeny Differences, EPDs) on sale prices of beef bulls (sires). They attempt to find whether commercial beef cattle producers, who ultimately purchase the bulls as a productive input, pay a premium for superior genetics, which should produce a higher quality consumer product, beef.

The data used in their research included sales prices of bulls over a two-year period, from four large producers. Their data represented an unbalanced cross-section, since each ranch had a differing number of observations. They could have estimated four separate equations, one for each ranch. However, they proceeded by stacking the data, arranging it as a block matrix, which was estimated using a single equation.

The current research uses unbalanced, cross-sectional data, observed for each of five years. The number of observations in each cross-section are not equal, nor are the number of observations per year. Because the data will be unbalanced, using a covariance model is likely most appropriate. In the covariance model, each cross-sectional unit and each time period are characterized by intercept shifters.

Summary of Literature Review

Previous literature demonstrates the importance of accounting for differences in product characteristics, when attempting to identify any other determinants of differences in price. The hedonic technique is widely used to account for observable differences in product attributes and/or quality. Identifying meaningful customer segments is crucial in identifying potential reasons for price differences. It is common in the hedonic literature to use indicator variables to account for cross-sectional data and qualitative characteristic variables. The importance of testing for interaction, and using interaction terms when appropriate, has been established. Both the market power literature and the hedonic analysis literature have a strong precedent for applying theoretical models to durable goods markets, and the vehicle market is certainly no exception. Hedonic analysis has been applied successfully to intermediate (input) markets.

In the next chapter, the theoretical framework offered by Rudstrom (2004), which flows directly from Rosen (1974), and applies Rosen's hedonic theory to input markets, is augmented by incorporating the work of Anderson and De Palma (1988), to include relevant interaction terms between cross-sections and product attribute variables. In the spirit of Lancaster (1966) and Vanek et al (2008), a covariance model is used to simultaneously account for differences over time and between cross-sections, while estimating shadow prices of relevant product characteristics. Expanding on Pigou

(1932) and Machlup (1955), customer segments are based on meaningful differences in product characteristics, which match the specific uses demanded by each segment.

CHAPTER III

METHODS

Theoretical Model

As the previous chapter suggests, most studies employing hedonic pricing models have examined markets for final, consumer goods. However, the current market under study is for an intermediate good, or input into a production/service process. Bucket trucks are an input that have value in the production and maintenance of utility infrastructure, i.e. power and communication lines. The value of a bucket truck in the productive process lies in its physical characteristics. Rudstrom (2004) used hedonic analysis to study the dairy (milk production) input market. The theoretical backdrop offered here, begins by following Rudstrom's (2004) work, which is based on the seminal work of Rosen (1974).

Rather than specifying production as a function of finished inputs, production is expressed as a function of the characteristics of those inputs. Let x_j be the input characteristic, j, used in production. Production of output, q, can be represented as

(1) $q = F(x_1, x_2, \ldots, x_n)$.

In the bucket truck market, working height is an example of an input characteristic. One mile of finished, electric utility transmission line infrastructure is an example of a unit of output. The amount of a characteristic is a function of the amount of an input, v_i, and the amount of the characteristic contained in the input. The amount of an input characteristic, j, is

(2) $$x_j = G(v_1, v_2, \ldots, v_i, x_{j1}, x_{j2}, \ldots, x_{jn})$$

where v_i is the amount of input i and x_{ji} is the amount of characteristic j contained in one unit of input i. Assuming profit-maximizing behavior, the profit function becomes

(3) $$\pi = pF(x_1, x_2, \ldots, x_n) - \sum_{i=1}^{n} r_i v_i$$

where p is output price and r_i is the price of input i. Derived demands for input characteristics are obtained by differentiating (3) with respect to v_i, the amount of input i, resulting in

(4) $$\frac{\partial \pi}{\partial v_i} = p \sum_j \frac{\partial F}{\partial x_j} \frac{\partial x_j}{\partial v_i} - r_i = 0$$

The term, $p\frac{\partial F}{\partial x_j}$ is the marginal value, or implicit price, of the jth characteristic.

The term, $\frac{\partial x_j}{\partial v_i}$, is the marginal yield of characteristic j provided from one unit of input i. Equation (4) provides the basis for the hedonic pricing model for inputs, where the input price is a function of the input characteristics (Rudstrom 2004).

Unlike the input, hay, studied by Rudstrom (2004), bucket trucks are a durable good, which are not used up during a single productive process, hence there is a time element, or useful life, which must be considered in the profit function. The theoretical backdrop given above is not completely adequate for the current market under study. Equation (3) is adequate for examining profit as a single snapshot in time for a utility construction producer, where the quantity of output produced, per unit of work time, is a function of the physical characteristics of the bucket truck. However, at the time of purchase, the bucket truck buyer also assigns value based on the expected useful life of the asset, or the number of work-time units expected from the asset over its useful life. Lastly, the bucket truck buyer also assigns value based on the expected resale and/or salvage value of the asset upon disposal.

First, the present use of the term, “useful life.” should be clarified. In this context, useful life refers to the length of time that the purchaser expects the vehicle to remain in his/her fleet. The term is not intended to suggest that the bucket truck has no potential further use to any other entity or individual. Secondly, let us recognize that the useful life of a bucket truck is not predetermined at the time of purchase. A bucket truck's useful life can be extended (shortened) by the amount of maintenance/repair that the owner is willing (unwilling) to provide to the asset, but this is not without cost (savings). Bucket truck purchasers assign value based partially on the expected maintenance/repair costs of owning the asset, and having the asset in a condition such that it can be put to work. In the consumer market, similar costs are referred to as the cost of ownership. In the current setting it is perhaps more appropriate to refer to ongoing maintenance/repair costs as an additional cost of production.

Let us assume that two different bucket truck purchasers, each buy a bucket truck, and that the two bucket trucks will be used to produce the same output. It is expected that the physical characteristics, i.e. working height or 4x4, which determine q from equation (1), will be similar, if not exactly the same, such that

(5) $$F_1(x_{1,} x_{2,} \ldots, x_n) \equiv F_2(x_{1,} x_{2,} \ldots, x_n) \quad ,$$

where F_1 and F_2 are the production processes of bucket truck owners 1 and 2 respectively, and F is measured per unit of work time.

However, while the physical characteristics that determine F (output per unit of work time) are the same, not all other physical characteristics of the two bucket trucks are the same. Bucket truck buyer 1 purchases a used bucket truck that is three years old, while bucket truck buyer 2 purchases a bucket truck that is five years old. All other physical characteristics are assumed to be the same. Let us further assume that each purchaser expects their truck to remain in their respective fleet for five years. Bucket truck purchaser 2 expects to, and will likely, pay less for the five year old bucket truck, than purchaser 1 will pay for the three year old bucket truck. In this case, the price difference is not due to differences in output per unit of work time since they are assumed equivalent in equation (5). The price difference is not due to differences in useful life, they are assumed equal. The price difference is due to the expected difference in repair/maintenance cost during the five years that the trucks remain in the fleets, and differences in the expected resale/salvage value of the asset at the end of five years. The assumptions made are suitable, as it is common for some fleet operators to always buy newer bucket trucks and retire them in the same number of years as a fleet operator who purchases relatively older bucket trucks (Fumasi 2012). Certain purchasers pay more when they purchase the bucket truck, with the expectation that ongoing production costs associated with the bucket truck will be lower, and the bucket truck's resale/salvage value may be higher.

Based on the discussion above, it is recognized that the purchase price of a bucket truck is not only determined by a vector of physical characteristics, which determine output per unit of work time, but is also determined by a separate vector of physical characteristics that influence ongoing production costs and resale/salvage value.

