AN EMPIRICAL STUDY OF ISSUES RELATING TO HEARING LOSS AND HEARING AID MARKET

by

MENGZHI XIE, B.A.

A DISSERTATION

IN

ECONOMICS

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

DOCTOR OF PHILOSOPHY

Approved

Dakshina G. De Silva
Chairperson of the Committee

Amyn M. Amlani

Robert P. McComb

Accepted

John Borrelli
Dean of the Graduate School

December, 2006

ACKNOWLEDGEMENTS

I am deeply indebted to Dr. Dakshina G. De Silva, who, as the chairperson of my dissertation committee, has played an instrumental role in the completion of this project. His clear vision and invaluable professional knowledge have been the guiding lights throughout my entire research and writing process. I could not have done this without his support, and I could not have asked for a more compassionate, inspiring, motivating, and brilliant mentor and supervisor. I also gratefully acknowledge the contributions of Dr. Amyn M. Amlani. Without his constant supervision and clarification of the data, this dissertation would not have come into existence. His expertise in the field of audiology has helped shape the final product. In addition, I sincerely thank Dr. Robert P. McComb. His insightful comments and constructive suggestions have significantly improved the quality of this research. His gentle smiles, like rays of sunshine, always warm my heart.

I would like to thank the Department of Speech-Language and Hearing Clinic for allowing me access to its data. My appreciation goes especially to Ms. Dora T. Cortez, Ms. Diana A. Del Toro, and Ms. Mary Guadalcazar. I thank the Graduate School for its financial support during the past summer. I also graciously acknowledge the Department of Economics and Geography for its financial support with special thanks to Dr. Joseph King, Ms. Rosie Carrillo, and Ms. Staci Germon.

I would also like to extend my heart-felt gratitude to my colleagues, Ms. Zainah Arabyat, Mr. Michael Everett, Mr. Benhua Yang, and many others for their friendship and encouragement. I thank my professors, Dr. Klaus G. Becker, Dr. Thomas L. Steinmeier, and Dr. Terry von Ende. I thank ALL.

TABLE OF CONTENTS

3.3 Data

3.4 Empirical Model and Estimation

IV. THE IMPACT OF PAYMENT METHOD ON HEARING AID SELECTION

4.3 Data

4.4 Empirical Model and Estimation

V. A HEDONIC PRICE ANALYSIS OF HEARING AID TECHNOLOGY

5.3 Data

ABSTRACT

The hearing loss population has been increasing consistently, yet the market rate of hearing aid penetration has remained relatively stagnant. This research is an in-depth study of the risk factors associated with hearing impairment using patient profiles and audiograms. Furthermore, it explores how demographic and socioeconomic factors influence hearing aid consumers' purchasing decisions and analyzes the impact of technology on the price of hearing aid.

The study consists of three empirical essays. The first essay uses a probit model with marginal effect to determine the sources of hearing loss. Findings indicate that age, gender, ear infection, and diabetes are the most critical factors in predicting adult hearing loss. The results from the ordered probit models imply that these same factors are likely to result in a higher degree of hearing loss.

The second essay employs two separate multinomial logit models for the estimations of hearing aid style and signal processing scheme. Results suggest that consumers with financial stability are prone to select the more stylish hearing aids. There is a negative relationship between hearing aid procurement and payment method.

The third essay examines how functional and technical characteristics of hearing aids affect prices using a conventional hedonic price method. Empirical findings show that the style and signal processing scheme of the hearing aid are the two most important determinants of the wholesale prices in the hearing aid market. On average, the price-cost margin for a typical dispenser is .352.

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

1.1. Introduction

The hearing loss population in the United States (U.S) has reached a record-high of 31.5 million according to a most recent market estimate (Kochkin, 2005). Yet market penetration rate for hearing aids has remained stagnant at a relative average of 20.00%[1] throughout the last twenty years. Previous research has suggested that poor market penetration stems from a number of factors such as product quality, problems in fitting, acclimatization effects, and the perception of stigma attached to wearing a hearing aid on the consumers' end (Lee and Lotz, 1998). It is noteworthy that the price of hearing aid seems to play only a minor role in penetration, as suggested by the low price elasticity of demand (Lee and Lotz, 1998; Amlani and De Silva, 2005). In spite of this, there clearly exists a strong potential for growth in hearing aid sales as the number of the hearing-impaired continues to increase.

Thus far, no prior research has examined the relationship that exists between hearing aid procurement and payment method. In addition, purchasing decisions may be affected by age, gender, and employment status. At the manufacturer level, it remains unknown how the various electro-acoustic features of hearing aid affect prices. Hence, this research provides some insight into the factors that might influence market

---

[1] In 1980, the market penetration rate was 17.50%. It increased to 22.20% in 2001 (Amlani and De Silva, 2005). The most recent market survey estimates that the hearing aid market penetration has reached 23.60% as of 2004 (Kochin, 2005).

penetration by investigating consumer purchasing behaviors, manufacturer pricing strategies, and dispenser markups within the hearing aid industry.

1.2. Significance of the Study

A prominent feature of the hearing aid industry is its distinct character of production differentiation. Understanding the impact of product variation on consumer behaviors, manufacturer wholesale prices, retail prices, and price-cost margins at the distribution level is the key to comprehending the hearing aid market.

While studies have examined market power, markup factor, and prices for industries such as breakfast cereal (Bresnahan, 1996, 1997; Hausman, 1996, 1997; Nevo, 2001) and computed tomography scanner (CT) (Trajtenberg, 1989), there is no research published showing their impact on the hearing aid industry. This study, therefore, sets precedence for studies on the hearing aid industry. More importantly, it is the first study that attempts to examine the effects of various private and third-party payments on hearing aid purchasing decisions. Another important aspect of this research is that it uses patient profiles and audiograms to determine the sources of hearing loss.

1.3. Objective of the Study

The present study covers a broad range of topics ranging from risk factors of hearing loss to consumer behaviors in the end-users' market and to the price of hearing aid technology. One central motivation of this research is to investigate factors that might contribute to the discrepancy between the growing hearing-impaired populations and the relatively stagnant penetration rate within the hearing aid market. An equally important motive is to determine the impact of technology on hearing aid prices. These tasks are studied partly by analyzing the pricing structures within the industry from two perspectives: the wholesale and the retail markets. There are three keys players in the markets: hearing aid manufacturers, dispensers, and end-users. The specific objectives of this study are to:

1. Investigate the risk factors associated with adult and child hearing loss;
2. Assess the magnitude of impact those potential risk factors on hearing impairment;
3. Explore how demographic and socioeconomic factors affect consumer behavior in the hearing aid retail market;
4. Provide detailed retail and wholesale price analyses for both consumers and dispensers;
5. Evaluate the role of technology, i.e., to determine which functional and technological components have the greatest influence on manufacturer wholesale prices in the secondary hearing aid market; and
6. Estimate the "market shares" for manufacturers included in the study and to compute the price-cost margins for a typical hearing aid retailer.

1.4. Delimitation of the Study

As in any empirical study, data constitute an integral part of the research process. It is especially the case for this study, where the data utilized have laid the foundation for all the subsequent analyses.

The data collection process for this project underwent two stages. The initial phrase started from mid-December 2004 and continued till mid-January 2005. A total of 776 case history forms and 1426 audiometric observations were acquired in this short one-month period. The time of the data spans from January 01, 2001 to May 31, 2005, roughly a period of 53 months. An ensuing effort was made to collect the relevant pricing data from May 2005 to the end of August, 2005. This time the data emphasis was on hearing aid prices and product features of all hearing aids purchased during the 53 months under study. The final pricing data consist of 254 hearing aid observations for the period of June 01, 2001 to May 31, 2005. The uniqueness of this dataset is that it contains a detailed description of the various functional and technical features of each hearing aid procured and the different payment method used by buyers. It also contains the wholesale and retail prices for each specific transaction, including manufacturer-to-dispenser discounts and other miscellaneous charges. All data utilized in this research were acquired from a West Texas audiological clinic.

1.5. Results of the Study

This dissertation is comprised of three empirical essays, together addressing the specific objectives listed above. The analytical portion of the first essay attempts to achieve the specific objectives one and two. It relies on original patient profiles and audiograms to determine the risk factors associated with hearing loss. Results from the probit estimations indicate that age, gender, a history of recurrent ear infections, and diabetes are, by far, the most critical factors in predicting adult hearing loss. These same factors are found to be associated with a higher level of hearing loss as implied by the ordered probit outcomes. The child probit models suggest that chronic ear infection and drainage may be potential sources of hearing loss in children. Summary statistics for this portion of the study show that more than 80% of adult patients were diagnosed with some degree of hearing loss, yet hearing aid purchase intent was much lower. As mentioned earlier, there are many factors influencing hearing aid purchases; for instance, the degree of hearing loss and product quality. Customers' perception of the instruments, payment method, and their financial status can also impact purchasing decisions.

The second essay, entitled, "The Impact of Payment Method on Hearing Aid Selection," addresses how demographic and socioeconomic factors affect consumers' choices when procuring a hearing aid. The study utilizes 254 hearing aid pricing and product observations obtained from the same audiological practice. Independent variables include age, gender, actual retail price paid by the patient, and insurance and occupational dummies. Hearing aid style and signal processing scheme are the dependent variables. Summary statistics and the estimation results from the conventional multinomial logit (MNL) analyses show that buyers place more value on the size of the hearing aid rather than technology. Specifically, findings suggest that consumers with relative financial security are prone to select the more costly and aesthetic hearing aid styles. This demonstrates that consumers often take "vanity" into consideration when procuring a hearing aid. For both the style and processor regressions, a negative correlation between hearing aid procurement and payment dummies was found. The actual retail price paid by patient, in contrast, has a slightly positive impact on consumer behaviors.

The third essay, entitled "A Hedonic Price Analysis of Hearing Aid Technology," studies how technological components affect the prices of hearing aids using a traditional hedonic pricing method. The main goals of this essay are to: (1) determine those functional and technological features having the greatest influence on manufacturer-based prices in the hearing aid industry, and (2) analyze the price-cost margins at the distribution level. Results indicate that signal processing scheme and style are the two most important determinants of hearing aid prices. Other technical characteristics – such as directional microphone and noise cancellation features – are also positively related to price. The average price-cost margin for this clinical practice is .352.

1.6. Organization of the Study

This dissertation is organized as follows: Chapter I contains an introduction to the study. It highlights the purpose of the research and provides a brief insight into the six objectives of how the hearing aid market is being studied. Chapter II is a review of related literature on the hearing aid industry, which also includes a concise description of standard product types. Chapter III, IV, and V are the previously discussed empirical essays. Chapter VI contains the limitations, implications, and conclusions of this study.

CHAPTER II

LITERATURE REVIEW

2.1. Introduction

The hearing aid industry has been in existence for over 150 years, beginning with the establishment of the first manufacturing plant in 1847[2] by Siemens Hearing Instrument, Inc. Currently, there are almost 200 firms worldwide that manufacture hearing aids. Yet due to their small scale, local orientation, and the lack of sophisticated technology to produce functional products, many of these companies are virtually nonexistent (Lee and Lotz, 1998). For manufacturers having a larger market share, the present industry structure can be described as a "fragmented" oligopoly; i.e., lack of a dominant company. In terms of geographical location, most manufacturers are situated in Minnesota, North America and Denmark.

2.2. Hearing Aid Standard Product Types

A hearing aid is an electro-acoustic device designed for sound amplification and serves as a treatment form for individuals having sensorineural hearing loss (i.e., hearing loss that cannot be corrected by a medical procedure). The two main elements that define a hearing aid are the signal processing scheme and style. There are four[3] types of hearing aid style: (1) behind-the-ear (BTE), (2) in-the-ear (ITE), (3) in-the-canal (ITC), and (4)

---

[2] Before 1900, Siemens Hearing Instruments, Inc. manufactured acoustic devices. With the discovery of electricity in 1900, it began to make electrical devices.

[3] Body aid is not examined in this study; see Chapters IV and V.

completely-in-the-canal (CIC). The three signal processing schemes are: analog-adjustable (AA), analog-programmable (AP), and digital-programmable (DP) or digital signal processing (DSP). Hearing aid manufacturers are able to assemble 12 different types of hearing aid by alternating the combinations of these styles and processors. These 12 standard products are named as: AA-BTE, AA-ITE, AA-ITC, and AA-CIC; AP-BTE, AP-ITE, AP-ITC, and AP-CIC; DP-BTE, DP-ITE, DP-ITC, and DP-CIC.

2.3. Literature Review of the Hearing Aid Industry

Lee and Lotz (1998) provide the most comprehensive report on the history and structure of the hearing aid industry. The purpose of their study was to examine the stability factors within the industry by covering the entire value chain, including end-users, dispensers, manufacturers, and suppliers. They suggested that the systematic character of hearing aid technology and the sticky distribution channel are the most importance factors influencing stability. Hearing aid customers and suppliers also contribute to stability through their perception of stigma and the difficulty of making significant technological improvements in hearing aid components. Their analysis further demonstrated that the demand for hearing aid is price-inelastic.

With respect to hearing aid manufacturers, Lee and Lotz (1998) characterized them as a “friendly oligopoly.” This expression signifies the friendly coexistence of a number of important, competing hearing aid manufacturers, which, as noted, stems from a defensive attitude, since price reductions and advertising have little effect on market shares.

A number of studies have attempted to determine the effects of style and signal processing scheme on hearing aid prices. Hetu (1996) points out that style is an important factor influencing prices when one considers the perception of stigma resulting in a denial of hearing problems. Kochkin (2002) also finds that hearing aid purchasers tend to view devices more positively as their sizes decrease. However, a counter-active problem with less visible hearing aids is that they continue to be more expensive (Kirkwood, 1999, 2000, 2001; Strom, 2003). Technology is another factor that resulted in the high costs of hearing aids. Kochkin (2003) demonstrates that technology does make a difference on customer satisfaction. The more technologically advanced DP product lines are priced at higher levels compared to AA and AP lines. This finding is supported by Punch (2001), who showed that newer technologies are linked with higher prices. Furthermore, his results indicate that newer technology tends to be priced at levels of old technology over time.

Purchase intent has also been associated with customer satisfaction by researchers. It is dependent on several factors such as the severity of hearing loss, reliability of the hearing aid, perceived handicap, motivation, and personality of the wearer (Cox et al., 1999; Hume, 1999; Cox and Alexander, 2000). The ability to assess consumer purchase intent is important because it helps to understand the poor market penetration rate of hearing aids.

More recently, Amlani and De Silva (2005) have examined the effects of business cycle and the impact of the Food and Drug Administration's (FDA) regulation on the hearing aid industry. Their findings suggested that as income increased, demand increased. They also found that the demand function within the hearing aid industry was inelastic. Furthermore, the supply function indicated that a recessionary period reduced the manufacturing and dispensing of hearing aids by about six percent. The authors further illustrated that with the implementation of FDA's regulation policy on advertising, there was a decline in the number of hearing aids being supplied. Kirkwood (1994) reported similar results on the demand side by attributing a decrease in hearing aid sales to a recessionary economy and FDA intervention.

2.4. Conclusion

The hearing aid market for manufacturers can be characterized as an oligopoly despite the large number of firms existing in the market. This is because most of these companies are small-scaled and locally-oriented and hence, do not possess the advanced level of technology to make functional products (Lee and Lotz, 1998), which prevented them from gaining any considerable market influence. Consequently, the top 9–10 manufacturers have emerged as the dominant players in the market, covering approximately 80% of the global market. There are few empirical studies conducted on the hearing aid industry, with existing findings providing only an idea of how the market truly functions.

CHAPTER III

THE CAUSES AND THEIR DEGREE OF IMPACT ON HEARING LOSS

3.1. Introduction

Hearing loss is one of the most prevalent health chronic disorders in the United States (U.S.) and ranks third as the most common condition facing the aged population today.[4] Like blindness, hearing impairment is not merely a health problem, but has rather broad social implications. Researchers find that hearing loss contributes to strained relationships with family and friends, depression, and even a decline in the quality of life.[5] The most recent market survey reveals that the number of hearing-impaired population in the U.S. has reached an estimate of 31.5 million as of 2004 (Kochin, 2005). Furthermore, the same survey predicts that this figure will top 40 million in less than one generation. Given the seriousness of the problem, it certainly requires a closer examination.

In this chapter, the results of a study that assesses those health factors closely linked with hearing loss are reported. Although the causes of hearing impairment have been widely established, the impact of those factors on hearing disability has not yet been examined empirically. This research is unique in the sense that it utilizes a set of original data, which comprises patient profiles and audiometric data, for its investigation. The

---

[4] www.nidcd.nih.gov/health/hearing/hearingaid.asp.

[5] www.seniorjournal.com/NEWS/Health/6-06-02-StudyFindsHearing.htm.

self-compiled dataset was first applied to a simple probit model in an attempt to determine those factors most associated with a hearing loss. Next, an ordered probit model was used to estimate the relationship between the degree of loss and those potential causes. Estimation results indicate that age, gender, a history of ear infection, and diabetes are, by far, the most critical sources of hearing loss in adults. These same factors also contribute to an intensified level of hearing deficiency.

The remainder of this chapter is organized as follows: section 3.2 briefly describes the types and degrees of hearing loss, section 3.3 provides a narrative summary of the data, section 3.4 presents the empirical analysis, and section 3.5 is the conclusion.

3.2. Type and Degree of Hearing Loss

There is a general consensus within the audiological profession a propos the reasons of hearing disorder. The interested public can find information regarding these causes and preventions through many channels, such as the internet and hearing journals. Yet, these well-established factors are complicated and have an extensive breadth, which range from aging, ear infection and blockage to illness, medication, and noise.[6] Accordingly, hearing loss can be classified into three types: conductive, sensorineural, and mixed. Conductive hearing loss occurs when sound is abnormally transmitted through the outer ear, middle ear, or both, to the inner ear. It may result in a mild or moderate hearing loss and can be caused by frequent ear infections, buildup of earwax, or collection of fluid in the middle ear. It can also be triggered by ostosclerosis, a condition

---

[6] www.en.wikipedia.org/wiki/Hearing_impairment.

in which the middle ear becomes dysfunctional due to an irregularity in the surrounding bone structure. Conductive hearing loss is often reversible through medical intervention. The second type, sensorineural hearing loss, stems primarily from factors such as aging, loud noise, virus, and genetics. It has been suggested that protracted illnesses and certain painkiller medications can, too, have a negative effect on hearing (Sataloff and Sataloff, 1993). Sensorineural hearing loss is usually permanent and often times will increase in severity over time. Mixed hearing loss, on the other hand, refers to a combination of conductive and sensorineural loss. This means that a problem occurs in the outer ear, middle ear, or both, and the inner ear.

Aside from assorting hearing sensitivity according to various causes, audiologists also categorize hearing impairment by the degree, or severity, of loss. The severity of hearing loss is measured by the degree of loudness a sound must attain before being detected by an individual. Thus, hearing loss can be quantified into the following five categories according to their corresponding decibel (dB) ranges: mild (26-40 dB), moderate (41-55 dB), moderately severe (56-70 dB), severe (71-90 dB), and profound, which is at 91 dB or greater.[7]

3.3. Data

3.3.1. Data Description

Data employed in this chapter were assembled from an audiology clinic located in West Texas. The study investigates the causes of hearing impairment for two age groups:

---

[7] www.houseearclinic.com/hearingloss.htm.

(a) adults who are 18 years or older, and (b) children from birth to 17 years. A sample of 452 case history forms and 886 audiometric observations were collected for adults. For children under 17 years, 334 cases and 541 audiometric observations were acquired. All audiometric testing was performed by audiologists. Case history information, in contrast, is the patient's personal health profile, and is often completed by patients at the time of their clinical visits or can be completed ahead of the appointed testing time by requesting a copy of the form in advance. Due to the inherent characteristics pertinent to the distinct age groups, adult and child case forms have completely different entries. Consequently, for reasons of clarity, the two forms will be described and presented in separate sections as outlined below.

Each adult case history form was of uniform presentation, which allowed for a relatively easy recount and summary of data. For the child form, however, the process was slightly more complicated. Prior to the year 2002, the clinic used one case history form, hereafter termed the "old form," for all children aged from 0 to 17 years. Clearly, this practice was inadequate since children go through various stages of development. In the latter half of 2002, the clinic replaced the "old form" with two "new" forms designed specifically for two subgroups: birth to age 4 years and ages 5 to 17 years. This transition added difficulty to the analytical process because of the inconsistencies between the "old" and "new" forms. For the purpose of this study, I will only provide a narrative of the new forms as given in Appendix A. Relevant summary statistics regarding children are also supplied in Appendices A and B.

The following sections depict the general contents for the adult case history form and audiogram.

Adult case history form. The adult case history form has six sections: (I) Personal Background, (II) Subjective Hearing History, (III) Otology History, (IV) Family History, (V) General Medical History, and (VI) Communication History.