In an attempt to more fully exploit the use of the hedonic technique, conform to theory, and accommodate the aspect of durability discussed above, the assumption is made that useful life is equal between all bucket trucks, but that the cost to maintain the asset for a given useful life is determined by a vector of physical characteristics, which are known at the time of purchase. Resale/salvage value is affected by the same or similar vector of physical characteristics known at the time of purchase. Ongoing costs are additional production costs, which change the cost of producing one unit of output. Increases in resale/salvage value partially offset these costs. Equation (3) is adjusted, and it becomes

(6) $$\pi = pF(x_{1,}x_{2,.} \ldots, x_n) - \sum_{i=1}^{n} r_i(x_{n+1}, x_{n+2}, \ldots., x_z) v_i \quad ,$$

where a second set of physical characteristics, x_{n+1} to x_z , has been introduced. This second set of physical characteristics affects the cost per unit of input, and is independent of the x_1 to x_n vector. Differentiating equation (6) with respect to v_i gives derived demands for input characteristics as

(7) $$\frac{\partial \pi}{\partial v_i} = p \sum_j \frac{\partial F}{\partial x_j} \frac{\partial x_j}{\partial v_i} - r_i = 0$$

Equation (7) is identical to equation (4). The general profit maximizing condition for derived demands for input characteristics remains the same. Note that $(x_{n+1}, x_{n+2}, \ldots., x_z)$ does not depend on v_i , because the number of bucket trucks used in a particular productive process, does not impact the per unit cost associated with these variables. However, the profit maximizing condition is not independent of the $(x_{n+1}, x_{n+2}, \ldots., x_z)$ vector of variables, a fact that is easier seen by rearranging equation (7), to get

(8) $$\frac{\partial \pi}{\partial v_i} = p \sum_j \frac{\partial F}{\partial x_j} \frac{\partial x_j}{\partial v_i} = r_i(x_{n+1}, x_{n+2}, ..., x_z) \quad .$$

As r_i changes with changes in $(x_{n+1}, x_{n+2}, ..., x_z)$ so must the Marginal Value Product (MVP) on the left-hand-side, so that the two sides remain equal, and thus meet the profit maximizing condition. The $p \frac{\partial F}{\partial x_j}$ term still represents the implicit price of the jth characteristic, but the profit-maximizing value of the term, $p \frac{\partial F}{\partial x_j}^*$, sought in empirical analysis, is also a function of $(x_{n+1}, x_{n+2}, ..., x_z)$. The values of this vector are not exogenous to the bucket truck buyer's decision making process. He/she chooses the $(x_{n+1}, x_{n+2}, ..., x_z)$ values during the purchasing process, just as the $(x_{1,} x_{2,} ... , x_n)$ values are also chosen. The buyer makes a purchasing decision based on two sets of characteristics, one set affecting the product/service produced, and another affecting the per unit cost of that production. Hence, both sets of decision variables must be present and simultaneously accounted for in the hedonic equation, if accurate shadow prices are to be estimated.

Empirical Model

The primary objective of this project is to determine whether differences in price, which are not due to differences in physical product characteristics, exist between customer segments in the used bucket truck market. Hence, indicating whether or not differences in demand elasticity likely exist between segments. The most plausible differences in demand characteristics are in two distinct markets for bucket trucks: Non-insulated units used in the Telecommunications industry and insulated units used in the Electric Utility industry.

In the covariance model design used there are two distinct cross-sections, distinguishing the two primary markets into which bucket trucks are sold:

1. Electric Utility (EU)
2. Telecommunications (Telecom)

These two cross-sections are referred to as Industries 1 and 2 respectively. The cross-sectioning variable is denoted as $I_i, i=1 \text{ to } 2$. Using a covariance model in this way should result in increased precision for parameter estimates and increased power for tests of hypotheses (Ott and Longnecker 2001).

The value of a used bucket truck should increase when it is insulated, ceteris paribus. Additionally, bucket trucks used in the Electric Utility industry, tend to have higher working heights on average, which should also increase sales price, ceteris paribus. Hence, differences in price between these two markets are expected. However, within each industry, other specification variables should have similar marginal impacts on product price, if the law of one price holds. The same percentage change in price, given a one percent change in the level of each physical characteristic, is not expected to be equal. However, the absolute magnitude of each characteristic's impact on price should be approximately equal, regardless of the industry, if the law of one price holds. For example, it is expected that a 10,000 mile difference in the mileage of a vehicle will have the same dollar impact on the price of the vehicle, regardless of the level of I, assuming the law of one price.

Based on this idea, intercept differences between industries are expected. However, the absolute, marginal impacts of the specification variables on price, should not be significantly different between industries, so the slope coefficients for those characteristics should be the same between cross-sections. Interaction terms between cross-sections and each variable coefficient will be used to estimate any differences in slope coefficients between industries.

Hedonic price functions estimate neither supply nor demand, they model reduced form effects of product attribute levels on price, which are a function of *both* supply and demand (Rosen 1974). Hence, the value of bucket truck characteristics may vary over time, in response to the underlying supply and demand conditions. In the covariance model, each cross-sectional unit and each time period are characterized by intercept shifters. The general equation, is given by:

(9) $$P_{it}=\alpha_0+\alpha_1 I_{1t}+\ldots+\alpha_{i-1} I_{(i-1)t}+\beta_1 X_{it,1}+\ldots+\beta_k X_{it,k}$$
$$+\gamma_{11} I_{1t,1} X_{it,1}+\ldots+\gamma_{(i-1)k} I_{(i-1)t,k} X_{it,k}+\delta_1 Y_{i1}+\ldots+\delta_{T-1} Y_{i(T-1)}+\epsilon_{it}$$

where P_{it} is the average price in Industry i during Year t. $I_{it}=1$ for the ith Industry, and $I_{it}=0$ otherwise. $X_{it,k}$ is the value of the kth physical characteristic found in Industry i in Year t. $Y_{it}=1$ for the ith Year, $Y_{it}=0$ otherwise. ϵ_{it} is the random error in Price associated with Industry i during Year t. The $\alpha, \beta, \gamma, \delta$ terms represent parameters to be estimated. Note that one industry indicator variable and one year indicator variable are excluded to avoid perfect collinearity.

In the context of this problem, the $X_{it,k}$ variables represent levels of physical product characteristics, which affect either the product/service produced by the bucket truck purchaser, or the per unit cost of that production. Note that the equation also includes interaction terms between the $X_{it,k}$ variables and the I_{it} indicator variables that denote the industries. The γ parameters to be estimated for these interaction terms are of particular interest in this research. If the null hypothesis, $H_0: \quad \gamma_{11} = \gamma_{12} = \ldots = \gamma_{ik} = 0$, is rejected, then there are apparent price differences between industries, which are not accounted for by differences in physical characteristics.

Summary of Methods

Based on production theory and specifically using derived input demands, a theoretical backdrop for using hedonic analysis for productive inputs in general has been established. However, it is recognized that buyers of durable goods condition their purchasing decisions based on two, distinct, sets of specification variables, one set affecting the product/service produced, and another affecting the per unit cost of that production. Both sets of variables are included so that more accurate estimates of implicit prices are discovered.

In an attempt to identify potential differences in price between industries, which cannot be explained by differences in product attributes, a covariance model is used, which includes interaction terms between relevant cross-sections and relevant specification variables in the model. Cross-sections used indicate different industry buyers, for which differences in demand elasticity could exist, and therefore introduce potential opportunities for price differences. The interaction terms measure whether there are significant differences in estimated shadow prices for specification variables between those cross-sections.

The next chapter, DATA, describes the specific set of specification (attribute) variables chosen. Practical justification is given for the reason the set of variables is expected to have the greatest influence on price. The *a priori* expected signs for variable coefficients are also indicated. A discussion of the data source, and a complete set of descriptive statistics for the variables is given. The next chapter ends by identifying and discussing the limitations of the data.

CHAPTER IV

DATA

The purposes of this chapter are to describe the specific variables hypothesized to have a significant impact on price, and to explore the sample data, which will be applied to the empirical model. Data used are based on those required to most accurately test the research hypothesis. Reasons for the inclusion of specific variables are given, along with each variable's expected direction of influence on price; either a positive relationship or a negative relationship. Any estimation challenges/nuances potentially created by the specific data sample are noted. The chapter concludes with a discussion of the data limitations.

Specification Variables

Specification variables in this project are subset into two groups; variables affecting the product/service produced, and another affecting the per unit cost of that production. Variables in both subsets are based on professional observation of the bucket truck market. Each variable listed is followed by a brief explanation of the variable, and a justification as to why/how it is expected to influence price.

Variables Affecting the Product/Service Produced

Working Height (feet) – Working height is a continuous variable, which denotes the maximum platform height plus five additional feet. Platform height is measured from the ground to the bottom of the platform (bucket). As services are performed further upstream in the electric utility grid (further from the end-user) greater working heights are required. For example, electric utility transmission towers and lines are positioned at greater heights than are electric utility lines in housing subdivisions. Upstream services require not only working at greater heights, but require working on/near higher voltage and amperage. All of which increase the hazard and specialization of the work. As the need for more working height increases, so does the revenue per unit of output. Thus, increasing working height is expected to have a positive effect on bucket truck price.

Material Handling – A material handling bucket truck, commonly referred to as a material handler, possesses a material handling winch at the boom tip. This winch is designed to lift tools, parts and materials up to the elevation they are needed. It lifts items up to the crew-members who are positioned in the bucket. In the absence of material handling capabilities, the crew must rely on additional equipment, which is capable of lifting the objects. For example, the crew may need an additional truck, which is fitted with some type of crane or elevated winch. Non-material handling bucket trucks are referred to as Personnel Units. Material handling bucket trucks have the ability to perform a wider variety of specific tasks independently, thus increasing the potential revenue generated by the bucket truck. Material handling capability is a categorical variable expected to positively effect price. Note that the vast majority of utility bucket trucks, which have material handlers, are insulated. In the current data set, zero non-insulated, material handling bucket trucks were observed.

Front Drive Axle – Front drive axle is a qualitative (categorical) variable that denotes whether a bucket truck's front axle is a drive (powered) axle. A common example is 4-wheel drive, in which the front axle gets power directly from the powertrain of the vehicle. Bucket trucks with front drive axles are either 4-wheel drive (4x4), or 6-wheel drive (6x6). A tandem axle truck (two rear, drive axles) with a front drive axle is 6-wheel drive. Bucket trucks with front drive axles have increased ability to safely and efficiently travel and perform work in more diverse terrains. Utility lines are not always located next to easily accessible roads, nor next to roads at all. Fleets that possess bucket trucks with front drive axles are more capable of performing services in a wider range of terrain and weather conditions, thus increasing their potential revenue. Possessing a front drive axle is expected to have a positive effect on price.

Variables Affecting the Cost of Production

Mileage (miles) – Mileage is a continuous variable, which denotes the total miles that the vehicle has been driven prior to the time of purchase. Bucket trucks are mechanical in nature. Mechanical systems tend to break down or work less efficiently as they wear (break-in period aside). Increased wear is associated with increased use. Higher mileage is associated with increased use. Hence, higher mileage trucks are expected to require a higher level of maintenance and/or repair to keep them in operating condition, and to reach any particular useful life time period. Bucket truck price is expected to decrease as mileage increases. Furthermore, bucket trucks with extremely low mileage, are often considered "like new" to buyers, hence it is expected that price declines more rapidly over the lower range of mileage, as a truck moves out of the perceived, "like new" status. Mileage should then have a more gradual, linear effect on price.

Age (years) – Age is an ordinal variable, which refers to the age of the bucket truck (in years) at the time of purchase. Age is calculated as the difference between the year of sale and the model year of the truck. While usage, represented by mileage, increases the potential wear of mechanical components, some components wear over time, with some independence from usage. Batteries, seals, and gaskets are examples of components that can actually wear faster during periods of non-use. Regardless of mileage, buyers tend to associate newer vehicles with higher quality and less need for maintenance and repair. However, there is also another reason that buyers may pay more for newer vehicles. Body styles and technology change over time. A bucket truck with a newer body style can give the impression of higher quality, especially if one does not know the mileage. This appearance of quality can be beneficial to the bucket truck fleet, as it may give crew-members and customers greater confidence in the company and its services. New and improved technology may offer such things as improved fuel efficiency or better traction control.

Age is expected to be weakly correlated with mileage, however the miles driven per year can vary greatly depending on the type of work that is done by a particular fleet. It is not uncommon to see newer bucket trucks with much higher mileage than relatively older ones. Both the mileage and the age variables should have significant, independent effects on price. Bucket truck price is expected to decrease, as the age at time of purchase increases. Additionally, the effect of increasing age on price is expected to increase in absolute magnitude for higher values of age, thus the variables are expected to have an exponential relationship, and age will enter the estimating equation in both linear and quadratic form.

Cross-Sectioning Characteristic

Insulated vs Non-Insulated – Insulated bucket trucks are designed to be used in the electric utility industry, or other support industries, which work near energized power infrastructure. These bucket trucks offer a secondary insulation source for crew-members, by being designed with non-conductive components. When in good working condition and properly used in specific, intended environments, these non-conductive components isolate personnel from being electrically grounded. Specialized tools and personal protective equipment, such as cover-ups, hot sticks, and rubber gloves, are the lineman's primary source of protection. Non-insulated bucket trucks are not designed for electric utility work and are used in the telecommunications industry. Electric utility work commands a higher price per unit of output than does the telecommunications industry, due to increased hazards and specialization. Due partially to being insulated, bucket trucks sold into the Electric Utility industry are expected to have a higher average price than non-insulated units sold into the Telecommunications industry.

Data Sample

Sales data were collected from one of the large used bucket suppliers that exhibit the characteristics described in Chapter 1. These characteristics are hypothesized to potentially create an environment in which the law of one price does not hold. The data represent used bucket truck sales of the firm in years 2008 – 2012. Observations in each year are in no particular order, hence the data are considered annual. The sample does not include specialized types of aerial devices such as cable placers, track carrier propelled devices, specialized high line units, or backyard aerial devices. The sample includes only highway-legal, vehicle mounted bucket trucks, which are not specifically intended for placing fiber optic cable, do not posses over 99 feet of working height, and are not considered new.

The data sample includes 974 individual sales transactions. Each of the six variables/characteristics, discussed above was measured for all observations. Frequencies for qualitative variables, and descriptive statistics for continuous variables are given in the following tables.

Table 1. Frequency Totals & By Year (2008 – 2012).

	Total	**2008**	**2009**	**2010**	**2011**	**2012**
Unit Sales	974	116	163	199	237	259
% of Total Unit Sales	100%	12%	17%	20%	24%	27%
Electric Utility Unit Sales	749	77	112	162	205	193
% of Annual Unit Sales	77%	66%	69%	81%	86%	75%
Telecom Unit Sales	225	39	51	37	32	66
% of Annual Unit Sales	23%	34%	31%	19%	14%	25%
Material Handler Unit Sales	291	33	42	65	101	50
% of Annual Unit Sales	30%	28%	26%	33%	43%	19%
Front Drive Axle Unit Sales	169	7	19	48	46	49
% of Annual Unit Sales	17%	6%	12%	24%	19%	19%

Table 1 shows that total sales of bucket trucks for the dealer have steadily increased each year. The percentage of telecommunications (telecom) units sold noticeably declined in years 2010 and 2011, as the percentage of electric utility (EU) units peaked in those years. In 2012, the percentage of telecom units sold nearly doubled over 2011, but EU sales still accounted for 75% of the total. The percentage of total sales that were material handling units had a significant drop in 2012 versus 2011, from 43% to 19%. Units with front drive axles tend to represent approximately 20% of total sales, particularly in more recent years.

Table 2. Descriptive Statistics for Sales Price ($) - Totals & By Year (2008 – 2012).

	Total	2008	2009	2010	2011	2012
Mean	45,345	32,539	40,245	44,230	51,161	49,825
StDev	18,159	17,454	19,530	16,149	17,464	15,712
95 % LCI[1]	44,039	28,859	36,785	41,645	48,603	47,624
95 % UCI[2]	46,651	36,219	43,706	46,816	53,720	52,026
CV	40.05	53.64	48.53	36.51	34.13	31.53
Min	9,250	9,250	11,000	10,500	14,400	14,400
Median	44,500	28,900	36,900	44,650	49,900	49,900
Max	125,000	125,000	120,000	85,000	109,000	119,900
Skewness	0.6501	1.7503	1.5195	0.2434	0.5580	0.5726
Kurtosis	0.9261	6.5186	3.0480	-0.4179	0.2620	1.3877

The means and medians given for sales price in table 2, above, appear relatively close for the total sample and in more recent years. This suggests that a strong and consistent central tendency exists. A strong central tendency is further indicated by the fact that the 95% lower confidence interval (LCI) and 95% upper confidence interval (UCI) bound a very small price range, relative to the absolute minimum and maximum prices each year. Comparing the absolute minimums and maximums with the confidence intervals suggests that significant outlying data points may be present at both the upper and lower ends of the price range. The coefficient of variation (CV) has declined in more recent years, suggesting that variability in sales price, relative to the mean, has been decreasing. Sales price tends to be skewed right, and has less kurtosis than a normal distribution.

1 LCI is the 95% lower confidence interval.
2 UCI is the 95% upper confidence interval.

Table 3. Descriptive Statistics for Working Height (ft) - Totals & By Year (2008 – 2012).