The first section (i.e., personal background) identifies the patients' personal background by asking the following questions: name, gender, birth date, address, telephone number, present and former occupation, referral source, and file number. This section also asks for the patient or guardian to complete a rationale for visiting the clinic. Of the variables aforementioned, only genders, year of birth or age, location of residence, occupation, and reason for visit are used in the data analysis.

The second section of the case history form asks the patient to provide a subjective history of his or her hearing. Questions include whether: (1) the patient has a hearing problem; if yes, which ear, time of onset, and suspecting cause; (2) s/he has ever had a hearing test, and if so, when and the results; (3) the patient wears a hearing aid(s); if yes, how long has the device been used, patient's satisfaction level, and who recommended the device; (4) the patient has any intention to purchase a hearing aid, and (5) the patient experiences difficulty hearing in certain situations, such as on the telephone, with background noise, or when watching television, et cetera. The final three subsections further inquire about the presence of noise, dizziness, and aural fullness or pain in the ear(s). For each of the eight questions, the patient is asked to respond with either a yes or no response. If a question yields a positive response, additional inquiries are pursued to determine (1) which ear has the problem: right ear, left ear, or binaural? (2) the time frequency: always, often, or sometimes, and (3) length of the problem and potential cause.

The subsequent three sections – patent's otologic, family, and medical histories – are essential to determining those factors initiating hearing loss. Section three of the adult form examines the patient's otologic history through four questions: (a) Has the patient ever experienced repeated ear infections? (b) Is the patient presently being treated by an ear specialist? (c) Has the patient undergone any otologic surgery? and (d) Was the patient exposed to excessive noise levels? Patients are also being asked to record their own judgments about the effect of noise on hearing. The fourth section contains a single question relating to family history of hearing loss. The patient is asked whether any blood relative has experienced any hearing loss, and if there is, which family member and the potential cause.

General medical history constitutes the fifth section of the adult case history form. Eight questions are asked: (1) patient's present health status; (2)-(4) ask whether the patient has any diabetes, high blood pressure, and heart or kidney disease. If yes, what treatment plans are used and the age of onset. Question (5) asks patients to indicate which 19 diseases or symptoms they have had previously (e.g., measles, scarlet fever, cancer, head injury, jaundice, rheumatic fever, TB, polio, pneumonia, allergies, malaria, chickenpox, meningitis, headaches, chronic colds, mumps, diphtheria, venereal disease, epilepsy, and other). The last three queries request the patient to relate their prescriptive medication history, smoking habits, and additional disabilities or significant medical problems not specified in (5).

The final section, termed “communication history,” is made up of four questions: (1) Does hearing loss interfere with communication? (2) Have you been enrolled in an aural rehabilitation program? Did it seem to help? (3) Have hearing problem affected your relationships with family or friends? (4) Are you able to use lip-reading efficiently?

Audiograms. Audiometric data for both adult and child are obtained and used by an audiologist to diagnose the type and severity of a hearing loss. They are recorded onto an audiogram, which represents intensity as a function of frequency. Specifically, the intensity of sound – measured in decibels (dB) for Hearing Level (HL) – is recorded at the frequency levels of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz for both the left and right ears. From this data, a high-frequency pure-tone average (PTA) – or average amount of hearing loss at the frequencies of 1000, 2000, and 4000 Hz – can be computed. This calculation allows the audiologist to make sensitivity diagnosis and assess the degree of loss. These three frequencies were used in lieu of the traditional 500, 1000, and 2000 Hz data points because most listeners who obtain hearing aids are more likely to experience reduced hearing sensitivity in the higher frequencies (Dillon, 2001). In general, when the PTA exceeds 25 dB HL, it is diagnosed as a hearing loss.

The next step is to examine the degree or severity of the loss. In terms of severity, hearing loss can be categorized as mild, moderate, moderately severe, severe, and profound. For their corresponding decibel ranges, please refer to the footnote.[8] Results from these audiometric data were used chiefly to determine a patient's hearing aid candidacy. Besides the pure-tone averages, performance from speech reception thresholds, word-recognition scores, and tympanometric data was also used to define the type, degree, and configuration of loss.

3.3.2. Summary Statistics

The following is a detailed description of the summary statistics for the adult dataset. This portion of the data consists of 452 adult patients along with 886 ear observations acquired for the period of January 01, 2001 – May 31, 2005.

Tables 3.1 and 3.2 portray adult demographics. The statistics included in the columns of Table 3.1 were obtained directly from patient profiles or case history forms. There existed a slight discrepancy in gender, in which the number of visits made by male patients exceeded that of the female by 8.84 percent. Table 3.1 exposes that the number of seniors aged at least 60 years accounted for 62.17% of all the adult visits during the period under study. The clinic received fewer visits from patients under age 50, and most visits from adults who were 70-79 years old. A sum of sixteen visits was made by patients who were 90 or older.

In terms of employment status, retirees and people employed (including self-employed) represented 74.11% of the sampled population. Adult demography was also

---

[8] Corresponding decibels (dB) ranges for degree of hearing loss are: (1) mild (26-40 dB), (2) moderate (41-50 dB), (3) moderately severe (56-70 dB), (4) severe (71-90 dB), and (5) profound (>91 dB).

imprinted with a distinct sense of locality, in which 70.80% adults were urban residents while only 29.20% came from the surrounding rural area. As to the various reasons that prompted their visits, approximately 82% of patients expressed explicitly that they were concerned about hearing loss, hearing aid fitting or repair, or ear noises.

In Table 3.2, the author provides adult demographic and ear characteristics summarized from the 886 audiometric observations. This segment of the data was reproduced from audiograms documented by audiologists for the four years and five months under study. The age and gender structures are comparable to those in Table 3.1. Left and right ears were almost equally observed by audiologist as revealed by column 2 in the table. Out of the 886 ears examined, approximately 83% of the sampled adults were diagnosed with a hearing loss. The number of people with intensified loss was quite high. Nearly 61% of the diagnoses could be placed in the categories of moderate to moderately severe loss. The average pure-tone threshold is 52.35 dB, indicating that moderate loss is more widespread among adults. Column 1 also indicates that middle ear function is within normal limits for 610 out of the 886 ears. Other relevant average values include word-recognition score (WRS) and speech presentation level (PL).

Subjective history reflects a person's own view of his hearing well-being and is recapitulated in detail in Table 3.3. An overwhelming 95.58% of adult patients responded definitely when being asked "Do you have any problem hearing?" The majority of cases displayed a bilateral loss, as indicated by the 321 out of 452 positive responses. The table also indicates that most patients considered their hearing loss to be gradual. As regards the sources of loss, some patients chose not to reply. For those who answered, the three most suspected factors were work-related noise, illness/medication, and age, respectively. A slight number of adults suspected their source of hearing impairment to be of heredity or congenital defects.

Over 74.56% of patients disclosed that they had a hearing test in the past, but only about five percent reported positively about their test results. With respect to hearing aid history, 125 out of 452 respondents had worn or used to wear a hearing aid. However, as the number demonstrates, their dissatisfaction rate ranked as high as 49.60%. Some hearing aid users even remarked on the form's margin that the hearing aid(s) had aggravated their hearing loss. Others simply stated that they "have a set of instruments but do not use them." Patients were also asked as to whether or not they had considered purchasing a hearing aid if they did not already possess one. If the number of people who own and used to own a hearing aid is discounted, then the hearing aid purchase intent rate among adults is approximately 66%.

Table 3.3 provides strong evidence in support of patients' claims of their hearing deficiency. Over 95% reported having trouble hearing in different background surroundings. Tinnitus (noises in the ear), dizziness, and fullness or pains in ear were also recurrent concerns. The statistics for these are 64.60%, 50.00%, and 33.85%, respectively.

Tables 3.4, 3.5, and 3.6 outline patients' otologic, family, and general medical histories, which allow the researcher to assess the potential origins of hearing impairment. In Table 3.4, 104 respondents reported that they had incidences of repeated ear infections during their lifetime, and almost 46% of these infections were binaural. Ear surgery is one of the methods available for hearing loss correction in the outer and middle ear, and column 2 shows that such a procedure was not a popular choice for the roughly 30% of individuals who experienced conductive type losses. As indicated here, only 10.40% asserted that they had surgeries performed on one or both ears.

Noise-induced hearing loss (NIHL) is a common cause of hearing impairment. Table 3.4 discloses that nearly 58% adult clinical visitors were exposed to excessive noises. These noises included hunting or military gunfire, factory noise, loud music, noises specified by the clinical patients, and so on. Practically all of the noises listed were related to the work environment. Noise exposure is anticipated to have a direct influence on hearing loss. Out of the 260 patients who received excessive noise exposures, 60.00% declared that noise had in some degree negatively affected their hearing capacity.

Family history of hearing loss is detailed in Table 3.5. Almost 48% of adult patients announced that they had one or more blood relative(s) with some degree of hearing loss. They attributed the causes to commonly suspected factors like aging, noise, illness, and medication. Only about five percent stated that it was due to hereditary or birth defects. In fact, research finds that genetic hearing loss accounts for at least 50% of all hearing disorders (Ruben, 1996).

Table 3.6 is a general summary of health characteristics for adult patients included in the study. It is interesting to note that although many of these patients had one or more medical problems, they still insisted that their health condition was good. As illustrated in column 2, 65.49% of the sampled adults believed that their health status was above average, even though 54.42% knew clearly that they may have had diabetes, high blood pressure, or heart/kidney disease. Diabetes is one of the major risk factors for hearing loss (Wackym and Linthicum, 1986). The table reveals that 80 out of the 452 adults sampled had this type of illness. High-blood pressure and heart/kidney diseases also prevailed among adults, as shown by the statistics. The percentage of people with other health problems, such as asthma and physical disabilities was also alarming at over 82%. Due to the high ratio of people with medical conditions, the rate of medication is expected to be high. Column 2 shows that approximately 76% of adults were regularly medicated.

Table 3.7 presents the statistics for patients' communication history. Approximately 81% maintained that hearing loss interfered with their communication, and 262 patients responded positively that hearing problem had affected their relationships with family and friends. Clearly, as suggested in the introductory paragraph, hearing loss is not just a health issue but also a societal problem. Social isolation resulted from hearing impairment can generate grim consequences such as depression and a general decline in the well-being of a person.

For summary statistics on children, refer to Appendices A and B.

3.4. Empirical Model and Estimation

3.4.1. The Empirical Model

The study searches for those factors that may predict hearing loss. Data for this chapter were acquired from retrospective patient profiles and audiograms in a West Texas audiolgocial clinic. A simple probit model was used to provide results. The empirical model is written as:

$$\Pr(Y = 1|X = x) = \Phi\left(x'\beta\right) \quad (1)$$

where Φ is the cumulative distribution function of the standard normal distribution. The vector $\left(x'\beta\right)$ is called the probit index and the parameter β is typically estimated by a maximum likelihood function. The dependent variable for the d-probit model is hearing loss, which was obtained from audiograms by calculating the pure-tone averages (PTA) using the intensity levels at 1000 Hz, 2000 Hz, and 4000 Hz.

Base specification for the adult regression includes age, gender, otologic, family, and medical histories. These explanatory variables are all dummies, with age as the only exception, which is continuous. Otologic history of a patient indicates whether s/he has experienced any ear infections, special ear treatments, ear surgeries, or exposures to excessive noise. Family history investigates the ear or hearing problem of a specific member of the family, including grandparents, parents, and/or other close blood relatives. The three major medical problems specified by the case history form are diabetes, high blood pressure, and heart/kidney diseases. The base model was then expanded to include the effects of specific noise exposures, illness, and genetics on hearing loss.

The same set of independent variables was utilized in the adult ordered probit models to estimate their relationship with the degree of hearing impairment. Here, the degrees or severities of hearing loss were categorized in an ordinal manner as (1) normal (< 25 dB HL), (2) mild (26-40 dB HL), (3) moderate (41-55 dB HL), (4) moderately severe (56-70 dB HL), (5) severe (71-90 dB HL), and (6) profound (> 91 dB HL).

3.4.2. Estimation Results

In order to estimate the proposed models, the case history forms and audiograms were merged using the patient's ID. The data merger resulted in a total of 866 adult observations for the period of January 01, 2001 – May 31, 2005. The following is a detailed explanation of the model outcomes.

Table 3.8 exhibits the estimation results for the adult d-probit models. Column 1 is the base model. The coefficient for age is positive and statistically significant, suggesting that natural aging is a leading cause in adult hearing loss. This is clearly understandable since auditory nerves lose their keenness as a person approaches his twilight years. When considering gender, more males tend to have hearing loss compared to female patients. This finding supports the notion that men are prone to experience loud noises in their occupational and recreational environments. However, the correlation coefficient between gender and noise is only 44.58%; hence, the data reported here shows an insufficient connection between gender and excessive noise exposure. One possible explanation for this may be that female patients under-reported the amount of time they were exposed to loud sounds.

Ear infection and illness are prime contributors to hearing loss. The coefficient for ear infection is .051, denoting that the probability of getting hearing loss from each additional contact with ear infection is about five percent. Analogous interpretations can be made on behalf of major health problems. This is because ear infections can result in lesions in the middle ear, causing damage to the eardrum and other essential organs inside the ear. At the same time, other diseases may affect blood supply, which cause fluctuations in the amount of nutrients that the organ of coti receives (Martin, 1991). Medication, on the other hand, shows no impact on hearing loss although it was reported that certain medicine such as aspirin could contribute to hearing loss (Martin, 1991).

To assess the risks associated with loud noise, the model is expanded in column 2 to include 11 types of noise, which were specified as gunfire, explosions, factory noise, power tools, heavy equipment, motorcycles, lawnmowers, aircraft, loud music, military tanks, and other noises specified by the clinical patients. Ceteris paribus, the only noise variable that is statistically significant is “loud music” in this model, whose sign indicates a negative correlation with hearing loss. This is somehow puzzling, since researches find that loud sound is one of the primary reasons people suffering from hearing loss (Martin, 1991; Sataloff and Sataloff, 1993). A possible explanation may be stated as follows. Because noise-induced hearing loss (NIHL) has become a matter of tremendous concern, employers and individuals have taken obligatory and voluntary actions to prevent NIHL, either by providing and wearing hearing protections or by keeping noise exposures to acceptable values (Ward, 1984). It should be pointed out that the above finding is in contrast with that of Table 3.4, where 34.51% of the 452 patients reviewed responded positively that loud noises had affected their hearing negatively. Nevertheless, hearing protection devices may have reduced the effects of noise exposures on ears, but it is not known how effectual they are. Alternatively, the dataset itself may have contributed to the abovementioned erroneous result, since some of the patient profiles were not filled by patient themselves.

Similar expansions were made for Models 3 and 4, where the variables "family history" of hearing loss and "major health problems" were explored in relation to the effects of heredity and illness. In column 3, when controlling for family members, the model yielded mixed results. The variable "grandfather" is statistically significant but with a negative sign. Thus, for this particular group of adults, the model seems to hint that genetic effect may be ruled out. The three major health problems specified by the audiological clinic, as shown in Model 4, are diabetes, high blood pressure, and heart or kidney disease. All three variables are positively related to hearing loss, but diabetes has the greatest impact. This finding is supported by clinical research, in which it was found that diabetic patients had significantly more hearing loss than the normal control group (Wackym and Linthicum, 1986). In both of the regressions, age, gender, and ear infection remain statistically significant and positive.

Model 5, presented in column 5 of Table 3.8, is the full model, which includes 11 noise types, 11 family members, and 3 disease categories. When considering the effect of various noise exposures on hearing, the model again generated mixed results. Exposures to aircraft and loud music showed a negative correlation with hearing loss. However, a history of driving a military tank does seem to imply a positive association with hearing impairment. In terms of family history, the results reveal that some relatives are more likely to pass or inherit the hearing loss genes than others.

Table 3.9 provides the estimation results for the ordered probit models, with the degree of hearing loss as the dependent variable. Due to the increasing nature of the ordered outcomes, the parameter set, β, has a straightforward interpretation: positive signs indicate a severe degree of hearing loss as the value of the associated variables increase, while negative signs suggest the converse (Kockelman, 2001). The primary regression in column 1 indicates that age, gender, and a history of repeated ear infections are critical factors contributing to a heightened degree of hearing loss. In the remaining columns of Table 3.9, the variables noise, family history, and major health problems are expanded in a similar manner as in the d-probit models. The goal is to control for the effects of noise, genetics, and disease on the severity of hearing loss. Table 3.9 also presents the estimation results for the full model. After controlling for otologic factors, noise, family history, and diseases, it revealed a slight deviation from the previous regressions. The interpretations of the full model will be presented shortly aided by its marginal effects.

The threshold parameters, α, must also be taken into account when considering the magnitudes of the estimated probabilities and partial effects (Wooldridge, 2002). This is because the sign of the estimated coefficients in the ordered-response models does not always decide the direction of the effect for the intermediate outcomes. Thus, in order to determine the most likely severity level, one must compare the coefficients to the ranges between the various thresholds. Taking the variable "age," for example, its coefficient is .021 in the base model, and given the threshold parameters, .067, .551, 1.240, 2.058, and 2.711, one can easily compute its impact on the degree of hearing loss holding other variables constant.[9] The marginal effects on event probabilities are

---

[9] The probability events of having a hearing loss are calculated as follows:
$\mathrm{Prob}(y = 0) = \Phi(-x'\beta), \mathrm{Prob}(y = 1) = \Phi(\alpha_1 - x'\beta) - \Phi(-x'\beta),$

presented in Table 3.10 for the adult base model. With an one year increase in age, the probability of having normal hearing will decrease by .005 and the probability of having "moderately severe (y = 4)" hearing loss will increase by .003. This result indicates that hearing loss has a tendency to intensify as people get older.

The interpretation for the dummy variables is slightly different. If the patient is a male, then the chance of having normal hearing will decrease by .061, and that of having "moderately severe" loss will increase by .036, which implies a greater likelihood of the male gender acquiring a more severe level of hearing loss. The same reasoning can be applied to show that ear infection and possibly ear surgery may result in aggravated loss. The marginal effects of excessive noise and medication, in contrast, suggest erroneously that they have no impact on the degree of hearing loss. This troubling result may be the product of unreliable reporting of patients' medication history and noise exposures. Marginal effects for the noise, family, disease, and full models are relegated to the appendix (Tables B.6, B.7, B.8, and B.9). Table B.9 shows that instead of ear infection, special ear treatment and ear surgery may potentially raise the level of hearing impairment. Noise and genetic effects are shown to have no clear connection with respect to the severity of loss. This, as stated previously, may be attributed partially to data defect. In general, the model demonstrates that age, gender, and diabetes are highly correlated with the severity of hearing loss.

$\mathrm{Prob}(y = 2) = \Phi(\alpha_2 - x'\beta) - \Phi(\alpha_1 - x'\beta), \ldots, \mathrm{Prob}(y = 6) = 1 - \Phi(\alpha_5 - x'\beta).$

The marginal effects of explanatory variables on the probability of having a hearing loss are simply the partial derivatives of probability with respect to x.

The probit model with marginal effects and ordered probit estimation results for children are given in Tables 3.11 and 3.12. In Table 3.11, Model 1 (data from "new" form) shows that gender, medication, and a family history of speech problems are all statistically significant but do not affect hearing loss. Repeated ear infection is found to have a significant link with hearing loss for this group of children. The results from Model 2 (data from "old" form) are quite different, where now they reveal that male children have a higher chance of being hearing-impaired than their female counterparts. Column 2 also indicates that ear drainage may have been a potential source of hearing disorder for children using the old form.

Table 3.12 provides the estimation results for the child ordered probit models and their corresponding marginal effects are provided in Tables 3.13 and 3.14. Compared to Table 3.11, the magnitudes of the coefficients for both models in Table 3.12 are larger. Marginal effects of the explanatory variables for children who used the new forms suggest that ear infection may be more likely associated with an intensified level of hearing loss. For children included in the old form, gender is shown to have a direct and positive impact on hearing impairment; i.e., male children tend to have a higher level of loss compared to females. Similarly, ear drainages may have also contributed to a more severe level of hearing deficiency. No other significant differences are found.

3.5. Conclusion

The purpose of this empirical analysis is to determine the causes of hearing loss. A proprietary set of data with 866 observations indicates that age, gender, ear infection, and diabetes are all significant risk factors for adult hearing loss. The models presented mixed results with respect to the effect of noise and genetics on hearing loss for this particular group of adults. There is no conclusive finding with respect to the sources of hearing loss in children.

It is interesting to note that among the adult population, approximately 83% were diagnosed with a hearing loss using audiometric data, yet only slightly over 50% of patients would consider purchasing a hearing aid. The lack of enthusiasm for hearing aid procurement may depend on many factors, including the degree of loss, market price of hearing instruments, amount of insurance payments, and aesthetic considerations. This will be the subject for future analysis.