	Total	2008	2009	2010	2011	2012
Mean	47.7	46.2	47.7	47.7	49.8	46.6
StDev	11.9	12.8	13.4	10.4	13.1	9.8
95 % LCI[3]	46.9	43.5	45.4	46.0	47.9	45.2
95 % UCI[4]	48.6	48.9	50.1	49.4	51.7	48.0
CV	24.83	27.75	28.05	21.87	26.40	21.07
Min	32	33	32	33	33	33
Median	42	42	42	42	42	42
Max	98	98	98	95	98	98
Skewness	1.4066	1.4687	1.3541	0.8448	1.4459	1.5385
Kurtosis	2.7042	2.9891	1.8017	0.7372	2.7068	3.3068

Table 3 suggests that working height is right-skewed, but overall has kurtosis similar to a normal distribution. Relative to the magnitude of the data values, the mean and median are not closely aligned. The minimum, maximum , and median values are essentially identical in every year. The data are heavily concentrated between 45 and 50 feet, with an absolute range spanning 32 to 98 feet. A long, right-hand tail exists. Variation, relative to the mean, reached its lowest point in 2012.

Table 4. Descriptive Statistics for Mileage (mi) - Totals & By Year (2008 – 2012).

	Total	2008	2009	2010	2011	2012
Mean	85,902	103,296	87,756	88,560	81,254	79,156
StDev	43,819	46,039	45,985	45,461	42,222	39,279
95 % LCI[5]	82,750	93,589	79,607	81,282	75,067	73,653
95 % UCI[6]	89,054	113,003	95,904	95,839	87,440	84,658
CV	51.01	44.57	52.40	51.33	51.96	49.62
Min	434	18,341	11,088	1,106	7,892	434
Median	79,035	92,327	84,880	81,437	75,748	73,092
Max	305,998	252,096	268,636	305,998	231,770	204,674
Skewness	0.7836	0.6938	0.6157	1.0025	0.5968	0.8594
Kurtosis	0.9067	0.1732	0.3926	2.7615	-0.0328	0.4813

3 LCI is the 95% lower confidence interval.
4 UCI is the 95% upper confidence interval.
5 LCI is the 95% lower confidence interval.
6 UCI is the 95% upper confidence interval.

Table 4 presents descriptive statistics for mileage. Average mileage of units sold has consistently decreased over time. Variation in mileage, relative to the mean, has been relatively consistent. The measurements of skewness and kurtosis suggest that the data do not have a distribution with a distinct peak near the mean value, and that it is right-skewed. Mileage spans a relatively high range of data, with a minimum of 434 miles and a maximum of nearly 306K miles.

Table 5. Descriptive Statistics for Age (years) - Totals & By Year (2008 – 2012).

	Total	2008	2009	2010	2011	2012
Mean	7.1	8.4	7.3	6.6	6.9	6.9
StDev	2.8	2.4	2.6	2.8	2.9	2.7
95 % LCI[7]	6.9	7.9	6.8	6.1	6.5	6.5
95 % UCI[8]	7.3	8.9	7.7	7.0	7.3	7.3
CV	38.98	28.38	35.49	42.04	42.02	39.34
Min	1	3	2	2	1	3
Median	7	9	8	6	6	7
Max	20	15	14	20	18	16
Skewness	0.7429	0.1901	0.0334	1.0691	1.1184	0.9289
Kurtosis	0.4671	0.0118	-0.7771	1.7946	1.3123	0.4184

Table 5 suggests that the variation in age, relative to its mean, has increased in recent years. However, the maximum value for age appears to have peaked in 2010, and has declined since. The lowest average age occurred in 2010, but the annual average has a relatively small range of 6.6 to 8.4 years. The descriptive statistics suggest that the data are not normally distributed, with a relatively flat peak (or lack thereof), and skewness to the right.

7 LCI is the 95% lower confidence interval.
8 UCI is the 95% upper confidence interval.

Table 6 is of particular interest in the present setting, as it presents descriptive statistics for sales price by industry. As expected, the electric utility (insulated) category has a much higher mean sales price than the telecommunications (non-insulated) cross-section. Telecom units have a higher variation in price, relative to the mean, but EU equipment prices tend to have the most absolute variation. Prices in both industries exhibit some skewness to the right, and have little kurtosis, relative to a normal distribution. Both industries have a relatively large price range, but the EU industry has a particularly large difference between minimum and maximum price.

Table 6. Descriptive Statistics for Sales Price ($) - By Industry (2008 – 2012).

	Electric Utility	Telecommunications
Mean	49,690	30,882
StDev	17,247	12,876
95 % LCI[9]	48,275	28,945
95 % UCI[10]	51,105	32,819
CV	34.71	41.69
Min	10,250	9,250
Median	48,900	29,900
Max	125,000	72,500
Skewness	0.7039	0.8793
Kurtosis	1.3440	0.8209

Table 7 shows descriptive statistics for working height by industry. Telecom units have a very narrow range of working heights, and thus low variation relative to the mean, compared to the EU group. Of potentially critical importance is the fact that average working height is very different between the cross-sections. This suggests that there is a potentially high degree of correlation between working height and industry, which could lead to potentially degrading collinearity in the analysis. However, it is

9 LCI is the 95% lower confidence interval.
10 UCI is the 95% upper confidence interval.

expected that there is enough variation in price and working height, within each industry, such that little collinearity will be present when all variables are simultaneously accounted for during estimation.

Table 7. Descriptive Statistics for Working Height (ft) - By Industry (2008 – 2012).

	Electric Utility	Telecommunications
Mean	51	37
StDev	12	3
95 % LCI[11]	50	37
95 % UCI[12]	52	37
CV	22.76	8.33
Min	34	32
Median	45	35
Max	98	43
Skewness	1.3927	0.2652
Kurtosis	2.7394	-1.5604

Table 8 presents descriptive statistics for mileage by industry. Mean mileage is approximately 20% lower for the EU group than it is for the telecom group. Mileage within the EU industry appears to have much more variation, relative to the mean value. The difference in average mileage between groups suggest that mileage is correlated with industry. Further statistical tests are required to confirm whether the correlation is statistically significant, and whether the relationship causes degrading collinearity.

Table 9 shows that the average age at the time of sale is higher for the telecom industry, but the average ages differ by less than a year. Like the other variables in this analysis, age at time of sale does not appear to come from a normal distribution. Slight skewness and a lack of kurtosis, appear to be very common in the sample.

11 LCI is the 95% lower confidence interval.
12 UCI is the 95% upper confidence interval.

Table 8. Descriptive Statistics for Mileage (mi) - By Industry (2008 – 2012).

	Electric Utility	Telecommunications
Mean	81,345	101,070
StDev	42,828	43,761
95 % LCI[13]	77,831	94,486
95 % UCI[14]	84,860	107,653
CV	52.65	43.30
Min	434	1,138
Median	73,677	99,901
Max	305,998	254,901
Skewness	0.9505	0.3673
Kurtosis	1.4443	0.29

Table 9. Descriptive Statistics for Age (years) - By Industry (2008 – 2012).

	Electric Utility	Telecommunications
Mean	6.9	7.7
StDev	2.8	2.6
95 % LCI[15]	6.7	7.3
95 % UCI[16]	7.1	8.1
CV	40.31	33.82
Min	1	2
Median	6	8
Max	18	20
Skewness	0.8281	0.5745
Kurtosis	0.3229	1.6305

Table 10. Material Handler & Front Drive Axle Frequency - By Industry (2008 – 2012).

	Electric Utility	Telecommunications
Unit Sales Per Industry	749	225
Material Handler Count	291	0
% of Industry	39%	0%
Front Drive Axle Count	156	13
% of Industry	21%	6%

13 LCI is the 95% lower confidence interval.
14 UCI is the 95% upper confidence interval.
15 LCI is the 95% lower confidence interval.
16 UCI is the 95% upper confidence interval.

Table 10 shows that all Material Handling units in the sample are insulated, which is common in the industry. Non-insulated material handling units are manufactured, but are rare compared to other configurations. Trucks possessing front drive axles appear to be far more common in the EU industry versus telecom.

Figure 1 is a graphical representation of table 6, Descriptive Statistics for Sales Price by Industry, and shows estimated Probability Density Functions (PDFs) for sales price for each industry. The vertical lines on each graph represent, from left to right, the lower quantiles, the averages, and the upper quantiles respectively. Figure 1 shows that the mean sales prices are considerably different between industries, but that there is significant overlap between PDFs. This suggests that industry is not adequate to define different and distinct price surfaces. A task that will be undertaken through the introduction of the other specification variables; working height, material handling capability, possessing a front drive axle, mileage, and age of the bucket truck at time of sale.