Table 3.1: Summary Statistics of Adult Demographic Characteristics from Case History Forms, January 01, 2001 – May 31, 2005

	Number of Patients (n = 452)	Percent of Total (%)
Gender		
Male	246	54.42
Female	206	45.58
Total observed for gender	452	100.00
Age group		
18-29	30	6.64
30-39	49	10.84
40-49	31	6.86
50-59	60	13.27
60-69	81	17.92
70-79	111	24.56
80-89	73	16.15
90-99	15	3.32
> = 100	1	.22
Unspecified	1	.22
Total observed for age group	452	100.00
Average age	62.63	
Employment status		
Employed	117	25.88
Self-employed	5	1.11
Unemployed and disabled	55	12.17
Homemaker	29	6.42
Student and child	14	3.10
Retired	213	47.12
Unspecified	19	4.20
Total observed for occupation	452	100.00
Rural or urban residence		
Urban	320	70.80
Rural	132	29.20
Total observed for location	452	100.00
State of residence		
Texas	438	96.90
New Mexico	14	3.10
Total observed for state	452	100.00
Reason for visit or principal complaint		
Hearing loss	254	56.19
Hearing test	32	7.08
Hearing aid	57	12.61
Ear fluid, infection, and noise	27	5.97
Dizziness, imbalance, and pressure	10	2.21
Other	15	3.32
No response	57	12.61
Total observed for principal complaint	452	100.00

Table 3.2: Summary Statistics of Adult Demographic and Ear Characteristics from Audiometric Data, January 01, 2001 – May 31, 2005

	Number of Observations (n = 886)	Percent of Total (%)
Gender		
Male	475	53.61
Female	411	46.39
Total observed for gender	886	100.00
Age group		
18-29	56	6.32
30-39	95	10.72
40-49	64	7.22
50-59	105	11.85
60-69	163	18.40
70-79	224	25.28
80-89	139	15.69
90-99	34	3.84
>= 100	2	.23
Unspecified	4	.45
Total observed for age	886	100.00
Ear		
Left	442	49.89
Right	444	50.11
Total observed for ear	886	100.00
Hearing loss diagnosis		
Yes	738	83.30
No	148	16.70
Total observed for diagnosis	886	100.00
Degree of loss		
Mild	110	14.91
Moderate	211	28.59
Moderately severe	242	32.79
Severe	115	15.58
Profound	60	8.13
Total observed for degree of loss	738	100.00
Tympanogram		
Type A	610	68.85
Type B	31	3.50
Type C	20	2.26
Type Ad	39	4.40
Type As	33	3.72
Not tested	153	17.27
Total observed for tympanometric data	886	100.00
Relevant average values		
Average age	62.80	
Pure-tone average	52.35	
Word-recognition score	73.72	
Presentation level	68.90	

Table 3.3: Summary Statistics of Adult Subjective Hearing History, January 01, 2001 – May 31, 2005

	Number of Patients (n = 452)	Percent of Total (%)
Do you have any problem hearing?		
Yes	432	95.58
No	20	4.42
Total observed	452	100.00
If yes, which ear?		
Left	41	9.49
Right	42	9.72
Both	321	74.31
Unspecified	28	6.48
Total observed	432	100.00
Suspected cause		
Age-related	23	5.32
Ear infection, wax, or fluid	13	3.01
Work-related noise	41	9.49
Birth defects and heredity	14	3.24
Illness and medication	36	8.33
Injury and accidents	6	1.39
Combination of factors	16	3.70
Unspecified	283	65.51
Total observed	432	100.00
Have you ever had a hearing test?		
Yes	337	74.56
No	115	25.44
Total observed	452	100.00
Have you ever worn a hearing aid?		
Yes	125	27.65
No	327	72.35
Total observed	452	100.00
If yes, are you satisfied with it?		
Yes	23	18.40
Sometimes	9	7.20
No	62	49.60
No response	31	24.80
Total observed	125	100.00
If not, have you ever thought about using a hearing aid?		
Yes	242	53.54
No	125	27.65
Already have one	77	17.04
Used to	7	1.55
Uncertain	1	.22
Do you have trouble hearing in any of these situations?	433	95.80
Do you hear any noises in your ears?	292	64.60
Have you had any dizziness?	226	50.00
Do you have a feeling of fullness or pain in your ears?	153	33.85

Table 3.4: Summary Statistics of Adult Otologic History, January 01, 2001 – May 31, 2005

	Number of Patients (n = 452)	Percent of Total (%)
Ever had repeated ear infections?	104	23.01
If yes, which ear?		
Left	12	11.54
Right	12	11.54
Both	47	45.19
Unspecified	33	31.73
Total observed	104	100.00
Presently being treated by an ear specialist?	49	10.84
If yes, for what reason?		
Hearing loss/aid	12	24.49
Ear fluid, infection, wax, and pain or pressure	8	16.33
Dizziness or vertigo	2	4.08
Noise	3	6.12
Routine checkup	1	2.04
Surgery	4	8.16
Other	3	6.12
Unspecified	16	32.65
Total observed	49	100.00
Ever had surgery on your ears?	47	10.40
If yes, type of surgery?		
Remove or place tube(s) in ears	13	27.66
Eardrum-related surgery	5	10.64
Cancer or tumor in ear(s)	3	6.38
Cochlear implant	2	4.26
Other and unspecified	24	51.06
Total observed	47	100.00
Ever been exposed to excessive noise?	260	57.52
If yes, type of noise?		
Gunfire (hunting or military)	98	12.47
Explosions	40	5.09
Factory noise	63	8.02
Power tools	113	14.38
Heavy equipment	107	13.61
Motorcycles	37	4.71
Power lawn mowers	109	13.87
Aircraft	44	5.60
Loud music	97	12.34
Military tanks	17	2.16
Other	61	7.76
Do you think that noise has affected your hearing?		
Yes	156	34.51
No	242	53.54
No response	54	11.95
Total observed	452	100.00

Table 3.5: Summary Statistics of Adult Family History, January 01, 2001 – May 31, 2005

	Number of Patients (n = 452)	Percent of Total (%)
Has any blood relative had a hearing loss?		
Yes	215	47.57
No	237	52.43
Total observed	452	100.00
If yes, what was the cause?		
Age	30	13.95
Birth defects and heredity	10	4.65
Noise	22	10.23
Illness and medication (ear infection, stroke, etc.)	23	10.70
Combination of factors	3	1.40
Unspecified	127	59.07
Total observed	215	100.00
If yes, what is your relation with the person?		
Father	90	22.06
Mother	75	18.38
Sister	38	9.31
Brother	48	11.76
Grandmother	23	5.64
Grandfather	35	8.58
Aunt	21	5.15
Uncle	28	6.86
Cousin	14	3.43
Child	23	5.64
Other relative(s) (grandchild, nephew, niece, etc.)	13	3.19
Total observed	408	100.00

Table 3.6: Summary Statistics of Adult Health Characteristics, January 01, 2001 – May 31, 2005

	Number of Patients (n = 452)	Percent of Total (%)
Perceived health status		
Excellent or superior health	32	7.08
Good health	264	58.41
Average	32	7.08
Poor	25	5.53
Very poor	2	.44
No response	97	21.46
Total observed	452	100.00
Major health problems		
Yes	246	54.42
No	206	45.58
Total observed	452	100.00
If yes, please indicate type of illness		
Diabetes		
Yes	80	17.70
No	372	82.30
Total observed	452	100.00
Average age of onset	55.55	
High blood pressure		
Yes	195	43.14
No	257	56.86
Total observed	452	100.00
Average age of onset	52.81	
Heart or kidney disease		
Yes	103	22.79
No	349	77.21
Total observed	452	100.00
Average age of onset	61.18	
If yes, type of heart or kidney disease?		
Heart	57	55.34
Kidney	12	11.65
Both	4	3.88
Unspecified	30	29.13
Total observed	103	100.00
Other specific health problems		
Yes	372	82.30
No	80	17.70
Do you take medication regularly?		
Yes	343	75.88
No	109	24.12
Have you ever smoked cigarettes or cigars		
Yes	75	16.59
Used to	16	3.54
No	361	79.87

Table 3.7: Summary Statistics of Adult Communication History, January 01, 2001 – May 31, 2005

	Number of Patients (n = 452)	Percent of Total (%)
Does your hearing loss interfere with communication?		
Yes	366	80.97
No	86	19.03
Total observed	452	100.00
Have you been enrolled in an aural rehabilitation program?		
Yes	10	2.21
No	442	97.79
Total observed	452	100.00
If yes, did it seem to help you?		
Yes	5	50.00
No	2	20.00
No response	3	30.00
Total observed	10	100.00
Has your hearing problem affected your relationships with family or friends?		
Yes	262	57.96
No	190	42.04
Total observed	452	100.00
Are your able to use lip-reading efficiently?		
Yes	75	16.59
No	377	83.41
Total observed	452	100.00

Table 3.8: Estimation Results for Adult Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
	Base Model	Noise Model	Family Model	Disease Model	Full Model
Age	.007*	.007*	.007*	.007*	.006*
	(001)	(.001)	(.001)	(.001)	(.001)
Gender	.074*	.068*	.084*	.077*	.079*
	(.025)	(.026)	(.026)	(.025)	(.025)
Otologic history					
Ear infection	.051*	.047*	.047*	.049*	.038
	(.021)	(.021)	(.021)	(.020)	(.019)
Special treatment	.049	.050	.039	.045	.033
	(.027)	(.025)	(.028)	(.026)	(.024)
Surgery	.030	.018	.038	.029	.036
	(.032)	(.034)	(.029)	(.030)	(.024)
Excessive noise	-.038		-.042	-.037	
	(.023)		(.023)	(.022)	
Gunfire		-.056			-.016
		(.039)			(.031)
Explosions		.001			-.036
		(.048)			(.055)
Factory noise		.024			.004
		(.031)			(.032)
Power tools		.031			.022
		(.031)			(.028)
Heavy equipment		-.015			-.025
		(.034)			(.033)
Motorcycles		-.012			-.025
		(.045)			(.044)
Power lawn mowers		.013			.032
		(.030)			(.025)
Aircraft		-.074			-.102*
		(.056)			(.059)
Loud music		-.074*			-.089*
		(.034)			(.036)
Military tanks		.082			.074*
		(.025)			(.016)
Other noise		.017			.013
		(.028)			(.025)
Family history	.023	.033		.022	
	(.021)	(.022)		(.021)	
Father			-.002		-.007
			(.026)		(.025)
Mother			-.045		-.050
			(.035)		(.034)
Sister			.010		.011
			(.044)		(.040)

Table 3.8. Continued.

Brother			.037		.045
			(.030)		(.023)
Grandmother			.051		.054
			(.028)		(.020)
Grandfather			-.094*		-.095*
			(.056)		(.055)
Aunt			.048		.058
			(.045)		(.027)
Uncle			.065		.073*
			(.025)		(.016)
Cousin			.024		-.056
			(.067)		(.114)
Child			.085		.078*
			(.022)		(.016)
Other member			-.000		-.032
			(.072)		(.084)
Major health problems	.052*	.042	.048		
	(.027)	(.026)	(.026)		
Diabetes				.084*	.077*
				(.021)	(.019)
High blood pressure				.001	-.019
				(.025)	(.023)
Heart or kidney disease				.037	.047
				(.026)	(.022)
Other diseases or symptoms	.009	.013	.003	.013	.013
	(.031)	(.031)	(.029)	(.031)	(.029)
Medication	-.056*	-.046	-.030	-.051*	-.011
	(.022)	(.022)	(.024)	(.020)	(.023)
Number of Observations	866	866	866	866	866
Pseudo R^2	.262	.280	.291	.273	.329

Standard errors are in parentheses. * Significant at the .05 level.

Table 3.9: Estimation Results for Adult Degree of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
	Base Model	Noise Model	Family Model	Disease Model	Full Model
Age	.021*	.020*	.021*	.021*	.020*
	(002)	(.002)	(.002)	(.002)	(.002)
Gender	.265*	.316*	.377*	.277*	.425*
	(.084)	(.088)	(.086)	(.084)	(.091)
Otologic history					
Ear infection	.207*	.166	.211*	.181*	.143
	(.092)	(.093)	(.092)	(.092)	(.094)
Special treatment	.214	.226	.191	.202	.183
	(.125)	(.125)	(.129)	(.126)	(.130)
Surgery	.236	.225	.234	.275*	.309*
	(.124)	(.127)	(.126)	(.124)	(.131)
Excessive noise	-.310*		-.357*	-.315*	
	(.085)		(.086)	(.085)	
Gunfire		-.448*			-.333*
		(.116)			(.118)
Explosions		-.025			-.132
		(.159)			(.164)
Factory noise		.128			.132
		(.116)			(.119)
Power tools		.183			.139
		(.116)			(.118)
Heavy equipment		-.189			-.268*
		(.108)			(.113)
Motorcycles		.158			.211
		(.162)			(.164)
Power lawn mowers		-.173			-.124
		(.110)			(.113)
Aircraft		-.331*			-.360*
		(.139)			(.142)
Loud music		-.178			-.260*
		(.102)			(.106)
Military tanks		.252			.242
		(.221)			(.227)
Other noise		.003			-.016
		(.105)			(.105)
Family history	-.001	.061		.009	
	(.073)	(.075)		(.073)	
Father			-.255*		-.218*
			(.093)		(.094)
Mother			-.145		-.144
			(.099)		(.102)
Sister			.157		.065
			(.138)		(.140)

Table 3.9. Continued.

Brother			.199		.236*
			(.118)		(.119)
Grandmother			.113		.134
			(.179)		(.182)
Grandfather			-.278		-.286
			(.152)		(.155)
Aunt			.386		.493*
			(.202)		(.205)
Uncle			.259		.455*
			(.160)		(.167)
Cousin			.280		.053
			(.257)		(.265)
Child			.505*		.582*
			(.171)		(.174)
Other member			-.181		-.237
			(.236)		(.240)
Major health problems	.119	.066	.117		
	(.087)	(.088)	(.088)		
Diabetes				.488*	.506*
				(.097)	(.101)
High blood pressure				-.016	-.084
				(.082)	(.086)
Heart or kidney disease				.038	.019
				(.091)	(.095)
Other diseases or symptoms	-.103	-.072	-.096	-.066	-.020
	(.098)	(.101)	(.099)	(.099)	(.102)
Medication	-.300*	-.247*	-.211*	-.325*	-.175
	(.103)	(.106)	(.105)	(.100)	(.105)
Threshold Parameters					
α_1	.067	.068	.122	.060	.136
	(.170)	(.176)	(.174)	(.170)	(.180)
α_2	.551	.561	.622	.551	.653
	(.173)	(.179)	(.177)	(.173)	(.183)
α_3	1.240	1.268	1.330	1.253	1.396
	(.176)	(.183)	(.181)	(.177)	(.188)
α_4	2.058	2.107	2.173	2.087	2.274
	(.179)	(.186)	(.184)	(.180)	(.191)
α_5	2.711	2.771	2.848	2.750	2.967
	(.181)	(.188)	(.186)	(.182)	(.194)
Number of Observations	866	866	866	866	866
Pseudo R^2	.046	.056	.062	.054	.080

Standard errors are in parentheses. * Significant at the .05 level.

Table 3.10: Marginal Effects of Independent Variables in the Adult Base Model: The Severity of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Base Model					
	Prob (y=1)	Prob (y=2)	Prob (y=3)	Prob (y=4)	Prob (y=5)	Prob (y=6)
Age	-.005*	-.002*	-.001*	.003*	.003*	.002*
	(.001)	(.000)	(.000)	(.000)	(.000)	(.000)
Gender	-.061*	-.029*	-.015*	.036*	.038*	.030*
	(.020)	(.009)	(.005)	(.012)	(.012)	(.010)
Otologic history						
Ear infection	-.044*	-.023*	-.015	.026*	.031*	.026*
	(.018)	(.011)	(.008)	(.011)	(.014)	(.013)
Special treatment	-.044	-.024	-.017	.025*	.032	.028
	(.024)	(.014)	(.012)	(.012)	(.019)	(.019)
Surgery	-.048*	-.027	-.019	.027*	.035	.031
	(.023)	(.014)	(.013)	(.012)	(.019)	(.019)
Excessive noise	.068*	.034*	.020*	-.040*	-.045*	-.037*
	(.019)	(.010)	(.007)	(.012)	(.013)	(.011)
Family history	.000	.000	.000	-.000	-.000	-.000
	(.017)	(.008)	(.004)	(.010)	(.011)	(.008)
Major health problems	-.027	-.013	-.007	.016	.017	.014
	(.020)	(.010)	(.005)	(.012)	(.013)	(.010)
Other diseases or symptoms	.022	.012	.007	-.013	-.015	-.013
	(.021)	(.011)	(.008)	(.012)	(.015)	(.013)
Medication	.062*	.034*	.023*	-.035*	-.045*	-.039*
	(.020)	(.012)	(.010)	(.011)	(.016)	(.016)

Note: Y=1 (normal); Y=2 (Mild), Y=3 (Moderate), Y=4 (Moderately Severe), Y=5 (Severe), Y=6 (Profound)

Table 3.11: Estimation Results for Child Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Model 1 (New forms)	Model 2 (Old form)
Age	-.064	.001
	(.053)	(.010)
Gender	-.119*	.201*
	(.047)	(.069)
Otologic history		
Ear infection	.104*	-.154
	(.040)	(.087)
Earache		-.128
		(.086)
Ear drainage		.293*
		(.116)
Surgery	-.047	
	(.046)	
Ear treatment and surgery		.149
		(.086)
Birth problem	.014	-.037
	(.043)	(.079)
Medical problem	.039	-.210
	(.044)	(.178)
Medication	-.145*	-.040
	(.039)	(.080)
Family history of ear problem	.061	.051
	(.046)	(.073)
Family history of speech problem	-.167*	-.191
	(.034)	(.084)
Number of Observations	365	176
Pseudo R^2	.104	.157

Standard errors are in parentheses. * Significant at the .05 level.

Table 3.12: Estimation Results for Child Degree of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Model 1 (New forms)	Model 2 (Old form)
Age	-.286	.007
	(.181)	(.028)
Gender	-.533*	.597*
	(.165)	(.222)
Otologic history		
Ear infection	.382	-.548*
	(.208)	(.241)
Earache		-.528*
		(.246)
Ear drainage		.814*
		(.286)
Surgery	-.243	
	(.203)	
Ear treatment and surgery		.353
		(.240)
Birth problem	.127	-.025
	(.163)	(.239)
Medical problem	.134	-.434
	(.183)	(.409)
Medication	-.585*	-.182
	(.198)	(.245)
Family history of ear problem	.146	-.071
	(.167)	(.217)
Family history of speech problem	-.896*	-.702
	(.243)	(.455)
Threshold Parameters		
α_1	.471	.120
	(.270)	(.394)
α_2	.899	.424
	(.274)	(.394)
α_3	1.452	.883
	(.284)	(.394)
α_4	1.563	1.175
	(.287)	(.401)
α_5	2.022	1.408
	(.311)	(.412)
Number of Observations	365	176
Pseudo R2	.070	.105

Standard errors are in parentheses. * Significant at the .05 level.