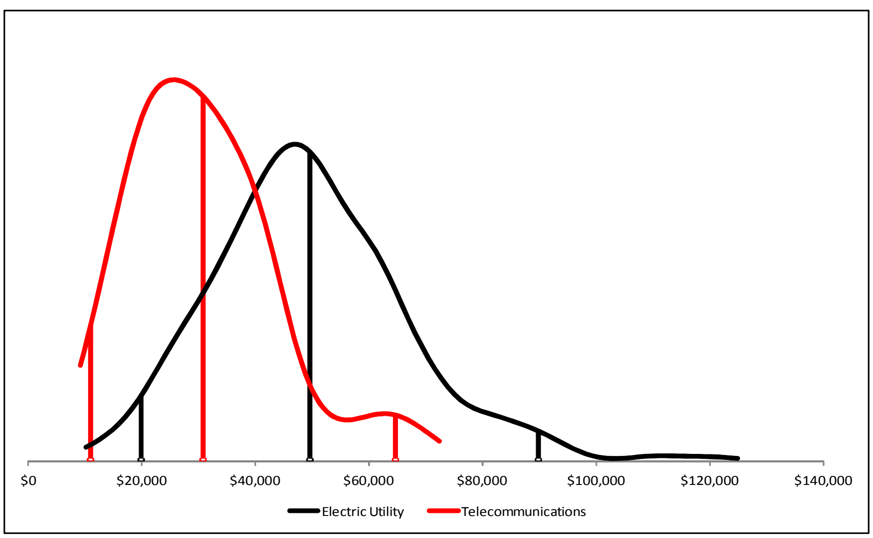

Figure 1. PDF Approximations of Sales Price ($) by Industry.[17]

17 Vertical lines on each graph represent, from left to right, the lower quantiles, the averages, and the upper quantiles respectively.

Limitations of the Data

One limitation of the sample, is that it does not include make (brand) of the equipment or chassis. As is pointed out by Borenstein (1985), sorting customers based on brand preference can be a stronger sorting mechanism than differences between basic product characteristics. While brand likely has *some* impact on price, it is doubtful that brand has a more significant impact than the specification and cross-sectioning variables that will be applied to the model.

The final limitation of the data is that the sample comes from only a single firm in the industry. While it is true that the firm chosen appears to posses the characteristics necessary for the exercise of market power, it would be remiss to think that the data from a single firm can accurately describe the supply and demand characteristics of an entire industry.

Data Summary

The most plausible physical characteristics that may significantly affect bucket truck price have been identified as: Insulated/non-insulated status, material handling capability, working height, possessing a front drive axle, mileage, and age at time of sale. Actual transaction prices and measurements of these six variables for each transaction, were collected from one of the largest U.S. bucket truck suppliers in the secondary market for years 2008 through 2012. The firm sampled appears to have a relatively high level of specialized industry expertise, training, and human capital. Additionally, the firm is of relatively significant scale, appears to offer a truly differentiated product, and to posses a high level of operational efficiency and marketing dominance.

CHAPTER V

RESULTS

Chapter 5 presents the econometric parameter estimation results for the empirical model proposed in Chapter 3. Statistical tests for validation of the the model are carried out, and the parameter estimates are evaluated for applied accuracy. Estimated parameters for interaction terms are used to test the research hypothesis proposed.

Notation

In the estimating equation(s), variables are denoted as follows:

P = Sales Price ($)

I_1 = Industry 1 (Electric Utility) Indicator

I_2 = Industry 2 (Telecommunications) Indicator

X_1 = Working Height (ft)

X_2 = Material Handling Capability Indicator

X_3 = Front Drive Axle Indicator

X_4 = Mileage (mi)

X_5 = $\sqrt{Mileage}$

X_6 = Age (years)

X_7 = Age^2 (years)

Y_1 = Year Sold 2008 Indicator

Y_2 = Year Sold 2009 Indicator

Y_3 = Year Sold 2010 Indicators

Y_4 = Year Sold 2011 Indicator

Y_5 = Year Sold 2012 Indicator

Variables, $X_5(\sqrt{Mileage})$ and $X_7(Age^2)$ are considered based on the expected curvilinear relationships between sales price and these variables. Units with extremely low mileage are considered "almost new" by buyers, and therefore typically sell at considerably higher prices. Sales Price is expected to fall rapidly as mileage increases over the lower range, but then have a more gradual, negative impact on sales price over the rest of the mileage range. Age is expected to negatively affect price at an increasing rate.

To test the research hypothesis, two, competing estimating equations are considered:

(10) $$\hat{P}=\hat{\alpha}_0+\hat{\alpha}_2 I_2+\sum_{i=1}^{7}\hat{\beta}_i X_i+\sum_{t=1}^{4}\hat{\delta}_t Y_t$$, and

(11) $$\hat{P}=\hat{\alpha}_0+\hat{\alpha}_2 I_2+\sum_{i=1}^{7}\hat{\beta}_i X_i+\sum_{\substack{i=1}}^{\substack{i\neq 2\\7}}\hat{\gamma}_i X_i I_2+\sum_{t=1}^{4}\hat{\delta}_t Y_t$$.

Note that Industry 1 (electric utility) and Year 2012, indicator variables have been excluded to avoid perfect collinearity. Thus, electric utility units, sold in 2012 will serve as the reference case. Additionally, note the $i\neq 2$ notation above the summation sign for interaction terms. Recall that only electric utility units, in the sample, possess material handlers. Hence, an interaction term between the industry indicator and the material handling indicator would be nonsensical and it would create perfect collinearity. The I_2X_2 interaction term was therefore left out of the equation.

<u>Results of Econometric Parameter Estimation</u>

The full equation, Equation 11, was estimated using Ordinary Least Squares (OLS). A White's test revealed significant heteroscedasticity. The variance of the error term was significantly dependent on the values of numerous explanatory variables. This form of heteroscedasticity is common in cross-sectional data. As a more efficient estimator in the presence of heteroscedasticity, weighted least squares (WLS) was then employed. The absolute values of the OLS residuals were regressed on all non-discrete, explanatory variables in the model, producing $\hat{\sigma}_i$. Weights used for WLS estimation were $w_i = 1/\hat{\sigma}_i$. A White's test on the WLS residuals found no significant heteroscedasticity.

The WLS results of the parameter estimation for Equation 11 are presented in table 11. Equation 11 has an F-Statistic that is significant at the $\alpha = .01$ level, indicating that the group of explanatory variables is statistically significant in explaining variation in sales price. All of the basic variables (non-interaction terms), except two, were significant at the $\alpha = .05$ level. Most were significant at $\alpha = .01$.

All of the basic variables were found to have the correct, *a priori* expected signs. Note that while X_4 (Mileage) had an estimated coefficient that was positive, and statistically insignificant, this was not necessarily unexpected. X_5 (Square Root of Mileage) had an estimated coefficient with the correct, negative sign, and was found to be significant. The effect of X_4 and X_5 combined, over the range of data, has the expected effect on P. Price drops rapidly as mileage increases, when mileage is extremely low.

Table 11. WLS Parameter Estimation Results for Equation 11.

Variable	Estimated Parameter		Standard Error
Intercept	64,876.7600	***	4,753.0760
Telecom Indicator (I_2)	-27,367.3300	***	8,955.5930
Working Height (X_1)	680.7763	***	46.7846
Material Handling Indicator (X_2)	7,847.2930	***	567.5552
Front Drive Axle Indicator (X_3)	510.1281		620.9701
Mileage (X_4)	0.0031		0.0403
Square Root Mileage (X_5)	-60.8686	**	23.8749
Age (X_6)	-5,728.9890	***	609.7234
Age^2 (X_7)	128.0158	***	41.0359
Telecom x Working Height (I_2X_1)	527.4875	***	143.2520
Telecom x Front Drive Axle (I_2X_3)	1,876.1850		2,119.9560
Telecom x Mileage (I_2X_4)	0.1469	**	0.0612
Telecom x Square Root Mileage (I_2X_5)	-74.0054	*	39.3752
Telecom x Age (I_2X_6)	2,620.3120	***	861.9180
Telecom x Age2 (I_2X_7)	-70.1418		52.8018
Year Sold 2008 Indicator (Y_1)	-9,068.5020	***	706.0095
Year Sold 2009 Indicator (Y_2)	-7,652.4910	***	600.1018
Year Sold 2010 Indicator (Y_3)	-7,389.0410	***	623.9398
Year Sold 2011 Indicator (Y_4)	-2,223.5090	***	616.4140
Adjusted R-Squared	86.6585		
Standard Error of Regression	6,411.9900		
F-Statistic	352.1131	***	

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Three of the interaction term coefficients were found to be statistically significant at the $\alpha = .05$ level. All three estimated coefficients had positive signs. The estimation results suggest that the dealer can charge more for increased working height within the telecom industry, all else being equal. Furthermore, increased mileage and increased age, have less of a negative impact on price within the telecom industry. Apparently, the telecommunications buyers are willing to pay more for increased working height, and require less of a discount for more "negative" characteristics, ceteris paribus. However, for the majority of physical characteristics, no differences were found between industries, in how their changes affected price.