Table 3.13: Marginal Effects of Independent Variables in the New Child Model: The Severity of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Base Model					
	Prob (y=1)	Prob (y=2)	Prob (y=3)	Prob (y=4)	Prob (y=5)	Prob (y=6)
Age	.076	-.029	-.028	-.003	-.010	-.006
	(.051)	(.019)	(.019)	(.003)	(.008)	(.005)
Gender	-.141*	-.053*	-.051*	-.007	-.019*	-.011
	(.046)	(.018)	(.019)	(.005)	(.009)	(.006)
Otologic history						
Ear infection	-.085*	-.036	.030*	.004	.010	.005
	(.041)	(.019)	(.015)	(.003)	(.005)	(.003)
Surgery	.056	-.023	-.020	-.003	-.007	-.003
	(.043)	(.019)	(.016)	(.002)	(.005)	(.003)
Birth problem	-.032	.013	.012	.002	.004	.002
	(.042)	(.016)	(.015)	(.002)	(.005)	(.003)
Medical problem	-.032	.013	.012	.002	.004	.002
	(.043)	(.018)	(.016)	(.002)	(.005)	(.003)
Medication	.130*	-.054*	-.047*	-.006	-.015*	-.008
	(.039)	(.019)	(.016)	(.004)	(.007)	(.004)
Family history of ear problem	-.037	.015	.014	.002	.005	.003
	(.043)	(.017)	(.016)	(.002)	(.006)	(.003)
Family history of speech problem	.170*	.075*	-.060*	-.007	-.018*	-.009
	(.033)	(.019)	(.015)	(.004)	(.007)	(.005)

Note: Y=1 (normal); Y=2 (Mild), Y=3 (Moderate), Y=4 (Moderately Severe), Y=5 (Severe), Y=6 (Profound)

Table 3.14: Marginal Effects of Independent Variables in the Old Child Model: The Severity of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Base Model					
	Prob (y=1)	Prob (y=2)	Prob (y=3)	Prob (y=4)	Prob (y=5)	Prob (y=6)
Age	-.002	.000	.001	.000	.000	.000
	(.009)	(.002)	(.003)	(.002)	(.001)	(.002)
Gender	-.185*	.041*	.061*	.030*	.018	.034*
	(.066)	(.018)	(.025)	(.015)	(.011)	(.017)
Otologic history						
Ear infection	.183*	-.036*	-.058*	-.031	-.019	-.039
	(.082)	(.018)	(.028)	(.018)	(.013)	(.023)
Earache	.173*	-.036*	-.056*	-.029	-.018	-.035
	(.081)	(.018)	(.028)	(.017)	(.012)	(.021)
Ear drainage	-.293*	.043*	.083*	.050*	.034	.082
	(.107)	(.016)	(.032)	(.026)	(.021)	(.046)
Ear treatment and surgery	-.115	.024	.037	.019	.012	.023
	(.079)	(.017)	(.026)	(.015)	(.010)	(.018)
Birth problem	.008	-.002	-.003	-.001	-.001	-.001
	(.076)	(.017)	(.025)	(.013)	(.007)	(.014)
Medical problem	.153	-.026	-.047	-.026	-.017	-.037
	(.155)	(.021)	(.044)	(.029)	(.020)	(.048)
Medication	.057	-.013	-.019	-.009	-.005	-.010
	(.074)	(.018)	(.025)	(.012)	(.008)	(.013)
Family history of ear problem	.023	-.005	-.008	-.004	-.002	-.004
	(.069)	(.015)	(.023)	(.012)	(.007)	(.013)
Family history of speech problem	.178*	-.049	-.062	-.027	-.015	-.025*
	(.085)	(.031)	(.033)	(.015)	(.010)	(.013)

Note: Y=1 (normal); Y=2 (Mild), Y=3 (Moderate), Y=4 (Moderately Severe), Y=5 (Severe), Y=6 (Profound)

CHAPTER IV

THE IMPACT OF PAYMENT METHOD ON HEARING AID SELECTION

4.1. Introduction

Hearing aids have undergone numerous technological advances during the past two decades. In spite of these advancements, their market penetration has remained relatively stagnant (Amlani and De Silva, 2005; Kochkin, 2005). In 1980, an estimated 17.6 million people in the United States were hearing-impaired, and market penetration yielded a mere 17.50%. The estimated hearing-impaired population increased to 28.6 million by 2001, with 22.20% market penetration (Amlani and De Silva, 2005). A recent market survey reveals that the hearing-impaired population has grown to 31.5 million, yet market penetration remains only 23.60% (Kochkin, 2005).

Studies have suggested that poor market penetration stems from factors such as product quality (Lee and Lotz, 1998), acclimatization effects (Cox and Alexander, 1992; Bentler et al., 1993a, 1993b; Arkis and Burkey, 1994; Gatehouse 1992, 1993; Horowitz and Turner, 1997; Kuk et al., 2003), and the stigma related to wearing a hearing aid (Kochkin, 1990, 1993; Hetu, 1996). Furthermore, there is evidence indicating that the demand for hearing aids is price-inelastic (Aaron, 1987; Lee and Lotz, 1998; Amlani and De Silva, 2005). What remains unclear, however, is the effect of market price or, more precisely, the actual retail price that consumers pay for hearing aids and the type of payment method that is most likely to result in hearing aid procurement.

The objective of this chapter is to examine how patients' payment method, demographics, and amount of out-of-pocket payment influence the decision to select a hearing aid. By adopting a multinomial logit (MNL) framework, the study finds that consumers who are financially well-off are more inclined to select a style of hearing aid that is not only customized to fit inside each user's ear canal, but also pricier and more technologically advanced. This seems to suggest that style is income-elastic. Results also indicate that when patients pay with Medicaid, private insurance, and other public and private payment methods, they tend to purchase behind-the-ear instruments – which are modular – rather than the miniature custom-made hearing aids, which are likely to be more expensive. This result is related directly to the amount of payment covered by insurance and third-party assistance. Accordingly, the relevant retail price to a hearing aid customer is the difference between the final market price and insurance coverage. Finally, the study finds that retirees are less likely to purchase a hearing aid with a digital signal processing than the basic analog processed signal. The data utilized in this study cover a period of 48 months and were gathered from a hearing clinic in West Texas.

The remainder of the chapter is organized as follows. Section 4.2 briefly outlines the relation between the two main components of a hearing aid: the styles and signal processing schemes. Section 4.3 provides a narrative of the data. Section 4.4 recounts the empirical analysis, and section 4.5 concludes.

4.2. Hearing Aids

By combining the signal processing scheme and style, a hearing aid manufacturer is able to construct a matrix of 12 different types of hearing instruments. Since the underlying configuration of a hearing aid lies in these two primary elements, i.e., style and signal processing scheme, this section outlines the distinct styles and signal processing schemes.

In general, a hearing aid can be made in any of the four[10] designs: (1) behind-the-ear (BTE), (2) in-the-ear (ITE), (3) in-the-canal (ITC), and (4) completely-in-the-canal (CIC). ITC and CIC are commonly referred to as canal aids. Hearing aids are also manufactured using three types of signal processing schemes: analog-adjustable (AA), analog-programmable (AP), and digital-programmable (DP). AA, often referred to simply as analog, allows the audiologist some flexibility in making adjustments, but is restricted in that it often contains only a single frequency response and a limited number of adjustable features. This type of signal processing is generally the least expensive to manufacture and, hence, costs less to the consumer. AP aids are more expensive than AA aids and allow the audiologist to program the internal components of the hearing aid with greater precision using a personal computer. These aids are often equipped with an external control or toggle switch, which permits the wearer to change the program (frequency response) as the listening environment changes. DP, in contrast, is the most expensive circuitry, partly because it incorporates AP programmable technology plus

---

[10] Body aid is a special type of hearing aid style and is suppressed from the description in this study since it is rarely prescribed and, more importantly, my dataset does not observe it.

more advanced technology. Features exclusive to DP technology include noise cancellation, feedback cancellation, and dual-microphone directionality.

4.3. Data

4.3.1. Data Collection

Hearing aid data were manually compiled from four sources over an eight month period from an audiology practice in West Texas. The final market price, including the professional service fee, was collected from the hearing aid contracts or dispenser-to-end-user invoices. Hearing aid contracts are sales agreements made between the dispensing clinic and their patients. I used these contracts and the supplementary hearing aid data sheets to collect information regarding the model and type of payment exercised during a business transaction. The retail cost paid by each patient was computed by subtracting the insurance payment from the total retail price. Payment methods were classified using the following categories: (a) private pay, (b) private insurance, (c) Medicaid and Texas Department of Health (TDH), (d) other public-assistance and charity organizations, including regional assistance programs for the elderly and socio-economically challenged, and (e) worker's compensation.

Manufacturer-to-dispenser invoices were the second source of data. These invoices were used to determine the dispenser's cost, the shipping and handling fees, and the hearing aid style and signal processing scheme for each aid procured. The third source of data included each patient's year of birth, gender, and occupation, which were extracted from case history forms. Variables from these invoices and case forms relevant to this study include the patients' age, gender, occupation, model or style of hearing aid, signal processing scheme, retail price, insurance payment, and actual patient payment. Finally, for clarifications of specific transactions, patient log sheets, which contain meticulous details of each patient's clinical visit, were reviewed to ensure accuracy. The final dataset consist of 254 transactions for one audiological practice during the period of June 01, 2001 to May 31, 2005.

4.3.2. Summary Statistics

The following detailed description of the summary statistics provides some insight into how occupational status, payment method, and retail price influence the end-users' choice of the hearing aid style and signal processing scheme.

Table 4.1 is a summary of the total numbers of styles and signal processors purchased by patients between June 01, 2001 and May 31, 2005. The style that attracted the greatest demand was the ITE aid, which accounted for 54.33% of the units sold. BTE ranked second in popularity, but represented only 25.98% of all transactions. The least bought shell style across processor types was CIC, a miniaturized custom-made shell, which inherently attracts a higher price given its miniaturization and greater labor during production. Among the three distinct signal processing schemes, DP was selected in 130 cases, exceeding the combined sum of AA and AP. AA ranked second with 78 units, while AP had the least number of transactions with 46 aids. This trend is expected given that the hearing aid industry is phasing out AP in favor of DP (Lee and Lotz, 1998).

Table 4.2 reports average statistics regarding the retail prices for the four hearing aid styles and three signal processing schemes separately. The highest average total cost to the dispenser was found for the CIC style ($753.54) and products engineered with DP ($607.09). Therefore, it is not surprising that, on average, this particular dispenser commands the highest market prices: $1,384.04 and $1,034.73 for CIC and DP, respectively. Column 3 details the average final retail price for consumers, which includes professional service fee and shipping and handling costs. The price pattern shows that as the device becomes smaller and less visible, the price increases. This is a positive indication that patients put a premium on the "vanity" of the hearing instrument. Note that the only slight exception is the BTE style, which costs $35.00 more on average than an ITE. This unexpected abnormality, however, can be attributed to reasons other than technology. Since most Medicaid and TDH provide only a fixed payment amount to the economically-disadvantaged and because most patients experience difficulty with dexterity due to aging, dispensers are more likely to recommend the BTE style. Given this condition and the "inelastic" demand for BTE among these Medicaid patients, the clinic has possibly exercised some of its "market power" to slightly raise the price of BTE aids. There also exists the possibility that the anomaly may be a reflection of higher manufacturer costs and service inputs for this type of instrument or a combination of all three causes.

The price disparity between the basic AA processor and the most technologically advanced DP is $476.59. Clearly, technology becomes more costly as it progresses. Yet, this price discrepancy in the processor is only roughly 75% ($476.59 / $635.15) of the price-difference in style. Given that CIC has the highest average retail price and assuming that BTE costs the least, on average, the high-and-low variation for style is \$635.15. This finding again suggests that "vanity" may be a primary factor on the part of consumers when making hearing aid procurement decisions. However, one must be cautious when making such a statement since purchasing decisions may also depend on the degree of hearing loss, income, and a number of other factors.

The amount of insurance coverage for the sundry processor and style types are provided in column 4 of Table 4.2. The average insurance payment for a hearing aid is \$374.37. Insurance includes private insurance, public insurance (Medicaid and TDH), other public-assistance (e.g., local agencies, charitable organizations), and workers' compensation. With respect to signal processing scheme, the average payments for AA, AP, and DP made on behalf of consumers by various agencies were \$442.27, \$316.55, and \$354.08, respectively. The amounts of assured indemnity for BTE, ITE, ITC, and CIC were \$399.55, \$389.95, \$221.77, and \$412.64, respectively.

The median retail price paid by each patient after third-party payment, shown in column 5 of Table 4.2, is \$461.73. A comparison between the amounts covered by insurance and patient out-of-pocket expenses shows that the hearing aid customer paid, on average, \$87.36 more per instrument. Note that the entries in column 5 were computed by subtracting the amount of insurance reimbursement from the final retail price. It should be noted that this is the price (i.e., the actual retail cost paid by the patient) that could potentially impact consumer choices when making purchasing decisions. The most conspicuous actual patient payment, labeled at $1,006.69, was bestowed on the ITC style.

For additional enlightenment, average dispenser costs and consumer prices are provided in Table 4.3 for the 12 style-by-signal processing combinations. Column 1 introduces one anomaly where the total dispenser cost for AP-ITC is $626.03, exceeding that of DP-ITC by $10.09. If taking note of the assumption that digital technology is more expensive than either AA or AP, then by keeping the style constant, DP-ITC should cost more than AP-ITC to the dispenser. This, however, is not the case in this instance. One rationale for this finding might be the result of a special manufacturer discount provided to the dispenser. There is an equally probable explanation; that is, manufacturer differences may have occasioned the presence of this peculiarity.

Continuing with Table 4.3, the average total dispenser cost for a hearing aid (style-by-signal processing) is $497.92, while the final market price for consumers was increased to $836.10. This positive difference between the total retail price and manufacturer wholesale price is the markup of the dispensing clinic. The mean price-cost margin for the audiology practice under study is .352. Evidently, acting as a "middleman" allows the dispenser to inflate hearing aid prices to end-users. On average, the DP-CIC aid has the highest market price since it combines the smallest style and the most complex technology. A quick survey of column 3 confirms that DP technology commands the price in all styles. Explicitly, keeping the processor constant, as style evolves from BTE to the smaller, customized designs, the succeeding prices escalate likewise.

Table 4.4a specifies in detail the types of payment method used by patients to purchase hearing aids (style-by-signal processing). Approximately 31% of all purchases made during the 48 months under study were paid 100% out-of-pocket by the patient. While private pay ranked as the second most common type of payment method, other public-assistance (e.g., local agencies, charitable organizations) exceeded it by a slight margin: 32.28% of all transactions. The third largest payment party was Medicaid (including TDH), which financed almost 20% of all hearing aid acquisitions. Private insurance, on the other hand, covered about only nine percent of all sales.

Columns 5, 6, and 7 in Table 4.4a enumerate payment categories for each of the three signal processing schemes. Note that Medicaid and other public-assistance insurance provided payments for 58 out of the 78 hearing aid purchases that used an AA processor. Private insurance, alternatively, helped to procure more DP than any AA and AP processor combined when discounting purchases by private payment. Referring back to Table 4.2, this observation may be instructive as to why insurance payment is higher for AA and DP. One cause of speculation may be the amount provided by these insurances as explained below.

Table 4.4b catalogs the average dollar amount provided by insurance category. In general, private insurance guaranteed \$518.18 per instrument for each patient. Blue Cross Blue Shield (BCBS), the main health insurance provider in the West Texas region, made up 90.91% of all private insurance payments and disbursed \$500.00 for each hearing aid procured by each patient. Hearing aid patients with this type of insurance normally have the pecuniary means to procure the more expensive signal processing and style types, such as digital and CIC. Therefore, the resultant insurance pay (in column 4, Table 4.2), is higher for digital circuitry. A parallel reasoning ensues for the protected payments among styles and the same interpretation can be taken to defend the high insurance pay for CIC.

Employing the same reasoning as in the previous paragraph, I next refer to Medicaid for a possible explanation of the high insurance pay for AA. As indicated in column 3, Table 4.4b, Medicaid usually endows each candidate with an average of \$388.22 for each hearing aid purchase. Receivers of Medicaid, therefore, are restricted in their choices and can only acquire the most affordable processor and style with the limited funds provided to them. On average, other public-assistance (including regional assistance programs for the elderly and socio-economically challenged and charity organizations) pays \$227.96 more than Medicaid. This monetary surplus generally allows patients to elect a smaller style while remaining with the basic technology, as shown in columns 2 and 5 of Table 4.4a. By and large, the outcome of the above analysis substantiates my prediction. Specifically, patients who are covered by Medicaid and other public-assisted programs tend to be in the bottom-tier of the income level. Since these types of assistance impose a fixed dollar amount which barely covers the cost of the least expensive processor and style, it is only natural that the 51.97% of patients supported by Medicaid and other public-assistance choose AA over the more costly AP and DP processor types. Table 4.4b also reveals the corresponding dollar amount paid by patients with insurance coverage. On average, after accounting for private insurance payment, a hearing aid patient usually pays an additional \$794.32 out of pocket.

Occupational status and the type of payment are closely associated since people are likely to obtain insurance through their employers. The relationship between employment and hearing aid style and signal processing selection is presented in Table 4.5. The numerical values for each style and processor purchased show that hearing aid patients are of a diverse socioeconomic status. Retirees are the leaders in hearing aid consumption, accounting for 60.24% of all sale transactions. This is not surprising given that aging is one of the most conventional sources of hearing loss (Moscicki et al., 1985). The second largest purchasing group, accountable for 14.96% of the 254 purchases, consists of people who are employed, including farm-owners and people with other forms of self-employment. Students and children trail closely in third place with 12.60%.

Table 4.6 recapitulates the descriptive statistics on the variables used in the regressions. For technical definitions on the style and signal processing scheme, refer to Table C.2 in the appendix. The appendix also provides a synopsis of the demographics of hearing aid users surveyed in this study.

4.4. Empirical Model and Estimation

4.4.1. The Empirical Model

The objective of this chapter is to identify the factors that affect end-users' selection of a particular style and signal processing scheme among the 12 style-by-processing combinations. To investigate this issue, I implemented a multinomial logit model and ran two separate regressions for the style and signal processing dummies. The explanatory variables include age, gender, occupational dummies, dummy variables for payment method, and the actual retail price paid by the patient. Hearing aid consumers were classified into three groups: retired, employed (including self-employed workers), and non-working (children, students, homemakers, disabled, and unemployed). The non-working group served as the reference category for occupational status. Five payment dummies were also created: private pay, Medicaid (including TDH payments), other public-assistance, and workers' compensation; "workers' compensation" was the omitted group. The empirical structure of the MNL model is thus specified:

$$P(y = j \mid x) = \frac{\exp(x\beta_j)}{1 + \sum_{h=1}^{j} \exp(x\beta_h)} \qquad \text{for } j = 1, \ldots, J \tag{1}$$

where y_j identifies hearing aid style and signal processing scheme, x is the matrix of independent variables, and β_j is the K x 1 coefficient vector. The dependent variables for the two MNL models were the style and signal processing scheme, respectively. Style was categorized into three general classes: BTE, ITE, and in-the-canal (ITC and CIC). Types of signal processing consist of AA, AP, and DP. For the style model, BTE was designated as the reference category and AA acted as the comparison group for signal processing. Tables 4.7 and 4.8 present the estimation results for the separate style and processor MNL regressions.

4.4.2. Estimation Results

In Table 4.7, column 1, the estimation results for the impact of gender, actual patient payment, and payment and occupation dummies on hearing aid style selection are provided. The control variable is BTE, which represents the basic and least expensive hearing aid style. In reference to the BTE style, Model 1 reveals that retirees and the employed tend to choose the more invisible and expensive designs such as ITE and the in-the-canal aids (ITC and CIC). Results indicate that, in general, consumers and insurance firms are unwilling to pay for the elegant and miniature designs, regardless of the payment method. In other words, patients who are solely responsible for the payment of their hearing aid would avoid buying ITE and ITC/CIC due to their high costs. Similarly, since Medicaid provides only a fixed dollar amount to the dispenser which usually meets or just exceeds the cost of the least expensive style, it appears that economically-disadvantaged users are limited in their choices. Therefore, buyers of hearing aids who are eligible for Medicaid coverage are expected to choose BTE style devices instead of the more aesthetic in-the-canal aids.

Private insurance is statistically significant for the ITE model but loses its statistical significance in the ITC/CIC regression. This, as elucidated in the data summary in section 4.3.2, may be justified by the fact that patients with private insurance are free to procure the more aesthetic styles, regardless of the cost. Yet, overall, patients with private insurance tend to purchase ITE and in-the-canal aids less in comparison to the BTE style, considering the relatively large amount of out-of-pocket payment. Other public-assisted payment, in contrast, gains statistical significance in the latter model. I attribute this to the rationalization previously offered for Medicaid. That is, since public-assistance pays only a fixed dollar amount, patients under such coverage do not have many choices but to select the less costly styles.

The actual price paid by the patient is positive and statistically significant for in-the-canal instruments, although the magnitude of the coefficient is small. Nevertheless, this is an adequate indication that the actual retail price has a positive impact on consumer choices. Provided that insurance covers some portion of the retail price, end-users tend to procure the more expensive and invisible ITC and CIC styles.

When age is added as a descriptive variable in Model 2, the variables "retired" and "employed" lose their statistical significance for ITE. Similarly, for "in-the-canal" estimation, only "employed" retains its statistical significance. This outcome may be the product of reduced observations since, with age included as an explanatory variable, the data have only 251 observations; but it seems unlikely that a slight reduction in the number of observations could effect such changes in the variables. As illustrated in Table 4.7, Model 2 actually shows a slight improvement in the fit-measure as it increases from .204 in Model 1 to .208.

Table 4.8 reports the estimation results for the hearing aid signal processing scheme. The resulting models are much less informative than their predecessors in Table 4.7. Model 1 regresses signal processing on the same set of explanatory variables used for hearing aid style. The only variables that are statistically significant are "actual retail price paid by patient" and "retired" in the digital model but with contrasting signs. Instead of remaining positive as in the style models in Table 4.7, "retired" now assumes a negative sign. This appears to imply that retirees do not value technology as much as they do the miniaturization of styles. Hence, it is evident that this generation of consumers is more willing to "sacrifice" quality, i.e., technology, for reasons of vanity.

In general, retirees have restricted their choices to less expensive signal processing schemes such as AA and AP by not purchasing hearing aids with digital circuitry.

The actual retail price paid by the patient preserves its significance in the digital estimation as it does in all the ITC/CIC style regressions. Yet the scale of the coefficient continues to be small once again. Next, in column 2, age is added as a descriptive, but the results remain invariable, as in Model 1.

4.5. Conclusion

The aim of this analysis is to determine those factors that influence end-users' choice in their selection of hearing aid styles and signal processing schemes. By applying a unique set of data to a multinomial logit framework, it was found that consumers often forego quality in order to maximize vanity. Moreover, there is a diminutive prospect of private insurance, Medicaid, and other public programs providing coverage for ITE and ITC/CIC. In terms of how occupational status affects a consumer's selection of a hearing aid style, the model outcome signifies that retirees and people who are employed are likely to procure an ITE style or an in-the-canal aid rather than the standard BTE design. This, of course, may be ascribed to their financial stability and aesthetic preferences.

The processor MNL models are less revealing. They simply demonstrate that retirees are less inclined to purchase the more expensive signal processors such as DP rather than AA. The estimation results also imply that the actual retail price paid by the patient has a positive influence on consumer decisions to procure a processor.

Table 4.1: Summary Statistics of Hearing Aid Style and Processor Types, June 01, 2001 – May 31, 2005

Signal Processing Scheme	Style				Total	Percent of Total
	BTE	ITE	ITC	CIC		
AA	23	49	6	0	78	30.71
AP	4	30	8	4	46	18.11
DP	39	59	16	16	130	51.18
Total	66	138	30	20	254	100.00
Percent of Total	25.98	54.33	11.81	7.87	100.00	

Table 4.2: Summary Statistics of Average Retail Prices for Hearing Aid Style and Signal Processing Scheme, June 01, 2001 – May 31, 2005

Hearing Aid Style and Signal Processing Scheme	Dispense – to – End-user Price					
	Total Dispenser Cost (1)	Retail Price (2)	Total Retail Price (3) = (2) + hearing aid service fee + S&H fee	Insurance/other Pay (4)	Actual Patient Pay (5) = (3) – (4)	Price-cost Margin[11] (6) = [(3) – (1)] / (3) (PCM)
Style						
BTE	484.68	683.12	748.89	399.55	349.34	.287
	(249.72)	(458.52)	(466.55)	(341.36)	(591.59)	(.190)
ITE	453.22	627.03	713.10	389.95	323.15	.333
	(267.95)	(408.39)	(401.44)	(250.08)	(573.61)	(.194)
ITC	562.24	1156.69	1228.46	221.77	1006.69	.503
	(187.06)	(452.89)	(451.66)	(331.01)	(671.04)	(.173)
CIC	753.54	1292.79	1384.04	412.64	971.40	.468
	(343.21)	(615.09)	(582.78)	(420.08)	(737.35)	(.282)
Processor						
AA	325.28	478.30	558.14	442.27	115.87	.350
	(78.04)	(300.40)	(299.33)	(222.33)	(371.23)	(.193)
AP	482.13	662.48	746.09	316.55	429.54	.314
	(213.43)	(355.01)	(361.57)	(301.39)	(546.81)	(.197)
DP	607.09	956.85	1034.73	354.08	680.64	.367
	(310.74)	(546.98)	(539.16)	(341.17)	(732.04)	(.223)
Average	497.92	756.58	836.10	374.37	461.73	.352
Number of Observations	254	254	254	254	254	254

---

[11] The PCM was calculated as the average of relevant observation's PCM rather than straight from the columns of Table 4.2. Thus, the column 6 entries may not correspond exactly with a calculation based on the entries in columns 3 and 1.

Table 4.3: Summary Statistics of Average Retail Prices, June 01, 2001 – May 31, 2005

Types of Hearing Aid	Dispenser – to – End-user Price					
	Total Dispenser Cost (1)	Retail Price (2)	Total Retail Price (3) = (2) + hearing aid service fee + S&H fee	Insurance/other Pay (4)	Actual Patient Pay (5) = (3) – (4)	Price-cost Margin[12] (6) = [(3) – (1)] / (3) (PCM)
AA – BTE	335.49	423.70	504.38	411.45	92.93	.300
	(109.27)	(147.41)	(176.22)	(245.91)	(178.28)	(.171)
AA – ITE	319.43	446.17	526.65	472.06	54.59	.351
	(56.59)	(169.04)	(159.20)	(203.60)	(187.60)	(.187)
AA – ITC	333.98	950.00	1021.34	317.17	704.17	.531
	(97.96)	(853.81)	(848.16)	(255.66)	(1090.89)	(.235)
AP – BTE	453.12	656.25	728.26	220.38	507.88	.291
	(219.83)	(471.86)	(508.69)	(269.65)	(696.08)	(.269)
AP – ITE	401.47	518.02	600.79	327.46	273.33	.299
	(166.95)	(261.68)	(263.52)	(235.35)	(446.35)	(.201)
AP – ITC	626.03	1006.55	1081.55	193.75	887.80	.389
	(152.82)	(331.66)	(336.34)	(267.85)	(559.58)	(.178)
AP – CIC	828.25	1064.00	1182.75	576.50	606.25	.296
	(172.92)	(99.30)	(34.35)	(665.68)	(700.04)	(.167)
DP – BTE	575.90	838.86	895.21	410.91	484.29	.279
	(271.70)	(513.57)	(525.10)	(393.67)	(693.45)	(.198)
DP – ITE	590.66	832.66	925.05	353.53	571.53	.336
	(342.47)	(509.19)	(493.33)	(276.87)	(723.51)	(.196)
DP – ITC	615.94	1309.27	1379.58	200.00	1179.58	.549
	(165.72)	(219.70)	(220.85)	(389.87)	(501.73)	(.124)
DP – CIC	734.87	1349.99	1434.37	371.68	1062.69	.511
	(375.98)	(678.09)	(645.34)	(354.90)	(739.07)	(.292)
Average	497.92	756.58	836.10	374.37	461.73	.352
Number of Observations	254	254	254	254	254	254

---

[12] The PCM was calculated as the average of relevant observation's PCM rather than straight from the columns of Table 4.3. Thus, the column 6 entries may not correspond exactly with a calculation based on the entries in columns 3 and 1.

Table 4.4a: Summary Statistics of Payment Method, June 01, 2001 – May 31, 2005

Payment Method	Style				Signal Processing Scheme			Total	Percent of Total
	BTE	ITE	ITC	CIC	AA	AP	DP		
Private Pay	18	34	19	8	10	18	51	79	31.10
Private Insurance	6	4	4	8	2	2	18	22	8.66
Public Insurance									
Medicaid	8	23	1	0	20	10	2	32	12.60
TDH	17	0	1	0	4	0	14	18	7.09
Other Public-Assistance									
SPAG	0	7	0	0	4	1	2	7	2.76
CFS	9	53	3	0	28	12	25	65	25.59
Nursing Home	4	4	2	0	2	0	8	10	3.94
Workers' Compensation	4	13	0	4	8	3	10	21	8.27
Total	66	138	30	20	78	46	130	254	100.00
Percent of Total	25.98	54.33	11.81	7.87	30.71	18.11	51.18	100.00	

Table 4.4b: Average Amount of Insurance Payment by Category, June 01, 2001 – May 31, 2005

	Payment Method				
Dollar Amount	Private Pay	Insurance and Other Payment Categories			
		Private Insurance	Medicaid and TDH	Other Public-Assistance	Workers' Compensation
Insurance Pay	$.00 (.00)	$518.18 (153.67)	$388.22 (71.40)	$616.18 (216.26)	$651.80 (227.76)
Corresponding Out-of-Pocket Pay by Patient	$1263.36 (495.59)	$794.32 (426.86)	$.00 (.00)	$.00 (.00)	$.00 (.00)

Table 4.5: Total Number of Hearing Aid Style and Signal Processing Scheme Purchased by Employment Status, June 01, 2001– May 31, 2005

Employment Status	Style				Signal Processing Scheme			Total	Percent of Total
	BTE	ITE	ITC	CIC	AA	AP	DP		
Retired	28	98	25	2	56	30	67	153	60.24
Employed	7	14	5	12	5	10	23	38	14.96
Self-employed	0	4	0	2	2	0	4	6	2.36
Child and Student	26	4	0	2	6	2	24	32	12.60
Homemaker	0	1	0	0	0	1	0	1	.39
Disabled	2	8	0	0	4	2	4	10	3.94
Unemployed	3	9	0	2	5	1	6	14	5.51
Total	66	138	30	20	78	46	130	254	100.00
Percent of Total	25.98	54.33	11.81	7.87	30.71	18.11	51.18	100.00	

Table 4.6: Descriptive Statistics of the Variables used in the Regressions

Variables	Mean (n = 254)	Standard Deviation (n = 254)
Social Characteristics		
Age	64.498*	(23.473)
Gender	.555	(.498)
Retail Price		
Actual retail price paid by patient	461.733	(655.782)
Payment Method		
Private pay	.311	(.464)
Private insurance	.087	(.282)
Medicaid and TDH	.197	(.398)
Other public-assistance	.323	(.468)
(Workers' compensation)	.083	(.276)
Employment Status		
Retired	.606	(.490)
Employed (including self-employed)	.173	(.379)
(Non-working)	.220	(.415)

* n = 251.

Table 4.7: Estimation Results for Hearing Aid Style, June 01, 2001 – May 31, 2005

	Style	
	Model 1	Model 2
Variables	No age	With age
(Inside- the-ear instrument)		
Constant	.433	-.271
	(.622)	(.799)
Demographic Characteristics		
Age		.017
		(.012)
Gender	.647	.645
	(.351)	(.355)
Retail Price		
Actual retail price paid by patient	.001	.001
	(.001)	(.001)
Payment Method Dummies		
Private pay	-2.454*	-2.389*
	(1.007)	(1.023)
Private insurance	-3.507*	-3.189*
	(1.167)	(1.167)
Medicaid and TDH	-1.707*	-1.512*
	(.701)	(.719)
Other public-assistance	-.677	-.705
	(.737)	(.738)
Occupation Dummies		
Retired	1.770*	1.042
	(.424)	(.660)
Employed	2.097*	1.474
	(.749)	(.808)
(In-the-canal instrument = ITC and CIC)		
Constant	-1.064	-1.537
	(.833)	(1.075)
Demographic Characteristics		
Age		.010
		(.019)
Gender	.711	.730
	(.465)	(.468)
Retail Price		
Actual retail price paid by patient	.002*	.002*
	(.001)	(.001)
Payment Method Dummies		
Private pay	-3.056*	-2.722*
	(1.223)	(1.227)
Private insurance	-2.340	-1.997
	(1.223)	(1.198)

Table 4.7. Continued.

Medicaid and TDH	-3.119*	-2.841*
	(1.121)	(1.130)
Other public-assistance	-2.319*	-2.205*
	(1.039)	(1.036)
Occupation Dummies		
Retired	2.348*	1.793
	(.734)	(1.134)
Employed	2.707*	2.302*
	(.898)	(1.007)
Number of Observations	254	251
Pseudo R^2	.204	.208

Standard errors are in parentheses. * Significant at the .05 level.

Table 4.8: Estimation Results for Hearing Aid Signal Processor, June 01, 2001 – May 31, 2005

	Signal Processing Scheme	
	Model 1	Model 2
Variables	No age	With age
(Analog-programmable)		
Constant	-1.442	-1.853
	(.838)	(.973)
Demographic Characteristics		
Age		.016
		(.015)
Gender	.032	-.004
	(.406)	(.407)
Retail Price		
Actual retail price paid by patient	.001	.001
	(.001)	(.001)
Payment Method Dummies		
Private pay	.631	.431
	(1.169)	(1.176)
Private insurance	-.232	-.145
	(1.360)	(1.387)
Medicaid and TDH	.636	.571
	(.862)	(.850)
Other public-assistance	.515	.377
	(.879)	(.869)
Occupation Dummies		
Retired	-.122	-.841
	(.611)	(.921)
Employed	1.039	.445
	(.827)	(.915)
(Digital-programmable)		
Constant	.722	.591
	(.558)	(.747)
Demographic Characteristics		
Age		.004
		(.012)
Gender	-.165	-.180
	(.336)	(.338)
Retail Price		
Actual retail price paid by patient	.004*	.003*
	(.001)	(.001)
Payment Method Dummies		
Private pay	-1.451	-1.335
	(1.120)	(1.118)
Private insurance	.426	.450
	(1.154)	(1.146)

Table 4.8. Continued.

Medicaid and TDH	-.239	-.205
	(.634)	(.662)
Other public-assistance	.966	.963
	(.665)	(.674)
Occupation Dummies		
Retired	-1.756*	-1.949*
	(.491)	(.724)
Employed	-1.072	-1.104
	(.729)	(.771)
Number of Observations	254	251
Pseudo R^2	.155	.154

Standard errors are in parentheses. * Significant at the .05 level.

CHAPTER V

A HEDONIC PRICE ANALYSIS OF HEARING AID TECHNOLOGY

5.1. Introduction

Hearing aids are external electronic devices that are designed to either fit in or near the ear(s). The manufacturers of such devices are mainly concerned with how to better incorporate technology into their products as first-order treatment methods in alleviating hearing impairment. Hence, hearing aids are non-surgical methods of improving the power to hear for people suffering from hearing loss. Despite the existence of a strong hearing aid market, only approximately 23% of the hearing-impaired population has purchased a hearing aid (Kochkin, 2005). Further, there does not appear to be any robust price competition or product innovation in the market (Lee and Lotz, 1998). Researches have shown that the market for hearing aids is relatively price inelastic (Aaron, 1987; Lee and Lotz, 1998; Amlani and De Silva, 2005). Added to this is the fact that although hearing aids are durable consumer products, they cannot be purchased by consumers directly off the shelf. Audiologists need to recommend a certain type of hearing aid to a potential buyer based on cost considerations and the severity of hearing loss. This makes the supply chain of hearing aids crucially dependent on dispensers,[13] acting as the middleman between hearing aid manufacturers and end-users. The result is that various prices exist for hearing aids which seem to be fairly standard in

---

[13] Dispensers are most likely audiologists, but retailers like Wal-Mart may also dispense hearing aids.

their technology. This chapter seeks to dissect the components of the list price of hearing aids in order to better understand the contribution of technology to the determination of price. In addition, the price-cost margins are computed for a typical dispenser.

The author uses hedonic price analysis. Following the revival of the hedonic approach to analyze automobile prices[14] in the early 1960s, the regression technique has been applied to study the prices of a wide variety of merchandises including houses,[15] washing machines,[16] computers,[17] computed tomography scanners (CT), [18]personal digital assistants (PDAs),[19] and nondurable goods such as milk and wine.[20] However, to the best of my knowledge, the market for hearing aids has not been studied using the aforementioned hedonic method. This chapter, therefore, proposes to utilize a unique dataset to examine how functional and technical features affect the price of hearing aids and to analyze the price-cost margins at the intermediary level. The data employed in this section were gathered from a hearing clinic in West Texas.

---

[14] See Court (1939), Adelman and Griliches (1961), Griliches (1961, 1964), Triplett (1969), Dhrymes (1971), Berry, Levinsohn, and Pakes (1995), and Goldberg (1995) for more on the automobile industry.

[15] See Bailey, Muth, and Nourse (1963), Palmquist (1984), and Fallis and Smith (1985).

[16] See Gavett (1967).

[17] See Berndt, Griliches, and Rappaport (1995), Berndt and Rappaport (2001), Chwelos (2003), Pakes (2003), and Benkard and Bajari (2005) for more on the computer industry.

[18] See Trajtenberg (1989).

[19] See Chwelos, Berndt, and Cockburn (2004).

[20] See Buccola and Iizuka (1997) for an analysis on the pricing of milk; see Combris, Lecocq, and Visser (1997) for an analysis on wine.

The first hearing aid company, Siemens Hearing Instruments Inc., was established in 1847 but did not start manufacturing programmable hearing instruments until 1910;[21] since then, the number of hearing aid producers has grown tremendously (Lee and Lotz, 1998). Currently, there are almost 200 firms worldwide that manufacture hearing instruments. A large number of these companies are small-scaled and locally-oriented and therefore, do not possess adequate technology. Consequently, the 9–10 largest manufacturers have become the foremost players, dominating approximately 80% of the global market. In terms of location, most companies are concentrated in Minnesota, USA and Denmark.

This chapter shows that the signal processing scheme and style of the hearing aid are the two most important drivers of the list price in the hearing aid market. More precisely, digital processor contributes the most to cost, and the miniaturization of devices is definitely valued by consumers. When considering the price-cost margins at the secondary level, completely-in-the-ear digital instruments produce the highest markup factor. This attests to the usual assumption that "vanity" matters for hearing aid consumers.

The remainder of the chapter is organized as follows: section 5.2 gives a brief account of the different types of hearing instruments, section 5.3 provides a description of the data, section 5.4 reports the empirical analysis, and section 5.5 offers a few summary remarks.

---

[21] See also Footnote 1 in Chapter I.

5.2. Hearing Instruments

There are five types of hearing aids in terms of style.[22] (1) The behind-the-ear (BTE) device has a case at the rear of the ear that connects to a plastic ear mold. The ear-mold is then fitted to the inside of the outer ear. (2) The in-the-ear (ITE) hearing aid has a case that fits completely in the outer ear and is used for mild to severe hearing loss. It is usually worn by adults since, for children, the casings would need to be replaced as the ears grew. Canal aids fit into the ear canal and come in two subtypes: the ITC and the CIC. (3) The in-the-canal (ITC) device is customized to match the size and shape of the ear canal. (4) The completely-in-the-canal (CIC) device is largely concealed in the ear canal and is used for mild to moderately severe hearing loss. (5) Body aids are worn by people with profound hearing loss. Their large sizes allow the incorporation of many signal processors. In this study, body instruments are overlooked since they are rarely prescribed and, more importantly, my dataset records no such instance.

The internal mechanisms of hearing aids may vary across devices, even if they have the same external design.[23] A signal processor is essential to a functional hearing device and comes in three types: analog-adjustable (AA), analog-programmable (AP), and digital-programmable (DP). AA, often referred to as analog, allows the audiologist some flexibility to make adjustments and is generally the least expensive. The audiologist uses a computer to program AP hearing aids. If the aid is equipped with a remote control, the wearer can change the program to accommodate a given listening

---

[22] www.nidcd.nih.gov/health/hearing/hearingaid.asp.

[23] www.nidcd.nih.gov/health/hearing/hearingaid.asp.

environment. DP, on the other hand, is typically the most expensive since it provides the most flexibility for the audiologist to make adjustments and can be used in all types of devices.

According to studies done by Kochkin (2002) and Lee and Lotz (1998), the prices of instruments vary due to the style and signal processing types. However, the outcomes of their analyses seem to be based solely on observation of market trends. This analysis instead systematically investigates the variation in prices vis-à-vis specific features of technology and style using individual level data.

5.3. Data

5.3.1. Data Collection

Hearing aid cost and pricing data were compiled from three sources: manufacturer–to–dispenser invoices, hearing aid contracts and supplementary hearing aid data sheets, and patient log sheets. Hearing aid contracts are also referred to as dispenser–to–end-user invoices.

The dataset records nine makers of hearing aids and each firm has its own invoice form. The layouts of the account statements may differ, but their content remains basically the same. A manufacturer-to-dispenser proof of purchase usually has the following information: patient name, invoice number, customer number, dispenser contact information, and a thorough description of item(s) purchased. The item description includes the color, model, serial number, matrix, warranty, and the ear or ears for which the hearing aid is procured. It also documents the manufacturer prices for each feature of technology specified by the dispenser. This is extremely important since it breaks down the cost of the hearing aid according to each component of technology ordered. Note that the manufacturer selling or list price is sometimes called "cost of technology to dispenser." Essentially, these manufacturer-to-dispenser invoices were used to determine the inclusive costs for the dispenser (manufacturer's selling price – discount + S&H fees), maker, model or style, and electro-acoustic features for each device. There are a total of 22 electro-acoustic features available in a hearing aid, but a number of them are optional. See Table D.2 in Appendix D for a thorough explanation of the electro-acoustic features.

Data from hearing aid contracts were used to find final retail prices and insurance information for a given subject. Hearing aid contracts are purchase agreements made between the end-users and the dispenser (in this case, a West Texas audiological clinic). I also used these contracts and the accompanying hearing aid data sheets to confirm information regarding the model, style, manufacturer, and dispensing fees.

Finally, using patient log sheets, the ordering and dispensing dates of devices were verified. These sheets contain meticulous details of each clinical visit made by a patient and were used to sort out any confusion that might arise from unclear transactions. Patients' demographic characteristics, such as age and gender, were extracted directly from case history forms for the reason of maximum accuracy.

From these invoices, I located pricing data for 254 hearing instruments from June 2001 to May 2005. Relevant variables included are the patient ID, age, gender, employment status, residence, firm, model, manufacturer list price, discount, total dispenser cost, retail price, payment method and insurance amount, date ordered and shipped, and 22 possible technological components. Summary statistics are given below.