Applied Accuracy of the Model

As discussed above, the signs on coefficients match theoretical and applied, real-world, expectations. Based on T-ratios, the F-Statistic, and the adjusted R^2 for the equation, it represents a reasonable set of parameters for estimating bucket truck price. From an applied perspective, the sizes of the coefficients are also very reasonable. The model is capable of estimating an adequately accurate, average price, given a vector of values for explanatory variables, which are within the range sampled.

The Year Sold indicator variables, Y_1 through Y_4, accurately reflect what is known to be true about underlying supply and demand conditions in the industry. Since 2008, the market demand for bucket trucks, particularly in the Electric Utility industry, has continued to shift outward rapidly. The shift is primarily due to rapid build-out and government funding for utility infrastructure across the United States and Canada. At the same time, supply of high-quality, used equipment has tightened. The inward shift in supply is primarily due to higher rental utilization rates, which has prompted, and in some cases forced, bucket truck rental firms to keep bucket trucks in their fleets for longer time periods. Hence, making these "raw materials" unavailable to bucket truck remanufacturers. Also, a challenging macro-economic environment has prompted many larger utility fleets, who still *purchase* new units, to put off replacement. Thus limiting the number of used units on the market.

Misspecification Analysis

Collinearity/Multicollinearity

Potential correlation between regressors was a concern briefly mentioned in Chapter 4. The inclusion of the $\sqrt{Mileage}$ and Age^2 terms necessarily creates collinearity between these and their non-transformed counter-parts. Additionally, the inclusion of interaction terms systematically creates collinearity. The collinearity created by these additional variables is unavoidable in the model estimated, however the extent to which the variance of the estimates was being inflated was identified.

Variance Inflation Factors (VIFs) greater than 2.5 were found for the Mileage, $\sqrt{Mileage}$, Age, and Age^2 variables, which were expected. All interaction terms except I_2X_3 had high VIFs (greater than 65), which was also expected. The Year indicators were not found to be linearly related to other explanatory variables.

Coefficient variance decomposition was also carried out. Condition numbers for every eigenvalue were extremely small. For the form of decomposition used, extremely small condition values suggest further examination (unlike the typical 30, cut-off value). Examination of the variance decomposition proportions revealed that the most potentially problematic collinearity existed between the Industry indicator and X_3, Front Drive Axle. Recall from Chapter 4 that EU units were far more likely to have a front drive axle. The degrading collinearity between these variables, is likely the reason that X_3 is not shown to be statistically significant in table 11. X_1 (Working Height) was not found to have a degrading collinear relationship with the Industry indicator.

Influence Diagnostics

An analysis of the potential presence of influential observations was carried out next. First, a scatter plot of WLS residuals, which is shown in figure 2, was examined. Figure 2 suggests at least three outlying data points with residuals greater than $30,000. To gain more guidance on how to proceed, a graph of studentized residuals, figure 3, was viewed. Observation of figure 3 suggests that a relatively large number of observations produced residuals that were more than two standard deviations from the mean of zero. However, besides seven observations with abnormally high, positive residuals, the residuals tended to fall uniformly within a consistent range between ± $20,000. Those seven observations were examined more closely.

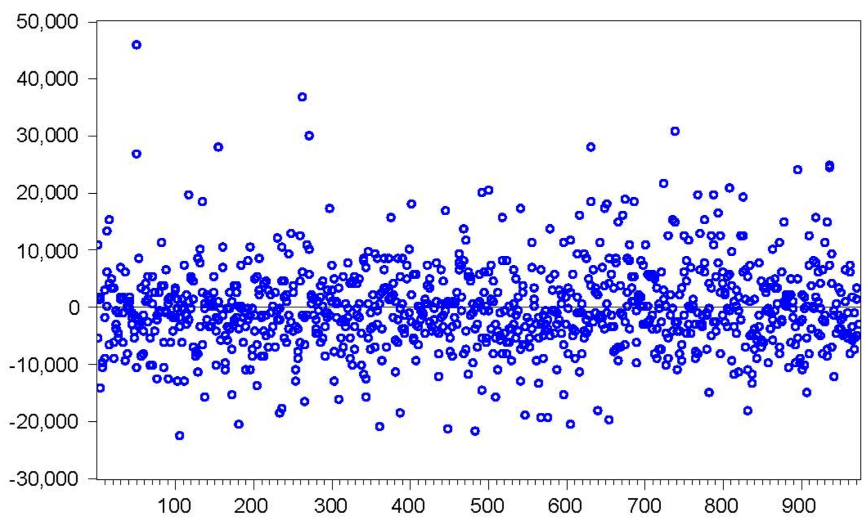

Figure 2. WLS Residuals from Equation 11.

Three of the seven, investigated observations appeared to produce extremely large residuals, because the sales price was atypically high, considering the age of the units. However, the observations had very high working heights, and two had relatively low mileage. The other three observations had atypically high sales prices, considering the values of their specification variables in general. Data was examined for human entry errors, none were found. These observations, producing outlying errors, were indeed bona fide, accurate observations.

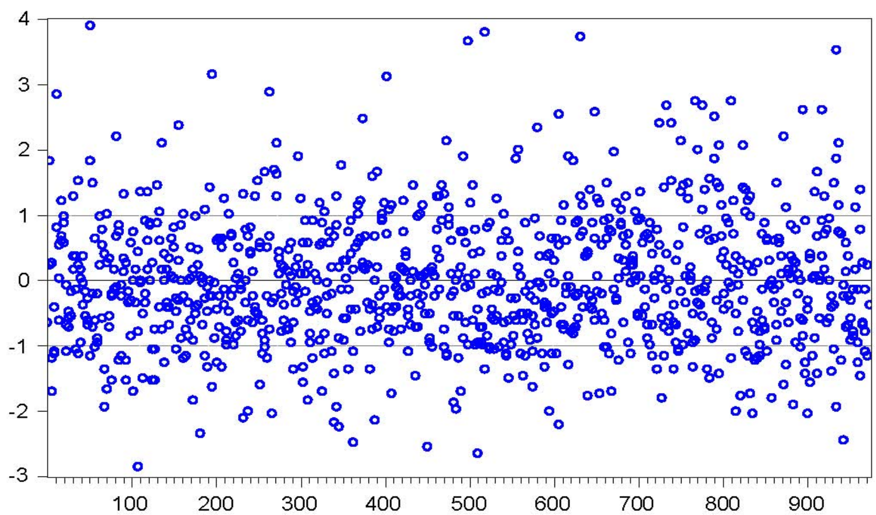

Figure 3. Studentized WLS Residuals from Equation 11.

Viewing residuals does not necessarily identify leverage points, points with extremely high values for explanatory variables. Nor does viewing residual plots quantify the potential influence of outlying data points. Hence, formal influence diagnostic tables were produced, these included studentized residuals, diagonal elements of the hat matrix, DFFits, and DFBetas. Using the hat matrix, three leverage points were identified. These observations had exceptionally low values for mileage. However, the studentized residuals for these observations were well below 2; the observations were not found to be influential.

Four additional observations were found to have high studentized residuals and either high DFFit, high DFBeta, or both. These four observations were closely examined. Observation 51 sold for $95,000, although it was ten years old and had 95,000 miles. However, it did have an 82 foot working height. Observation 493 sold for $109,000, although it only had a working height of 42 feet. However, it did possess a material handler, was only one year old, and had only 7,892 miles. Observation 518 sold for $42,400, although it only had a working height of 34 feet, had 126,000 miles, and was nine years old. Observation 633 sold for $45,000, although it had a working height of only 35 feet and was 15 years old. It did have relatively low mileage of 49,000.

Observations 51 and 493 represent the importance of more working height and low age in determining price, respectively. While these two observations potentially had a profound impact on estimated parameter values, they were not removed. The influence of extreme working heights, above 70 feet, and extremely low age, one year old, should not be underestimated in determining price. Observations 518 and 633 were more of a quandary. These data points potentially had an undue influence on the fit of the model. For some reason the dealer was able to command a higher price than expected, relative to the ages, working heights, and mileage of the bucket trucks. However, these types of observations speak to the very heart of the research hypothesis, which is that the *law of one price* does not hold for this industry. It is expected that additional sales transaction samples taken in the future from this, or similar dealers, will likely contain these same types of outlying and influential observations. These types of observations are accurate and instructive realities within this market. None of the influential observations were removed from the analysis.