5.3.2. Summary Statistics

After accounting for missing data, 254 observations on nine brands of devices were analyzed. Table 5.1a presents the distribution of observations across the style and signal processing scheme. In terms of the style and processor, ITE and digital were the most popular; each had a market share of 54.33% and 51.18%, respectively. Fifty-nine purchases were made for digital ITE – the largest of any processor-style combination. The least sold style was the CIC across all processor types; in fact, there was no observation for analog CIC. This appears somewhat surprising since CIC is the least visible of the styles and, for reasons of "vanity," might be more in demand. However, the high cost of CIC instrument may be a factor in consumers' purchasing decisions. In Table 5.1b, the sales of hearing aids by the style-processor combinations and brand/manufacturer are broken down. The last column of the table represents the market shares of firms over the period studied. Firm 8 had a predominant market share that amounted to 34.25% of the "entire market," with the next firm accounting for only half as much. The skewed market structure is indicative of the fact that vendor effects might be important even in the regression analysis. Market shares of the nine manufacturers included in this study are displayed in a pie-graph in Figure 5.1.

Table 5.2 summarizes the different components of the average retail price for the 12 style-by-processor combinations. The list price or manufacturer selling price is the highest for digital CIC. Digital processor has the highest manufacturer price in all styles too, except in BTE, where AP, at \$592.75, is slightly more expensive than digital, at \$580.64. However, this difference is statistically insignificant and I can infer that, keeping style constant, digital technology contributes the most to the price of a hearing aid. Furthermore, the statistical summary suggests that these price increments are not the same across processor types. While an AP-ITE costs \$63.42 (\$529.33 – \$592.75) less than an AP-BTE, a DP-ITE costs \$98.27 (\$678.91 – \$580.64) more than a DP-BTE. This irregularity can be explained by considering the additional 22 optional functional and technical components that a hearing aid might possess. The same trend continues even in the final retail price which includes the hearing aid service or professional fee, besides the shipping and handling fees. The professional fee is a fixed audiologist fee for fitting or dispensing the hearing aid. It is a one-time charge and varies according to the end-user's payment method. For instance, if a patient paid for the aid out-of-pocket, s/he would be charged a one-time fee of \$125.00 regardless of the number of devices acquired. For someone who pays with Medicaid, the dispensing fee is regulated at \$63.03.

It is possible that for hearing instruments like ITE, ITC, and CIC, the audiologist's role would be greater in dispensing them than for BTE, since the former are more sophisticated in terms of design and technology. This holds true for all processor types, barring AP. The smaller and more inside-the-ear the hearing aid, the greater the premium the audiologist can charge. This can be seen in column 5 (i.e., the average price-cost margins for the dispenser). On average, more than 30% of the end-user price is made up of the dispenser fee, professional service charge, and shipping and handling fees. This margin is the least for the BTE styles across all processor types, although the margins fluctuate in ranking across the other three types of styles across the different processor types.

Next, in Table 5.3, I analyze the trend of nominal list prices over the period of the study for each of the 12 combinations of style and signal processing scheme. Note that there is no uniform trend in the prices. If omitting 2001 and 2005 (since the data for these two years contain observations for only a quarter or two), then for the three years – 2002, 2003, and 2004 – for which there is consistent data, it was found that for DP-ITE, the average list price dropped from $780.00 in 2002 to $571.46 in 2004. Likewise, for AA-BTE, the price dropped from $433.38 in 2002 to $306.99 in 2004. An analogous decreasing movement in the wholesale price can be found for AA-ITE, which was priced at $372.92 in 2002 but declined to $327.85 and $316.16 in 2003 and 2004, respectively. For all other categories, there was no systematic development. A downward trend on prices is to be expected from fast-changing technologies with competitive market structures. The technology for hearing aids, however, is not very dynamic. The market structure, too, is described as a "friendly oligopoly" at best, where firms continue to charge the price they think fair and market shares remain almost in a status quo. For almost the same style and processor combination, there is a wide range of prices that manufacturers can charge. Hearing aid prices by each manufacturer are shown in Table D.1 of the appendix.

Table 5.4 lists the descriptive statistics on the various technology variables used in the regression analysis. A description of these variables is provided in Table D.2 in the appendix.

While patient characteristics are not pertinent to the analysis of the manufacturer list price, they are important in explaining the retail price of a hearing aid. Thus, for the curious reader, summary statistics on patient characteristics are given in Table D.3 of the appendix.

5.4. Empirical Model and Estimation

5.4.1. The Empirical Model

This study uses a linear log hedonic price model. Since the purpose of this chapter is to determine how technology and perceived characteristics of hearing aids affect manufacturer wholesale prices, I employ two specifications for this model: (1) the base case specification that includes only the 7 (= 4 + 3) technology variables which have been coded as the style and processor types, and (2) the more elaborate specification that embraces a host of other technology variables (Table 5.4). Almost all of the 22 technical variables have been represented as dummies, except the number of memory and channel, which are quantity variables. The base empirical model is thus given:

$$\log \mathrm{P}_{iyt} = \beta_0 + \sum \beta_j (style \text{ or } processor) + \varepsilon_{yt} \tag{1}$$

where P_{iyt} is the base price of the hearing aid i from the manufacturer y in the year t. The variables style and processor are sets of dummy variables that identify hearing aid styles and signal processing schemes. The random disturbance term, ε, is assumed to be independently and identically distributed. The elaborate version of the model can then be augmented by adding firm dummies, quarterly dummies, and other relevant functional and technical variables to the equation.

5.4.2. Estimation Results

The hearing aid style and signal processing scheme are two main variables that manufacturers might deem valuable in contributing to the consumer's willingness to pay. Style is especially important when one considers the perception of stigma associated with wearing a visible and chunky hearing device. Prior research validates the assumption that purchasers of hearing aids are more willing to accept these devices as they become smaller (Kochkin, 2002). The signal processing scheme has also become increasingly vital in view of the fact that manufacturers are replacing the outdated analog lines with more technologically advanced DP product lines. Table 5.5 reports the results from the regression analysis. The reference processor type is analog (AA) and the reference style is BTE. In Model 1, the seven most basic technology variables, namely the four types of style (BTE, ITE, ITC, and CIC) and the three kinds of signal processing schemes (AA, AP, and DP), are included. As expected, both DP and AP processors contribute statistically and significantly to the manufacturer price compared to AA technology. In terms of style, ITE has an insignificant impact while ITC and CIC have positive influences on prices. As mentioned before, vendor effects are suspected to be present in the hearing aid market. Thus, in column 2, Model 2 incorporates the firm as well as time-quarter effects. The F-test for the joint restriction of no vendor and time effects is rejected. Hence, the vendor and time effects are retained subsequently (F (23, 225) = 6.86), although only two out of the nine firms have significant coefficients while 14 out of the 17 time-quarters are statistically significant. Next, in Model 3, I added all the other technology variables.[24] While a majority of these electro-acoustic variables are not significant, their joint significance is supported by an F-test (F (36, 189) = 18.74).

Of the aforementioned seven styles and processor dummies, signal processing schemes continue to be statistically significant. The model certainly shows an improvement in the fitness measure, as the adjusted R-square increases from .541 in Model 2 to .767 in Model 3. Among the other significant technology variables, noise cancellation and directional microphone are terms that lend themselves to easy comprehension by the consumer. Therefore, it is not surprising that their presence allows a manufacturer to raise the price. The fact that most style variables lose their significance upon addition of the other technology variables may indicate that the technology variables are perhaps components of the style variables themselves or that style is not independently valued by the consumer. Hence, in Model 4, I ran the full model but used the style and processor interaction terms instead of controlling them individually. Here, it was found that given an AA, both ITE and ITC styles had reduced prices compared to the reference group AA-BTE. The coefficients for AP-BTE and AP-ITE also show a similar pattern. For the remaining DP scheme, all styles have positive coefficients but only CIC is statistically significant. Thus, for a DP signal processing scheme, a CIC style would increase the manufacturer price by 31.10% while an ITC would increase it by

---

[24] Refer to Table D.2 for a through description.

12.70% over the reference category, AA-BTE. Likewise, there is a similar ranking in the impact for AP over ITC and CIC styles. Overall, it appears that if a BTE style is being chosen, then manufacturers can charge the maximum for a DP than for either an AA or AP. If a CIC style is selected, then DP commands a greater premium than AP. The quarterly indicator variables are largely negative, as in the other two models. These time coefficients are illustrated in Figure 5.2, which shows an average negative price drift in hearing aids over the period of this study.

5.5. Conclusion

The aim of this chapter is to determine whether there is any systematic relationship between hearing aid technology and prices. The conventional hedonic price method was applied to a unique dataset of 254 observations acquired from a local audiological practice. Findings indicate that if not controlling for any other technological features, amid the different styles and processor types available to a consumer, the DP technology tends to increase prices. Equally, the smaller the hearing aid, the greater the upward pressure on prices, as reflected by the ITC and CIC styles. Another objective of this chapter is to provide a summary description of the pricing behaviors in the secondary market within the hearing aid industry. It was found that, on average, the price-cost margin for a typical public dispenser is 0.352 or approximately 35% of the retail price of the hearing aid.

There is a wide range of prices which the few manufacturers of hearing aids charge for what seems to be a fairly standard device. This study identified two sets of drivers for the list price of hearing aids. First, there are the technology variables, which demonstrate that the smaller the style and the more “advanced” the processor type, the higher the premium that a firm can charge. Second, there are joint vendor effects, indicating that firms charge high premiums for some reasons other than the technology variables controlled in this study. Perhaps these firm effects are proxies for their unique marketing channels or advertising efforts. Such efforts could not be identified in the data and the author contends that with this analysis it can only be inferred that, besides the technology itself, firms in the hearing aid market have a substantial influence on price.

The summary statistics on patient characteristics, in Table D.3, suggest that the traits of the sampled population are comparable to those of the national and international clinics. Therefore, I am confident that this study provides a reasonably comprehensive analysis of the major factors contributing to the cost of hearing aids in the secondary market. From the manufacturer’s perspective, digital technology and miniaturizations have a consequential effect on pricing behaviors. At the distribution level, the dispenser markup also adds significantly to the final retail price of hearing aids. Consequently, hearing aid consumers have to absorb higher costs independent of technology.

Table 5.1a: Summary Statistics of Hearing Aid Style and Processor Type, June 01, 2001 – May 31, 2005

Signal Processing Scheme	Style				Total	Percent of Total
	BTE	ITE	ITC	CIC		
AA	23	49	6	0	78	30.71
AP	4	30	8	4	46	18.11
DP	39	59	16	16	130	51.18
Total	66	138	30	20	254	100.00
Percent of Total	25.98	54.33	11.81	7.87	100.00	

Table 5.1b: Total Number of Hearing Aids Sold by Manufacturer, June 01, 2001 – May 31, 2005

Manufacturer	Types of Hearing Aid												Total	Percent of Total
	AA				AP				DP					
	BTE	ITE	ITC	CIC	BTE	ITE	ITC	CIC	BTE	ITE	ITC	CIC		
1	1	0	0	0	0	0	0	0	4	2	0	0	7	2.76
2	0	4	0	0	0	6	1	0	0	10	4	2	27	10.63
3	8	0	0	0	1	0	0	0	11	2	2	0	24	9.45
4	5	1	0	0	0	0	2	0	15	4	4	4	35	13.78
5	0	2	0	0	0	0	0	0	3	9	0	0	14	5.51
6	0	11	0	0	0	21	4	4	0	2	0	2	44	17.32
7	0	0	0	0	0	0	0	0	2	0	0	0	2	.79
8	9	30	6	0	3	3	1	0	2	23	4	6	87	34.25
9	0	1	0	0	0	0	0	0	2	7	2	2	14	5.51
Total	23	49	6	0	4	30	8	4	39	59	16	16	254	100.00

Table 5.2: Summary Statistics of Average Prices, June 01, 2001 – May 31, 2005

Types of Hearing Aid	Manufacturer – to – Dispenser Price			Dispenser – to – End-user Price	Price-cost Margin[25] (5) = [(4) – (3)] / (4)
	Manufacturer Selling Price (List price) (1)	Discounted Selling Price (2) = (1) – Manufacturer Discount	Total Dispenser Cost (3) = (2) + S&H fee	Total Retail Price (4)	(PCM)
AA – BTE	378.13	330.84	335.49	504.38	.300
	(129.45)	(106.33)	(109.27)	(176.22)	(.171)
AA – ITE	346.30	313.86	319.43	526.65	.351
	(68.83)	(54.49)	(56.59)	(159.20)	(.187)
AA – ITC	349.65	328.15	333.98	1021.34	.531
	(90.53)	(99.16)	(97.96)	(848.16)	(.235)
AP – BTE	592.75	445.25	453.12	728.26	.291
	(203.33)	(218.71)	(219.83)	(508.69)	(.269)
AP – ITE	529.33	394.80	401.47	600.79	.299
	(242.24)	(167.68)	(166.95)	(263.52)	(.201)
AP – ITC	747.61	617.66	626.03	1081.55	.389
	(198.73)	(154.62)	(152.82)	(336.34)	(.178)
AP – CIC	876.50	825.50	828.25	1182.75	.296
	(117.20)	(176.09)	(172.92)	(34.35)	(.167)
DP – BTE	580.64	570.10	575.90	895.21	.279
	(279.31)	(270.88)	(271.70)	(525.10)	(.198)
DP – ITE	678.91	582.80	590.66	925.05	.336
	(347.50)	(343.78)	(342.47)	(493.33)	(.196)
DP – ITC	773.12	610.32	615.94	1379.58	.549
	(212.29)	(165.96)	(165.72)	(220.85)	(.124)
DP – CIC	1004.19	729.81	734.87	1434.37	.511
	(296.69)	(374.42)	(375.98)	(645.34)	(.292)
Average	577.32	491.68	497.92	836.10	.352
Number of Observations	254	254	254	254	254

---

[25] The PCM was calculated as the average of relevant observation's PCM rather than straight from the columns of Table 5.2. Thus, the column 5 entries may not correspond exactly with a calculation based on the entries in columns 4 and 3.

Table 5.3: Average Manufacturer List Prices by Year and Type of Hearing Aid[26]

Types of Hearing Aid		2001	2002	2003	2004	2005
AA	BTE	357.50	433.38	377.52	306.99	
	ITE	337.59	372.92	327.85	316.16	532.00
	ITC	341.48	399.98	214.98		
	CIC					
AP	BTE	650.00	300.00		771.00	
	ITE	393.65	572.54	464.00		
	ITC		766.49	728.74		
	CIC	775.00	978.00			
DP	BTE		575.00	625.50	537.95	633.78
	ITE	1325.20	780.00	747.67	571.46	603.00
	ITC			828.49	700.35	770.00
	CIC			836.87	929.65	1367.00

---

[26] The blanks represent no sales of the particular combination of hearing aid in that year.

Table 5.4: Descriptive Statistics of the Variables used in the Regressions

Variables	Mean	Standard Deviation
Signal Processing Scheme		
(AA)	.307	(.462)
AP	.181	(.386)
DP	.512	(.501)
Style		
(BTE)	.260	(.439)
ITE	.543	(.499)
ITC	.118	(.323)
CIC	.079	(.270)
Signal Processing*Style Interactions		
(AA-BTE)	.091	(.288)
AA-ITE	.193	(.395)
AA-ITC	.024	(.152)
AP-BTE	.016	(.125)
AP-ITE	.118	(.323)
AP-ITC	.031	(.175)
AP-CIC	.016	(.125)
DP-BTE	.154	(.361)
DP-ITE	.232	(.423)
DP-ITC	.063	(.243)
DP-CIC	.063	(.243)
Manufacturer Dummies		
(Firm 1)	.028	(.164)
Firm 2	.106	(.309)
Firm 3	.094	(.293)
Firm 4	.138	(.345)
Firm 5	.055	(.229)
Firm 6	.173	(.379)
(Firm 7)	.008	(.089)
Firm 8	.343	(.475)
Firm 9	.055	(.229)
Quarterly Dummies		
(Quarter 1)	.008	(.089)
Quarter 2	.055	(.229)
Quarter 3	.028	(.164)
Quarter 4	.067	(.250)
Quarter 5	.075	(.264)
Quarter 6	.043	(.204)
Quarter 7	.051	(.221)
Quarter 8	.043	(.204)
Quarter 9	.059	(.236)
Quarter 10	.067	(.250)
Quarter 11	.083	(.276)
Quarter 12	.043	(.204)
Quarter 13	.055	(.229)

Table 5.4. Continued.

Quarter 14	.079	(.270)
Quarter 15	.091	(.288)
Quarter 16	.098	(.298)
Quarter 17	.055	(.229)
Technical Variables		
Output Limiting		
(CL)	.173	(.379)
Linear	.004	(.063)
PC	.130	(.337)
WDRC	.248	(.433)
CLPC	.024	(.152)
CLWDRC	.319	(.467)
CLPCWDRC	.063	(.243)
CLadaptiveC	.004	(.063)
WDRCadaptiveC	.008	(.089)
Transposition	.028	(.164)
Circuit		
(Class A)	.016	(.125)
Class B	.079	(.270)
Class D	.906	(.293)
Shell Material		
(Acrylic)	.130	(.337)
Hyperallergenic	.008	(.089)
Laser	.051	(.221)
Nemotech	.008	(.089)
UV	.783	(.413)
Vinyl	.020	(.139)
Quantity Variables		
Number of memories	1.445	(1.090)
Channel	3.335	(4.057)
The following technology variables are all distinct dummies:		
Telecoil	.630	(.484)
Directional microphone	.185	(.389)
DAI	.110	(314)
Boot	.083	(.276)
Venting	.575	(.495)
Volume control	.803	(.398)
Remote control	.012	(.108)
Removal aids	.445	(.498)
Gain	.787	(.410)
Output	.752	(.433)
Low-cut	.909	(.288)
High-cut	.709	(.455)
Resonance peak	.197	(.398)
Crossover	.350	(.478)
Threshold kneepoint	.622	(.486)
Compression ratio	.370	(.484)

Table 5.4. Continued

Feedback reduction	.283	(.452)
Noise cancellation	.272	(.446)

Table 5.5: Estimation Results for Log of Manufacturer Selling Price

Variables	Model 1	Model 2	Model 3	Model 4
	Base Model (1)	(2) = (1) + firm dummies + quarterly dummies	(3) = (2) + other technology variables	Full Model (4)
Constant	5.808*	6.348*	6.036*	6.372*
	(.053)	(.212)	(.255)	(.272)
Processor				
AP	.399*	.331*	.091	
	(.062)	(.081)	(.087)	
DP	.518*	.623*	.238*	
	(.053)	(.085)	(.101)	
Style				
ITE	.033	.089	-.160	
	(.061)	(.077)	(.082)	
ITC	.249*	.240*	-.016	
	(.081)	(.087)	(.104)	
CIC	.557*	.531*	.128	
	(.073)	(.106)	(.115)	
Processor*Style Interactions				
AA-ITE				-.217*
				(.102)
AA-ITC				-.275
				(.164)
AP-BTE				-.254
				(.166)
AP-ITE				-.155
				(.115)
AP-ITC				.203
				(.157)
AP-CIC				.207
				(.153)
DP-BTE				.188
				(.114)
DP-ITE				.054
				(.109)
DP-ITC				.127
				(.141)
DP-CIC				.311*
				(.143)
Manufacturer Dummies				
Firm 2		.064	.234	.235
		(.180)	(.203)	(.208)
Firm 3		-.175	.062	.054
		(.176)	(.214)	(.218)
Firm 4		-.070	.111	.081
		(.188)	(.176)	(.176)
Firm 5		-.700*	-.470*	-.465*
		(.190)	(.183)	(.181)
Firm 6		-.208	.157	.153
		(.178)	(.218)	(.208)

Table 5.5. Continued.

Firm 8	-.203	.023	.044
	(.178)	(.209)	(.207)
Firm 9	-.414*	-.151	-.163
	(.191)	(.200)	(.203)
Quarterly Dummies			
Quarter 2	-.275*	-.234	-.568*
	(.127)	(.164)	(.172)
Quarter 3	-.297	-.488*	-.707*
	(.157)	(.217)	(.199)
Quarter 4	-.335*	-.172	-.470*
	(.123)	(.179)	(.188)
Quarter 5	-.419*	-.333*	-.597*
	(.145)	(.165)	(.172)
Quarter 6	-.248	-.331	-.628*
	(.170)	(.189)	(.159)
Quarter 7	-.388*	-.387*	-.678*
	(.117)	(.177)	(.175)
Quarter 8	-.382*	-.417*	-.700*
	(.136)	(.179)	(.175)
Quarter 9	-.541*	-.383*	-.708*
	(.128)	(.160)	(.162)
Quarter 10	-.417*	-.332	-.642*
	(.135)	(.199)	(.190)
Quarter 11	-.401*	-.327	-.618*
	(.137)	(.167)	(.168)
Quarter 12	-.366*	-.228	-.475*
	(.135)	(.172)	(.167)
Quarter 13	-.488*	-.394*	-.677*
	(.139)	(.165)	(.177)
Quarter 14	-.355*	-.422*	-.725*
	(.136)	(.147)	(.173)
Quarter 15	-.835*	-.569*	-.854*
	(.156)	(.165)	(.183)
Quarter 16	-.392*	-.499*	-.778*
	(.147)	(.158)	(.175)
Quarter 17	-.381*	-.428*	-.713*
	(.156)	(.174)	(.186)
Technologies			
Output Limiting			
Linear		.193	.258
		(.186)	(.183)
PC		.034	.015
		(.098)	(.099)
WDRC		.055	.095
		(.058)	(.062)
CLPC		-.027	-.032
		(.264)	(.261)
CLWDRC		-.041	-.005
		(.062)	(.060)
CLPCWDRC		-.237*	-.148
		(.108)	(.120)

Table 5.5. Continued.

CLadaptiveC	.209	.134
	(.194)	(.162)
WDRCadaptiveC	-.389*	-.302*
	(.121)	(.129)
Transposition	.382	.366
	(.279)	(.281)
Circuit		
Class B	-.051	.010
	(.169)	(.182)
Class D	-.010	.023
	(.130)	(.143)
Shell Material		
Hyperallergenic	.514*	.383
	(.224)	(.209)
Laser	-.007	.022
	(.142)	(.163)
Nemotech	-.925*	-.818*
	(.160)	(.179)
UV	.086	.098
	(.077)	(.073)
Vinyl	.204	.244
	(.183)	(.188)
Quantity Variables		
Number of memories	.112	.098
	(.091)	(.098)
Channel	.016	.025
	(.040)	(.042)
Other Distinct Dummies		
Telecoil	-.008	-.003
	(.038)	(.037)
Directional microphone	.221*	.214*
	(.059)	(.058)
DAI	-.520*	-.571*
	(.133)	(.137)
Boot	.191	.242
	(.171)	(.173)
Venting	.050	.035
	(.052)	(.053)
Volume control	-.035	-.061
	(.070)	(.069)
Remote control	-.245	-.243
	(.176)	(.193)
Removal aids	.101*	.089
	(.051)	(.049)
Gain	.064	.062
	(.095)	(.093)
Output	-.075	-.103
	(.082)	(.083)
Low-cut	.001	-.010
	(.075)	(.076)

Table 5.5. Continued.

High-cut			.120*	.129*
			(.055)	(.057)
Resonance peak			-.010	-.007
			(.079)	(.087)
Crossover			.107	.111
			(.063)	(.063)
Threshold kneepoint			.017	.000
			(.075)	(.080)
Compression ratio			.156*	.155*
			(.062)	(.059)
Feedback reduction			.046	.066
			(.074)	(.077)
Noise cancellation			.296*	.282*
			(.072)	(.073)
Number of Observations	254	254	254	254
Adj. R^2	.380	.541	.767	.774

Standard errors are in parentheses. * Significant at the .05 level.

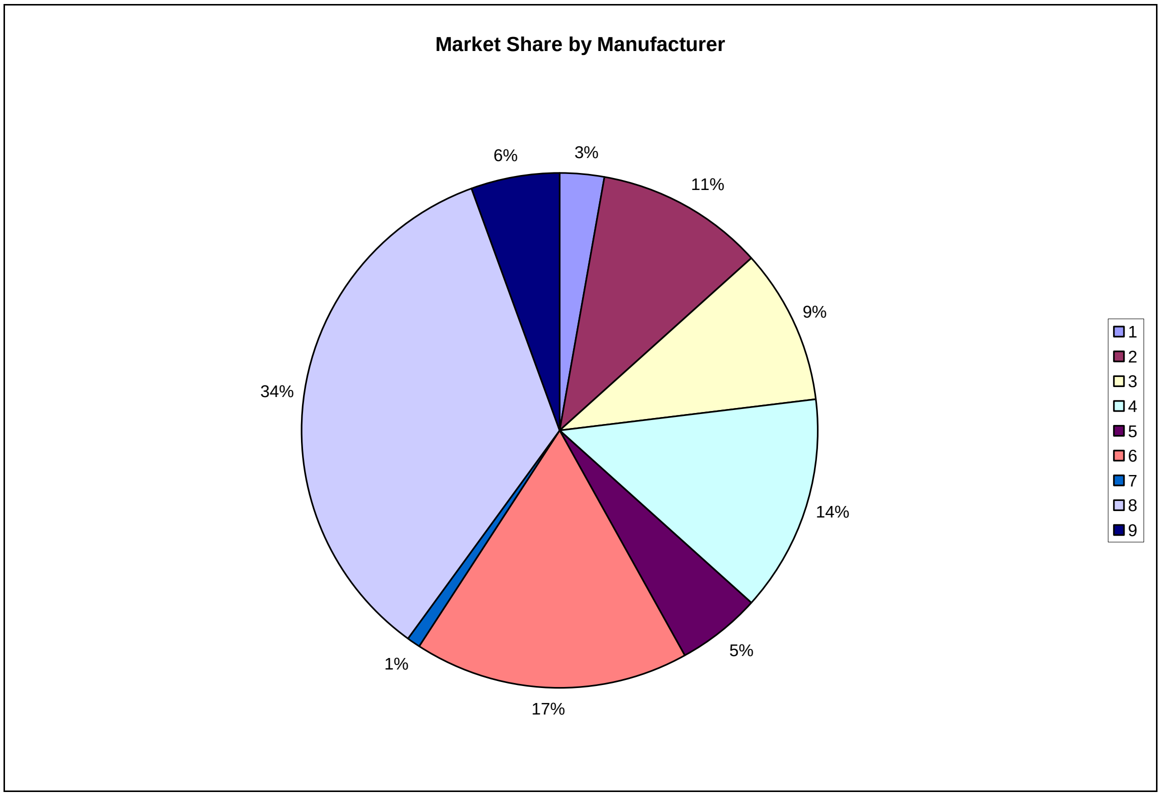

Figure 5.1: Market Share of the Nine Firms

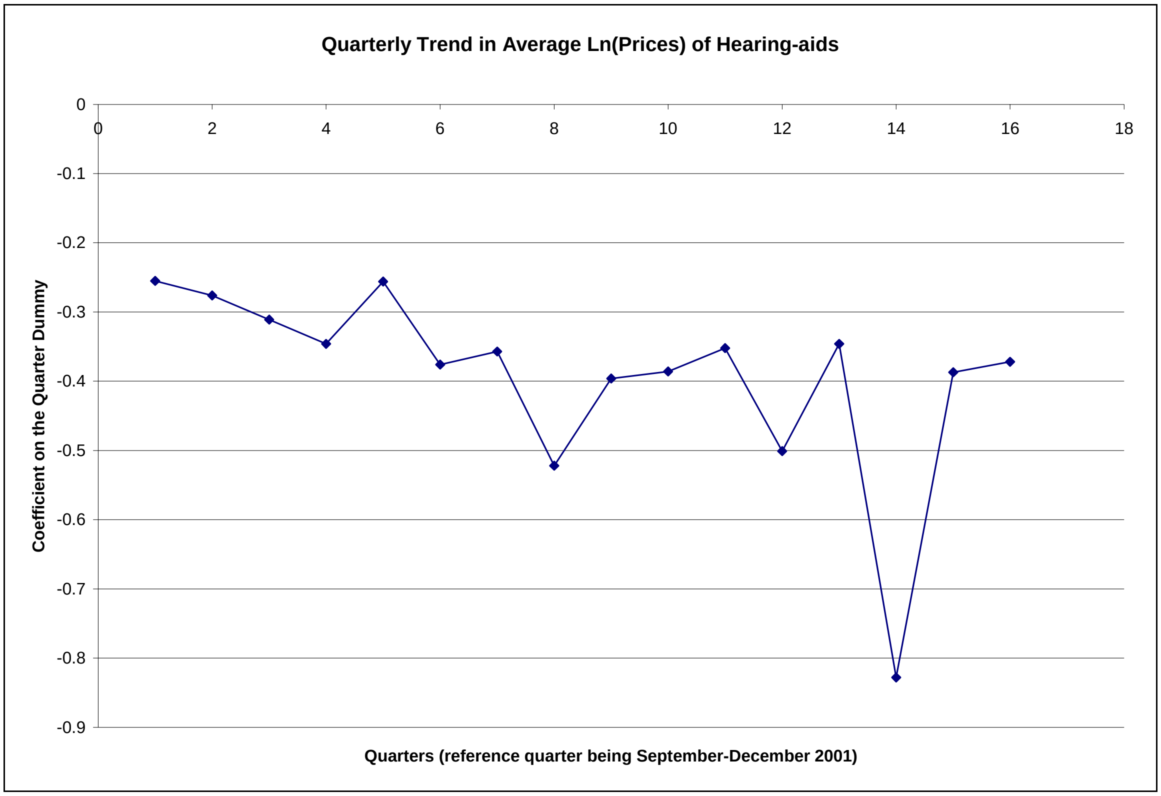

Figure 5.2: Quarterly Time Trend in Log of Manufacturer Price

CHAPTER VI

CONCLUSIONS

6.1. Introduction

Hearing is critical for the development of speech, language, and communication skills. The loss of hearing, conversely, can cause social tension and emotional fatigue for the hearing-impaired individuals and for their family members and friends. Yet many people do not realize that most hearing losses can be corrected partially with assistive devices such as hearing aids.

This study focuses on the issues of hearing loss by analyzing its causes and degree of impact. It aims to provide an explanation for the poor hearing aid penetration rate from the consumers' perspectives. Specifically, an attempt was made to determine the factors that might influence hearing aid procurement. The study also examines the relationship between the technical features of hearing aids and their prices.

The research consists of three empirical essays. The first essay is entitled "The Causes and Their Degree of Impact on Hearing Loss." It was found that age, gender, recurring ear infection, and diabetes are, by far, the most critical factors initiating hearing loss in adult. Summary statistics suggest that although approximately 83% of adult patients were diagnosed with a hearing loss using audiometric data, yet only slightly over 50% of patients would consider purchasing a hearing aid. The possible factors that contributed to this divergence between the number of hearing-impaired and hearing aid purchase is the subject of the second essay, which is entitled “The Impact of Payment Method on Hearing Aid Selection.”

The second essay investigates the demographic and socioeconomic factors that most likely result in hearing aid procurement. The results suggest that payment method is negatively related to hearing aid style and signal processing selections. Consumers who are financially secured are likely to choose an expensive and less visible style. The actual retail price paid by the patient, on the contrary, implies a positive relation with hearing aid purchasing decisions, but the scale of its coefficients is relatively small.

The third essay, entitled “A Hedonic Price Analysis of Hearing Aid Technology,” analyzes the relationships between hearing aid product characteristics and their varying costs and prices. Empirical findings show that, amid the different style and processor types available to a consumer, digital technology contributes positively to price increases. Equally, the smaller the hearing aid, the greater the upward pressure on prices, as reflected by the ITC and CIC styles. Summary statistics reveal that, on average, hearing aid markup factor is approximately 35%.

6.2. Limitations of the Study

The main limitation of this research is its sample size. It was intended from the beginning that this study should be an empirical analysis. The primary threat, therefore, lies in the possibility of insufficient data points, which may undermine the accurateness of some of the results.

6.3. Implications for Future Research

While the sample size used is small, the methods employed in this research can be applied to a larger dataset for future studies. The existing empirical literature on the hearing aid market is fairly sparse and leaves many interesting questions unattended. For example, how do hearing aid manufacturers compete in the market? Although Lee and Lotz (1998) have provided a historical perspective on the issue, no attempt has been made to analyze it using an econometric model. Therefore, it is important to be able to construct a systematic model that explores how manufacturers' pricing strategies, incentive schemes, advertising efforts, and product variety affect the market structure. Researchers can also examine the relationship between product variety and rival competition in the retail market for hearing aids. Further study on the role of dispensers as "middleman" may impart additional insight on hearing aid pricing behaviors.

6.4. Conclusion

Hearing aid penetration depends on many factors and on many levels. For the end-users, the perception of product quality, stigma, and the lack of trust for professional help are primary factors. The systematic character of hearing aid technology itself and the slow adoption rate of new technology at the distribution level also contribute to the poor market performance. The primary aim of this research is to examine the different factors that impact hearing aid procurements and penetration. These factors include technology, hearing aid style, price, third-party payments, and consumer behaviors in the market.

BIBILOGRAPHY

Aaron M. J. "An Economic Study of the United States Hearing Aid Industry: A Demand- and Supply-Side Examination." Ph.D. Dissertation, University of Illinois at Chicago, Chicago, Illinois, 1987.

Adelman, Irma and Griliches, Zvi. "On an Index of Quality Change." *Journal of the American Statistical Association* 56 (1961): 535-548.

Amlani, Amyn M. and De Silva, Dakshina G. "Effects of Business Cycle and FDA Intervention on the Hearing Aid Industry." *American Journal of Audiology* 14.1 (2005): 1-9.

Arkis, P. and Burkey J. "What WRS's Say about Client Performance, Adjustment to Hearing Aids. Word Recognition Scores: Do They Support Adaptation?" *Hearing Instruments* 45.1 (1994): 24-25.

Bailey, Martin J., Muth, Richard F., and Nourse, Hugh O. "A Regression Method for Real Estate Price Index Construction." *Journal of the American Statistical Association* 58.304(1963): 933-942.

Benkard, C. Lanier and Bajari, Patrick. "Hedonic Price Indexes with Unobserved Product Characteristics and Application to Personal Computers." *Journal of Business and Economic Statistics* 23.1 (Jan., 2005): 61-75.

Bentler, R.A., Niebuhr, D.P., Getta, J.P., and Anderson C.V. "Longitudinal Study of Hearing Aid Effectiveness I: Objective Measures." *Journal of Speech and Hearing Research* 36 (1993a): 808-819.

Bentler, R.A., Niebuhr, D.P., Getta, J.P., and Anderson, C.V. "Longitudinal Study of Hearing Aid Effectiveness II: Subjective Measures." *Journal of Speech and Hearing Research* 36 (1993b): 820-831.

Berndt, Ernst R., Griliches, Zvi, and Rappaport, Neal J. "Econometric Estimates of Price Indexes for Computers in the 1990s." *Journal of Econometrics* 68 (1995): 243-268.

Berndt, Ernst R. and Rappaport, Neal J. "Price and Quality of Desktop and Mobile Personal Computers: A Quarter-Century History Overview." *American Economic Review* 91.2 (May, 2001): 268-273.

Berry, Steven T. "Estimating Discrete-Choice Models of Product Differentiation." *Rand Journal of Economics* 25.2 (Summer, 1994): 242-262.

Berry, Steven T., Levinsohn, James, and Pakes, Ariel. "Automobile Prices in Market Equilibrium." *Econometrica* 63.4 (July, 1995): 841-890.

Bresnahan, Timothy F. "Comment on the Valuation of New Goods under Perfect and Imperfect Competition." *The Economics of New Goods*. National Bureau of Economic Research Studies in Income and Wealth, Volume 58. Ed. Timothy F. Bresnahan and Robert J. Gordon. Chicago, IL: University of Chicago Press, 1996. 237-247.

Bresnahan, Timothy F. "The Apple-Cinnamon Cheerios War: Valuing New Goods, Identifying Market Power, and Economic Measurement." Mimeo, 1997.

Buccola, Steven and Iizuka, Yoko. "Hedonic Cost Models and the Pricing of Milk Components." *American Journal of Agricultural Economics* 79.2 (May, 1997): 452-462.

Chwelos, Paul. "Approaches to Performance Measurement in Hedonic Analysis: Price Indexes for Laptop Computers in the 1990's." *Economics of Innovation and New Technology* 12.3 (2003): 199-224.

Chwelos, Paul D., Berndt, Ernst R., and Cockburn, Iain M. "Faster, Smaller, Cheaper: A Hedonic Price Analysis of PDAs." National Bureau of Economic Research working paper 10746, September, 2004.

Combris, Pierre, Lecocq, Sebastien, and Visser, Michael. "Estimation of a Hedonic Price Equation for Bordeaux Wine: Does Quality Matter?" *Economic Journal* 107.441 (March, 1997): 390-402.

Court, Andrew T. "Hedonic Price Indexes with Automotive Examples. *The Dynamics of Automobile Demand*. New York: General Motors, 1939. 99-117.

Cox, R.M. and Alexander, G.C. "Maturation of Hearing Benefit: Objective and Subjective Measurements." *Ear and Hearing* 13 (1992): 131-141.

Cox R.M., Alexander, G.C., and Gray, G. "Personality and the Subjective Assessment of Hearing Aids." *Journal of the American Academy of Audiology* 10 (1999): 1-13.

Cox, R.M. and Alexander, G.C. "Expectations about Hearing Aids and Their Relationship to Fitting Outcome." *Journal of the American Academy of Audiology* 11 (2000): 368-382.

Epple, Dennis. "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products." *Journal of Political Economy* 95.1 (Feb., 1987): 59-80.

Dillon, H. *Hearing Aids*. New York, NY: Thieme, 2001.

Dhrymes, Phoebus J. "Price and Quality Changes in Consumer Capital Goods: An Empirical Study. *Price Indexes and Quality Changes: Studies in New Methods of Measurement*. Ed. Zvi Griliches. Cambridge, MA: Harvard University Press, 1971. 88-149.

Fallis, George and Smith, Lawrence B. "Price Effects of Rent Control on Controlled and Uncontrolled Rental Housing in Toronto: A Hedonic Index Approach." *Canadian Journal of Economics* 18.3 (Aug., 1985): 652-659.

Gandal, Neil. "Hedonic Price Indexes for Spreadsheets and an Empirical Test for Network Externalities." *Rand Journal of Economics* 25.1 (Spring, 1994): 160-170.

Gatehouse, S. "The Time Course and Magnitude of Perceptual Acclimatization to Frequency Responses: Evidence from Monaural Fitting of Hearing Aids." *Journal of the Acoustical Society of America* 92 (1992): 1258-1268.

Gatehouse, S. "Role of Perceptual Acclimatization in the Selection of Frequency Responses for Hearing Aids." *Journal of the American Academy of Audiology* 4 (1993): 296-306.

Gavett, Thomas W. "Research on Quality Adjustments in Price Indexes, Part III: Experiments in Multivariate Analysis of Quality Change." Bureau of Labor Statistics memorandum (Office of Prices and Living Conditions). Washington D. C., 1967.

Goldberg, Pinelopi K. "Product Differentiation and Oligopoly in International Markets: The Case of the U.S. Automobile Industry." *Econometrica* 63.4 (July, 1995): 891-951.

Greene, W.H. *Econometric Analysis*. Fourth Ed. Upper Saddle River, NJ: Prentice Hall, 2000.

Griliches, Zvi. "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change." *The Price Statistics of the Federal Government*. National Bureau of Economic Research Staff Report No. 3, General Series No. 73. New York: Columbia University Press, 1961. 173-196.

Griliches, Zvi. "Notes on the Measurement of Price and Quality Changes." *Models of Income Determination*. National Bureau of Economic Research Studies in Income and Wealth, Volume 28. Princeton, NJ: Princeton University Press, 1964. 381-418.

Griliches, Zvi, ed. *Price Indexes and Quality Change*. Cambridge, MA: Harvard University Press, 1971.

Hausman, Jerry A. "Valuation of New Goods under Perfect and Imperfect Competition." *The Economics of New Goods*. National Bureau of Economic Research Studies in Income and Wealth, Volume 58. Ed. Timothy F. Bresnahan and Robert J. Gordon. Chicago, IL: University of Chicago Press, 1996. 209-237.

Hausman, Jerry A. "Reply to Professor Bresnahan." Mimeo, 1997.

Hausman, Jerry, Leonard, Gregory, and Zona, J. Douglas. "Competitive Analysis with Differenciated Products." *Annals d'Economie et de Statistique* 34 (1994): 159-180.

Hetu, R. "The Stigma Attached to Hearing Impairment." *Scandinavian Audiology* 25 (Suppl. 43) (1996): 12-24.

Horowitz, A. and Turner, C. "The Time Course of Hearing Aid Benefit." *Ear and Hearing* 18 (1997): 1-11.

Humes, L.E. "Dimensions of Hearing Aid Outcomes." *Journal of the American Academy of Audiology* 10 (1999): 26-39.

Kirkwood, D.H. "After a Two-year Slump, Hearing Aid Market Shows First Signs of Recovery." *Hearing Journal* 47.12 (1994): 7-13.

Kirkwood, D.H. "Dispensers in Survey Take Satisfaction in Their Work, but Many Feel Unappreciated." *Hearing Journal* 52.3 (1999): 19-32.

Kirkwood, D.H. "To Expand Market, Dispensers in Survey Urge More Consumer Education, Marketing." *Hearing Journal* 53.4 (2000): 21-33.

Kirkwood, D.H. "Most Dispensers in *Journal's* Survey Report Greater Satisfaction with Digitals." *Hearing Journal* 54.3 (2001): 21-32.

Kochkin, Sergei. "One More Time . . . What Did the 1984 HIA Market Survey Say?" *Hearing Instruments* 41 (1990): 10-18.

Kochkin, Sergei. "MarkeTrak III: Why 20 Million in US Don't Use Hearing Aids for Their Hearing Loss." *Hearing Journal* 46 (1993): 26-31.