Formal Testing of the Research Hypothesis

Hypothesis

Differences in price between customer segments are primarily due to differences in physical product characteristics, but these characteristics do not fully account for differences in price.

Formal Null Hypothesis

H_0: $\gamma_{11}=\gamma_{12}=...=\gamma_{ik}=0$

The γ parameters represent the coefficients of the interaction terms in the model. The estimated parameters were used to test $\gamma_{21}=\gamma_{23}=\gamma_{24}=\gamma_{25}=\gamma_{26}=\gamma_{27}=0$. An F-test was used to test this restriction, using the estimates from the WLS model. The test results indicate that the null hypothesis should be rejected at the $\alpha=.01$ level.

Conclusion

The null hypothesis is rejected with 99% confidence, and it is concluded that the estimated shadow prices for bucket truck characteristics are not equal between the Electric Utility and Telecommunications industries.

The bucket truck dealer can charge more for increased working height within the telecom industry, all else being equal. Increased mileage and increased age, have less of a negative impact on price within the telecom industry. Apparently, telecommunications buyers are willing to pay more for increased working height, and require less of a discount for more "negative" characteristics, ceteris paribus.

Summary of Results

The econometric parameter estimation yielded results that conformed to theoretical and real-world expectations. The original OLS estimation was found to have significant heteroscedasticity, resulting in lack of efficiency. Subsequently, estimation was carried out using WLS, which resulted in homoscedastic residuals. F-test results on a group of interaction terms, and t-test results on individual interaction terms, suggested that changes in certain physical characteristics had differing effects on bucket truck price, depending on the industry into which they are sold. All statistically significant interaction terms were positive, indicating that bucket truck buyers in the telecommunications industry pay more than buyers in the electric utility industry, for marginal increases in working height, and pay more for bucket trucks that are marginally older and have marginally higher mileage, ceteris paribus. The results suggest that the law of one price is not holding true in the used bucket truck market.

CHAPTER VI

CONCLUSIONS

Introduction

Historically, secondary (used) durable goods markets have not possessed the characteristics necessary for product differentiation and/or market power to exist. Hence, the majority of secondary market research has focused only on how their existence affects market power in the primary market. However, in recent years a secondary market has emerged that appears to possess the characteristics for which it is possible that market power may exist; product differentiation, high barriers to scale, relative ease of customer segmentation, and limited arbitrage possibilities. Additionally, the market serves a critical need in providing the electric and communications utilities that people rely upon, because it provides specialized equipment, bucket trucks, to those companies who build and maintain utility infrastructure. The market is that of a necessary productive input, for which suitable alternatives do not exist.

The hedonic technique was used to determine whether price differences between customer segments was evident in the secondary bucket truck market. Five objectives were defined. The first objective was to identify the most suitable theoretical framework for the problem at hand. Second was to determine the appropriate empirical model for estimation. The third objective was to determine the most appropriate statistical technique to estimate parameters. Fourth was to validate the model both statistically and for applied accuracy. The final objective was to conduct the appropriate statistical tests to reach a conclusion about the research hypothesis. In what follows, the results of this study are summarized, and implications of these results are discussed.

Contributions of the Research

Past studies of primary – secondary market interaction have failed to incorporate the possibility that market power may exist in the secondary market, because the traditional structure of used, durable goods markets gave researchers little reason to do so. The growth of the world-wide-web, coupled with other market-specific factors, has the potential to change the way secondary markets develop. The results of this project suggest that the law of one price does not necessarily hold in the secondary bucket truck market. The current project lends itself to future research in the areas of market power and primary – secondary market interaction, because market power in secondary markets is likely to have some effect on primary markets. Conventional theorists may desire to take this potential effect into account, and adjust the assumptions used to relate secondary markets to primary ones. Additionally, this project identifies the factors, which can potentially lead to market power in a secondary market, thus providing a usable backdrop to make identifying such phenomenon an easier task.

This study supplements the hedonic literature, with respect to valuing the characteristics of productive inputs, by incorporating the aspect of durability directly into the hedonic equation. The buyers of older durables may well expect to get the same useful life from the asset, as those buyers who purchase relatively newer durables. The difference, is in the relative cost of maintaining each asset over a fixed, and equal useful life. These differences in expected costs are a function of certain physical characteristics, which are known to the buyer at the time of purchase. The purchase price of durable inputs is not only determined by a vector of physical characteristics, which determine output per unit of work time, but is also determined by physical characteristics that influence ongoing production costs and resale/salvage value.

The profit maximizing condition is not independent of these additional characteristics, and the values of this vector are not necessarily exogenous to the buyer's decision making process. The buyer makes a purchasing decision based on two sets of characteristics, one set affecting the product/service produced, and another affecting the per unit cost of that production. Hence, both sets of decision variables must be present and simultaneously accounted for in the hedonic equation, if accurate shadow prices are to be estimated.

Summary

Rosen's (1974) hedonic framework, which was used by Rudstrom (2004) to model productive inputs, was augmented to more fully exploit the use of the hedonic technique, conform to theory, and accommodate the aspect of durability in the bucket truck market. Using this theoretical backdrop, implicit prices for bucket truck characteristics were empirically estimated, which accounted for physical characteristics affecting both marginal output and marginal input costs for bucket truck users.

In an attempt to detect differences in price for similar products between customer segments, a covariance model was used, which cross-sectioned purchasers into two distinct industries; electric utility and telecommunications. Interaction terms between industry cross-sections and product attribute specification variables were included to detect any differences between industries in how prices were affected by changes in product attribute levels. Indicator variables for each time period were used to account for any underlying structural changes in supply and demand.

Five years of data were collected from one of the primary bucket truck suppliers in the United States. The dealer appeared to possess all the characteristics necessary for the potential exercising of market power. Data included actual transaction prices, as well as the observed levels of each physical characteristic deemed most important in determining price. Ordinary least squares (OLS) regression was attempted, but considerable heteroscedasticity prompted the use of weighted least squares (WLS), which removed the effect of the heteroscedasticity, and was found to be a more efficient estimator. The signs and magnitudes of the estimated coefficients were found to conform to theoretical and real-world expectations. Variables such as working height, material handling capability, age, and mileage were found to have a significant impact on bucket truck prices. Estimated coefficients for the annual time-series indicators were found to have a large and highly significant impact on bucket truck prices. These estimated effects from changes in underlying supply and demand conditions, conformed to what has appeared to be the case in the bucket truck market.

Estimated coefficients for the interaction terms between industry and physical characteristics, allowed the testing of the research hypothesis:

Differences in price between customer segments are primarily due to differences in physical product characteristics, but these characteristics do not fully account for differences in price.

Based on the statistical tests and the assumptions made in this project, the hypothesis should not be rejected. Results indicate that some bucket truck dealers may have the ability to charge higher prices to the telecommunications industry. Specifically, marginal changes in working height appear to more greatly raise price in this industry, and increasing mileage and age, do not have as severe negative impacts on price.

Implications of the Study

One potential implication of the study lies in the results of the hypothesis test. If the law of one price, does indeed not hold in this market, then it may be an indication that market power exists to some extent. The used bucket truck market appears to be oligopolistic. However, in most oligopolistic settings, prices are driven lower by fierce price or quantity competition, such that all prices are equal at marginal cost. Since this study does not compare prices between multiple dealers, it is possible that used bucket truck prices, in general, tend to possess the same differences in implicit prices between industries. If this is the case, then perhaps there is some level of information asymmetry. Not necessarily asymmetry between the information that exists for dealers versus customers, but asymmetry in the information that exists between electric utility buyers versus telecommunications buyers.

The second implication relies, not so much on the results of the study, but in the seemingly unique set of characteristics that the general bucket truck market appears to possess. It is a durable goods market, in which no comprehensive dealer network exists for the OEMs. There appears to be relatively high barriers to entry/scale, due to the fact that high levels of specific, technical skills are necessary, which are not common, due to the uniqueness of the product and market. The product is a necessity in certain industries, such that not buying at all, is often not a viable business choice. The secondary segment of the market may actually exhibit lower overall “search costs” for end-users than the primary market, due to production times. There is a high level of quality variation in product sold in the secondary market. A high level of product differentiation likely exists, because of high degrees of marketing dominance. The aerial device OEMs cannot fully exploit the idea of a profit maximizing obsolescence path, because they can only control the quality of the aerial device, not the truck chassis. Further, due to safety specifications, OEMs are forced to build aerial devices such that they will far outlast the useful life of the truck chassis.

When combined, the market characteristics described above, create a potentially important implication for aerial device OEMs and secondary market suppliers. It may be possible, that a properly organized, secondary market dealer/remanufacturer, can ultimately compete directly with the OEMs for market share in the “primary” market. If a secondary market dealer possesses the technical ability, scale, efficiency, and marketing dominance necessary to produce and promote a “like new” product, then it gives traditional, new bucket truck buyers, a potential alternative to the OEMs, without ever having to produce its own aerial devices. A properly remanufactured aerial device, mounted onto a new truck chassis, becomes a viable alternative to new.

Recommendations for Continuing Research

Four recommendations for future research should be considered. First, the model proposed here should be expanded to account for brand (make) of at least the mounted equipment, and perhaps the make of the chassis. Secondly, if similar sales data could be collected from at least one, additional dealer, then a comparison of prices between dealers could be conducted, while controlling for differences in physical product characteristics.

The third recommendation is that separate equations be estimated for the electric utility and telecommunications industries. If it is assumed that the error terms are correlated across equations, then seemingly unrelated regression (SUR) may be a suitable technique. Statistical tests could then be conducted to determine whether specification variable coefficients are equal across the two equations. No interaction terms would be necessary in the model.

Lastly, the proposed, or similar, model should be applied to other used durable, secondary markets, which may be economically critical. The secondary tractor market may be a suitable candidate. Like bucket trucks, the used tractor market likely has more barriers to entry than the used car market, which makes it more likely for market power to emerge. Tractors are a productive input, so the methods used here could be directly applied.

REFERENCES

Anderson, S.P., and A. De Palma. 1988. "Spatial Price Discrimination with Heterogeneous Products." *The Review of Economic Studies* 55(4):573-92.

Anderson, S.P., and V.A. Ginsburgh. 1994. "Price Discrimination Via Second-Hand Markets." *European Economic Review* 38:23-44.

Becker, G.S. 1965. "A Theory of the Allocation of Time." *The Economic Journal* 75(299):493-517.

Berry, S., J. Levinsohn, and A. Pakes. 1999. "Voluntary Export Restraints on Automobiles: Evaluating a Trade Policy." *The American Economic Review* 89(3):400-30.

Berry, S.T. 1994. "Estimating Discrete-Choice Models of Product Differentiation." *The RAND Journal of Economics* 25(2):242-62.

Borenstein, S. 1985. "Price Discrimination in Free-Entry Markets." *The RAND Journal of Economics* 16(3):380-97.

Bresnahan, T.F. 1987. "Competition and Collusion in the American Automobile Industry: The 1955 Price War." *The Journal of Industrial Economics* 35(4):457-82.

Chupka, M.W., R. Earle, P. Fox-Penner, and R. Hledik. 2008. *Transforming America's Power Industry: The Investment Challenge 2010-2030.* Washington D.C.: The Edison Foundation.

Clemons, E.K., I. Hann, and L.M. Hitt. 2002. "Price Dispersion and Differentiation in Online Travel: An Empirical Investigation." *Management Science* 48(4):534-49.

Clerides, S.K. 2004. "Price Discrimination with Differentiated Products: Definition and Identification." *The Journal of Economic Inquiry* 42(3):402-12.

Coase, R. 1955. "Published Comments on 'Characteristics and Types of Price Discrimination.'" *Business Concentration and Price Policy*. Cambridge, MA: National Bureau of Economic Research, 435-37.

Coase, R.H. 1972. "Durability and Monopoly." *Journal of Law and Economics* 15(1):143-49.

Corts, K.S. 1998. "Third-Degree Price Discrimination in Oligopoly: All-Out Competition and Strategic Commitment." *The RAND Journal of Economics* 29(2):306-23.

Deaton, A., and J. Muellbauer. 1980. *Economics and Consumer Behavior*. Cambridge, MA: Cambridge University Press.

Diekman, F., B.E. Roe, M.T. Batte. 2008. "Tractors on EBay: Differences Between Internet and In-Person Auctions." *American Journal of Agricultural Economics* 90(2):306-20.

Edington, D., Plant Manager, Utility Fleet Sales, Ltd., Personal Communication, July 15, 2012.

Esteban, S., and M. Sum. 2007. "Durable-goods Oligopoly with Secondary Markets: The Case of Automobiles." *The RAND Journal of Economics* 38(2):1-23.

Fisher, L. 2010. "Smart Grid Spending Will Top $45 Billion by 2015." *ABI Research, NextGen Unit.* Accessed via Internet, August 1, 2012. http://abiresearch.com.

Fumasi, R., Vice President of Marketing & Finance, Utility Fleet Sales, Ltd., and Primary Author of this work.

Griliches, Z. 1961. "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change." Staff Paper 3, Chicago: National Bureau of Economic Research and the University of Chicago.

Goldberg, P.K., and F. Verboven. 1999. "The Evolution of Price Discrimination in the European Car Market." Discussion Paper No. FS IV 99-14, Berlin: Social Science Research Center.

Hendel, I., and A. Lizzeri. 1999. "Adverse Selection in Durable Goods Markets." *The American Economic Review* 89(5):1097-1115.

Hendel, I., and A. Lizzeri. 2002. "The Role of Leasing Under Adverse Selection." *Journal of Political Economy* 110(1):113-43.

Holmes, T.J. 1989. "The Effects of Third-Degree Price Discrimination in Oligopoly." *The American Economic Review* 79(1):244-50.

Kumar, P. 2002. "Price and Quality Discrimination in Durable Goods Monopoly with Resale Trading." *International Journal of Industrial Organization* 20:1313-39.

Lancaster, K.J. 1966. "A New Approach to Consumer Theory." *The Journal of Political Economy* 74(2):132-57.

Liu, Q., and K. Serfes. 2005. "Imperfect Price Discrimination in a Vertical Differentiation Model." *International Journal of Industrial Organization* 23:341-54.

Machlup, F. 1955. “Characteristics and Types of Price Discrimination.” Chapter from *Business Concentration and Price Policy*. Cambridge, MA: National Bureau of Economic Research, 395-438.

Mertens, Y., and V. Ginsburgh. 1985. “Product Differentiation and Price Discrimination in the European Community: The Case for Automobiles.” *The Journal of Industrial Economics* 34(2):151-66.

Nerlove, M. 1995. “Hedonic Price Functions and the Measurement of Preferences: The Case of Swedish Wine Consumers.” *European Economic Review* 39:1697-1716.

Ott, R.L., and M. Longnecker. 2001. *An Introduction to Statistical Methods and Data Analysis, Fifth Edition*. Pacific Grove, CA: Duxbury.

Palmquist, R.B. 1989. “Land as a Differentiated Factor of Production: A Hedonic Model and its Implications for Welfare Measurement.” *Land Economics* 65(1):23-28.

Papendreou, A.G. “Published Comments on 'Characteristics and Types of Price Discrimination.'” *Business Concentration and Price Policy*. Cambridge, MA: National Bureau of Economic Research, 437-440.

Pigou, A.C. 1932. *The Economics of Welfare*. London: MacMillan.

Purohit, D. 1992. “Exploring the Relationship between the Markets for New and Used Durable Goods: The Case of Automobiles.” *Marketing Science* 11(2):154-67.

Robinson, J. 1933. *The Economics of Imperfect Competition*. London: MacMillan.

Rosen, S. 1974. “Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition.” *The Journal of Political Economy* 82(1):34-55.

Rudstrom, M. 2004. “Determining Implicit Prices for Hay Quality and Bale Characteristics.” *Review of Agricultural Economics* 26(4):552-62.

Stavins, J. 1996. *Price Discrimination in the Airline Market: The Effect of Market Concentration*. Boston: Federal Reserve Bank.

Vanek, J.K., M.J. Watts, and G.W. Brester. 2008. “Carcass Quality and Genetic Selection in the Beef Industry.” *Journal of Agricultural and Resource Economics* 33(3):349-63.

Waldman, M. 2003. “Durable Goods Theory for Real World Markets.” *The Journal of Economic Perspectives* 17(1):131-54.

Waugh, F. V. 1928. “Quality Factors Influencing Vegetable Prices.” *Journal of Farm Economics* 10:185-96.

Witte, A.D., H.J. Sumka, and H. Erekson. 1979. "An Estimate of a Structural Hedonic Price Model of the Housing Market: An Application of Rosen's Theory of Implicit Markets." *Econometrica* 47(5):1151-73.