Kochkin, Sergei. "The VA and Direct Mail Sales Spark Growth in Hearing Aid Market." *Hearing Review* 8.12 (2001): 16-65.

Kochkin, Sergei. "Factors Impacting Consumer Choice of Dispenser and Hearing Aid Brand: Use of ALDs and Computers." *Hearing Review* 9.12 (2002): 14-23.

Kochkin, Sergei. "On the Issue of Value: Hearing Aid Benefit, Price, Satisfaction, and Brand Repurchase Rates." *Hearing Review* 10.2 (2003): 12-26.

Kochkin, Sergei. "MarkeTrak VII: Hearing Loss Population Tops 31 Million People." *Hearing Review* 12.7 (2005): 16-29.

Kockelman, Kara Maria. "Driver Injury Severity: An Application of Ordered Probit Models." Submitted to *Accident Analysis and* Prevention, January, 2001.

Kuk, F.K., Potts, L., Valente, M., Lee, L., and Picirrillo, J. "Evidence of Acclimatization in Persons with Severe-to-Profound Hearing Loss." *Journal of the American Academy of Audiology* 14 (2003): 84-99.

Lee, Kristina and Lotz, Peter. "Noise and Silence in the Hearing Instrument Industry." Working paper, Department of Industrial Economics and Strategy, Copenhagen Business School, March, 1998.

Martin, Frederick N. *An Introduction to Audiology*. Englewood Cliffs, NJ: Prentice Hall, 1991.

Moscicki, Eve K., Elkins, Earleen F., Baurn, Herbert M., and McNarnara, Patricia M. "Hearing Loss in the Elderly: An Epidemiologic Study of the Framingham Heart Study Cohort." *Ear and Hearing* 6.4 (1985): 184-190.

Nevo, Aviv. "Measuring Market Power in the Ready-to-Eat Cereal Industry." *Econometrica* 69.2 (2001): 307-342.

Pakes, Ariel. "A Reconsideration of Hedonic Price Indexes with an Application to PC's." *American Economic Review* 93.5 (Dec., 2003): 1578-1596.

Palmquist, Raymond B. "Estimating the Demand for the Characteristics of Housing." *Review of Economics and Statistics* 66.3 (1984): 394-404.

Punch, J.L. "Technological and Functional Features of Hearing Aids: What Are Their Relative Costs?" *Hearing Journal* 54.6 (2001): 32-44.

Strom, K.E. "The HR 2003 Dispenser Survey." *Hearing Review* 10.6 (2003): 22-36.

Rosen, Sherwin. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82.1 (Jan. - Feb., 1974): 34-55.

Sataloff, Robert T. and Sataloff, Joseph. *Hearing Loss*. New York, NY: Marcel Dekker, Inc., 1993.

Trajtenberg, Manuel. "The Welfare Analysis of Product Innovations, with an Application to Computed Tomography Scanners." *Journal of Political Economy* 97.2 (April, 1989): 444-479.

Triplett, Jack E. "Automobiles and Hedonic Quality Measurement." *Journal of Political Economy* 77 (May - June, 1969): 408-417.

Triplett, Jack E. "Hedonic Functions and Hedonic Indexes." *The New Palgrave: A Dictionary of Economics,* Volume 2. Ed. M. Milgate Eatwell and P. Newman. London: MacMillan Press, 1987. 630-634.

Triplett, Jack E. "Hedonic Methods in Statistical Agency Environments: An Intellectual Biopsy." *Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth*. Ed. Berndt E. and Triplett J. Chicago, IL: University of Chicago Press, 1990. 207-233.

Ruben, Robert J. "Introduction." *Clinical Aspects of Hearing*. Ed. Thomas R. Van De Water, Arthur N. Popper, and Richard R. Fay. New York, NY: Springer, 1996. 1-9.

Wackym P.A. and Linthicum, FH Jr. "Diabetes Mellitus and Hearing Loss: Clinical and Histopathologic Relationships." *American Journal of Otology* 7.3 (May, 1986): 176-182.

Ward, W. Dixon. "Noise-Induced Hearing Loss." *Hearing* Disorders. Ed. Jerry L. Northern. Boston, MA: Little, Brown and Company, 1984. 143-152.

Wooldridge, Jeffrey M. *Econometric Analysis of Cross Section and Panel Data.* Cambridge, MA: The MIT Press, 2002.

www.emedicine.com/ent/topic478.htm, 26 August 2006

www.en.wikipedia.org/wiki/Hearing_impairment, 26 August 2006.

www.houseearclinic.com/hearingloss.htm, 26 September 2006.

www.mayoclinic.org/hearing-disorders/causes.html, 26 September 2006.

www.nidcd.nih.gov/health/hearing/hearingaid.asp, 25 February 2005.

www.seniorjournal.com/NEWS/Health/6-06-02-StudyFindsHearing.htm, 26 August 2006.

APPENDIX A

CHAPTER III

A DESCRIPTION OF CHILD CASE HISTORY FORMS AND SUMMARY STATISTICS

A.1. Data Description

A.1.1. Child and Adolescent Case History Forms

As previously mentioned in section 3.2 in the main text, the clinic currently uses two standard forms for children, one for infants and toddlers from birth to age 4; the other is for ages 5 to 17. Each of these forms has 12 sections, of which ten are relevant to this study. The first section asks the caregiver to provide identifying information (e.g., name, address, year of birth, etc.) for the child. It also asks information regarding parental age, education, employment, family structure, and language spoken at home.

Birth and/or pregnancy histories are being provided in section two. These are yes or no questions related to topics such as prenatal problems, premature birth, blood transfusion, meningitis, and intensive care unit after birth. The third section of the child/adolescent case history form queries the developmental history of the patient. Ten questions are asked relating to the age (in month) at which the patient: (1) sat alone, (2) crawled, (3) walked alone, (4) fed self, (5) was toilet trained, (6) dressed self, (7) rode tricycle, (8) tied shoes, (9) said first word, and (10) combined two words.

The fourth section, termed "medical history," asks for yes or no responses, date of occurrence, and diagnosis/diagnoses for 11 items. These items include matters such as head injuries, headaches, accidents, surgeries, serious infections, and ADD/ADHD. Respondents are also asked to provide a list of current medication if applicable.

"Hearing and ear history" is the fifth section, in which ten questions are posed. The first three answers require a yes or no response to questions: (1) Do you think his or her hearing is poor? (2) Does he or she complain of noises in the ears or head? and (3)

Does he or she have dizziness or imbalance? Question 4 asks at what age the child/adolescent experienced his or her first ear infection, and the subsequent three questions ask for the number of ear infections between ages 0-2 years, between 2-4 years, and between 4 and 6 years if applicable. The age at which the most recent ear infection took place is listed as question 8. Question 9 queries whether or not the child has undergone any otologic surgery. The final question of this section asks whether the child is using or has used hearing aids. The age values for the infection data are converted from years to months.

The sixth section asks for a list of tests done on the child, including hearing test, speech/language, vision exam, neurological, psychological, brain CT scan and IQ scores. Section 7 relates to family history of illness such as ear or hearing problem, neurological diseases, speech, and learning problems. Section 8 documents a child's emotional, sensory, and social histories while speech and language problems are given grave attention in section 9 of the form.

The final section gives information pertaining to school/education. This section is pertinent only to children over age 5. There are eight questions of interest, which ask (1) the patient's best academic subject, (2) the patient's poorest academic subject, (3) if the patient has been enrolled in special education, (4) type(s) of therapy or assistance, (5) repeating of a grade, and (6) whether the patient likes school.

A.1.2. Summary Statistics

The following is a brief description of the summary statistics for children included in the study. The information from the “old” and “new” forms was combined for this summary analysis. The dataset recorded a total of 334 child patients, of which 224 were taken from new forms and 110, from the old.

Gender discrepancy is significant for the child dataset (Table A.1), which shows that 63.77% male children visited the clinic, compared to 36.23% females. The difference between the numbers of visitors for the two age groups is rather obvious. As column 1 indicated, 93 more visits were made by children over 5 years old.

Table A.1 also reveals the family structure in which a child resides. Over 50% of all children lived with their birth parents and all had one or more sibling. The common form of language was English and more than 20% of children spoke two or more languages. In terms of locality, most children were urban residents and rural visitors accounted for 32.34% of all child and adolescent patients, which is slightly higher than the adult group. For information regarding parental age, education, and occupation, refer to Table B.1 in Appendix B.

Child’s ear characteristics are presented in Table A.2. Approximately 22% out of the 560 ears examined were diagnosed with a hearing loss and most of the diagnoses were in the ranges of mild to moderate loss. Tympanometric data reveals that 378 ears had type A shape, suggesting normal eardrum movement.

Table A.3 summarizes pregnancy and birth histories for children. About 39% of mothers encountered some form of complications during pregnancy or delivery, which could have a potential effect on a child's hearing ability. Note that the one-star sign indicates that these sections were not asked in the old child form. Column 2 shows that prenatal problems, premature birth, and intensive care presented a bigger threat to the health of the child than any others on the lists. On average, most children were born weighing less than 10 pounds.

Table A.4 is a description of child medical history. Over 70% of children had one or more type of medical problems. The most common medical conditions included surgery, earache, frequent cold, and allergy. Nearly 30% were taking medication at the time of testing.

Child's ear and hearing history is provided in Table A.5. Column 2 indicates that 43.11% of parents or guardians thought their child's hearing was poor. The number of repeated ear infections was high, as demonstrated by column 2, where 67.37% of children had recurrent ear infections before the age of six. Although some children complained about dizziness or ear noises, the ratio was small compared to ear infections. The data are quite revealing. Approximately 57% of children experienced their first ear infection between birth and the age 4; and 23.95% of them sought special treatment or surgery. Hearing aid purchase by children is insignificant compared to adult procurement. Only 19 out of the 334 child patients had a hearing aid.

Table A.6 details family history of medical problems. The number of relatives with speech problems, learning disabilities, and ear and hearing deficiencies were 20.54%, 24.11%, and 23.66%, respectively. Approximately 33.96% of children had three or more relatives with hearing problems. The rate of mothers with hearing problems was greater compared to that of father. In contrast, more grandfathers had either an ear or a hearing problem than grandmothers. Additional information with respect to child's development, communication, speech-language, and education histories can be found in Appendix B.

Table A.1: Summary Statistics of Child Demographic Characteristics from Case History Forms, January 01, 2001 – May 31, 2005

	Number of Patients (n = 334)	Percent of Total (%)
Gender		
Male	213	63.77
Female	121	36.23
Total observed for gender	334	100.00
Age group		
Birth to age 4	120	35.93
Age 5 to 17	213	63.77
Total observed for age group	334	100.00
Average age		
Family structure		
With whom does the child live?		
Both parents	178	53.29
One birth parent	88	26.35
Grandparent(s)	11	3.29
One birth and one stepparent	11	3.29
Other (e.g., adopt parent, foster parent, etc.)	14	4.19
No response	32	9.58
Total observed	334	100.00
Number of siblings		
None	0	
One	105	31.44
Two	73	21.86
Three	38	11.38
Four	8	2.40
Five	2	.60
Six	3	.90
Total observed for siblings	334	100.00
Language(s) spoken in home		
English	226	67.66
Spanish	8	2.40
American Sign Language	2	.60
Bilingual	58	17.37
More than two languages	9	2.69
No response	31	9.28
Total observed	334	100.00
Rural or urban residence		
Urban	226	67.66
Rural	108	32.34
Total observed for location	334	100.00
State		
Texas	319	95.51
Other state	15	4.49
Total observed for state	334	100.00

Table A.2: Summary Statistics of Child Demographic and Ear Characteristics from Audiometric Data, January 01, 2001 – May 31, 2005

	Number of Observations (n = 560)	Percent of Total (%)
Gender		
Male	343	61.25
Female	217	38.75
Total observed for gender	560	100.00
Age group		
Birth to age 4	131	23.39
Age 5 to 17	427	76.25
Unspecified	2	.36
Total observed for age	560	100.00
Average age	7.61	
Ear		
Left	259	46.25
Right	258	46.07
Unspecified	43	7.68
Total observed	560	100.00
Hearing loss diagnose		
Yes	124	22.14
No	436	77.86
Total observed	560	100.00
Degree of loss		
Normal	436	77.86
Mild	47	8.39
Moderate	42	7.50
Moderately severe	10	1.79
Severe	12	2.14
Profound	13	2.32
Total observed for degree of loss	560	100.00
Tympanogram		
Type A	378	67.50
Type B	74	13.21
Type C	40	7.14
Type Ad	7	1.25
Type As	21	3.75
Not tested	40	7.14
Total observed	560	100.00
Some average values		
Pure-tone average	18.70	
Word-recognition score	91.02	
Presentation level	55.26	

Table A.3: Summary Statistics of Pregnancy and Birth Histories, January 01, 2001 – May 31, 2005

	Number of Patients	Percent of Total
	(n = 334)	(%)
Any pregnancy or birth complications?		
Yes	130	38.92
No	204	61.08
If yes, please indicate		
Pregnancy history*		
Prenatal problems	29	12.95
Prenatal alcohol exposure	2	.89
Prenatal drug exposure	8	3.57
Herpes	1	.45
Blood incompatibility	3	1.34
Pre-or eclampsia***	5	9.62
Gestational diabetes**	2	3.85
Cytomegalovirus	0	.00
Toxoplasmosis	0	.00
Rubella	2	.89
Birth history*		
Premature birth	41	18.3
Birth trauma***	2	3.85
Blood transfusion	11	4.91
Intensive care unit after birth	40	17.86
Ventilation used	24	10.71
Neonatal infection	6	2.68
Meningitis	2	.89
Note: The following appeared on the old form only:		
C–section	25	22.73
Illness or infection	7	6.36
Induced labor	4	3.64
Premature birth	2	1.82
other	3	2.73
Total observed	41	100.00
Pregnancy length**		
< Full term	75	68.18
Full term	14	12.73
> Full term	3	2.73
No response	18	16.36
Total observed	110	100.00
Average pregnancy length		
Birth weight		
Less than 10lbs.	272	81.44
Greater than 10lbs	4	1.20
No response	58	17.37
Total observed	334	100.00
Average birth weight (lbs.)		

* n = 224; ** n = 110; *** n = 52.

Table A.4: Summary Statistics of Child Medical History, January 01, 2001 – May 31, 2005

	Number of Patients (n = 334)	Percent of Total (%)
Medical condition		
Yes	244	70.05
No	90	26.95
If yes, please indicate which		
Head injuries	18	5.39
Convulsions/seizures	21	6.29
Headaches*	28	12.50
Serious infections*	22	9.82
Other brain or spinal problems*	10	4.46
Surgeries*	58	25.89
Earaches**	87	53.70
Vision problems**	22	13.58
Frequent cold**	53	32.72
Meningitis**	0	.00
Tonsillitis**	14	8.64
High fevers**	30	18.52
Allergies**	41	25.31
Accidents(falls, burns, etc)***	20	15.87
ADD/ADHD***	17	13.49
Autism***	6	4.76
Other***	1	.79
APD****	13	17.57
ODD****	6	8.11
Taking medication		
Yes	100	29.94
No	234	70.06
Total observed	334	100.00

* n = 224; ** n = 162; *** n = 126; *** n = 74.

Table A.5: Summary Statistics of Child Ear and Hearing History, January 01, 2001 – May 31, 2005

	Number of Patients (n = 334)	Percent of Total (%)
Do you think child's hearing is poor?	144	43.11
Does child complain of noises in the ears or head?*	26	11.61
Does child have dizziness or imbalance?*	28	12.50
Does child have ear infections?		
Yes	225	67.37
No	109	32.63
Total observed	334	100.00
If yes, age of first ear infection?*		
No infection	61	27.23
Birth to age 4	127	56.70
Age 5 to 17	5	2.23
No response	31	13.84
Total observed	224	100.00
Number of ear infections age 0-2 years*		
No infection	69	30.80
Less than 10	119	53.13
Greater than 10	13	5.80
No response	23	10.27
Total observed	224	100.00
Number of ear infections age 2-4 years*		
No infection	106	47.32
Less than 10	83	37.05
Greater than 10	8	3.57
No response	27	12.05
Total observed	224	100.00
Number of ear infections age 4-6 years**		
No infection	87	50.58
Less than 10	50	29.07
Greater than 10	4	2.33
No response	31	18.02
Total observed	172	100.00
Age of last ear infection*		
No infection	58	25.89
Birth to age 4	69	30.80
Age 5 to 17	61	27.03
No response	36	16.07
Total observed	224	100.00
Ear treatment and surgeries	80	23.95
Has child used hearing aid(s)	19	5.69

* n = 224; ** n = 172 for children from ages 5 – 17.

Table A.6: Summary Statistics of Child Family History, January 01, 2001 – May 31, 2005

	Number of Patients	Percent of Total
	(n = 224)	(%)
Neurological diseases		
Yes	12	5.36
No	212	94.64
Total observed	224	100.00
If yes, who?		
Father	1	8.33
Mother	3	25.00
Brother	1	8.33
Sister	0	.00
Grandfather	0	.00
Grandmother	0	.00
Uncle	2	16.67
Aunt	0	.00
Other relative(s) (grandchild, nephew, niece, etc.)	2	16.67
Greater than two members	3	25.00
No response	0	.00
Total observed	12	100.00
Speech problems		
Yes	46	20.54
No	178	79.46
Total observed	224	100.00
If yes, who?		
Father	4	8.70
Mother	3	6.52
Brother	5	10.87
Sister	4	8.70
Grandfather	1	2.17
Grandmother	2	4.35
Uncle	5	10.87
Aunt	0	.00
Other relative(s) (grandchild, nephew, niece, etc.)	9	19.57
Greater than two members	12	26.09
No response	1	2.17
Total observed	46	100.00
Learning problem		
Yes	54	24.11
No	170	75.89
Total observed	224	100.00
If yes, who?		
Father	3	5.56
Mother	3	5.56
Brother	9	16.67
Sister	4	7.41
Grandfather	1	1.85

Table A.6. Continued.

Grandmother	0	.00
Uncle	3	5.56
Aunt	3	5.56
Other relative(s) (grandchild, nephew, niece, etc.)	12	22.22
Greater than two members	10	18.52
No response	6	11.11
Total observed	54	100.00
Other hereditary illness		
Yes	24	10.71
No	200	89.29
Total observed	224	100.00
If yes, who?		
Father	3	12.50
Mother	5	20.83
Brother	1	4.17
Sister	0	.00
Grandfather	2	8.33
Grandmother	1	4.17
Uncle	0	.00
Aunt	0	.00
Other relative(s) (grandchild, nephew, niece, etc.)	0	.00
Greater than two members	4	16.67
No response	8	33.33
Total observed	24	100.00
Ear and hearing problems		
Yes	53	23.66
No	171	76.34
Total observed	224	100.00
If yes, who?		
Father	2	3.77
Mother	8	15.09
Brother	4	7.55
Sister	1	1.89
Grandfather	6	11.32
Grandmother	3	5.66
Uncle	4	7.55
Aunt	1	1.89
Other relative(s) (grandchild, nephew, niece, etc.)	5	9.43
Greater than two members	18	33.96
No response	1	1.89
Total observed	53	100.00

APPENIDX B

CHAPTER III

SUPPLEMENTARY DATA

Table B.1: Summary Statistics of Parental Characteristics, January 01, 2001 – May 31, 2005

	Number of Father (n = 334)	Number of Mother (n = 334)
Age		
<19	4 (1.20%)	11 (3.29%)
20-29	34 (10.18%)	108 (32.34%)
30-39	243 (72.75%)	123 (36.83%)
40-49	21 (6.29%)	50 (14.97%)
50-59	5 (1.50%)	3 (.90%)
No response	27 (8.08%)	39 (11.68%)
Total observed	334	334
Average age	35.25	32.55
Education		
No school		
Equivalent of high school	130 (38.92%)	157 (47.01%)
Associate degree	33 (9.88%)	45 (13.47%)
Bachelor degree	49 (14.67%)	72 (21.56%)
Professional degree	23 (6.89%)	18 (5.39%)
Unspecified	98 (29.34%)	42 (12.57%)
Total observed	334	334
Average level of education	13.16	13.25
Employment status		
Employed	122 (36.53%)	105 (31.44%)
Self-employed	77 (23.05%)	54 (16.17%)
Unemployed/disable	14 (4.19%)	6 (1.80%)
Homemaker	0 (.00%)	65 (19.46%)
In the military	7 (2.10%)	1 (.30%)
Disabled	2 (.60%)	0 (.00%)
Student	2 (.60%)	11 (3.29%)
Deceased	3 (.90%)	2 (.60%)
Unspecified	107 (32.04%)	90 (26.95%)
Total observed for occupation	334	334
Payment method		
Medicaid	43	12.87
TX PACT	1	.30
Medicaid and TX PACT	118	35.33
TRC	0	.00
Contract	5	1.50
Chip	8	2.40
Private pay	6	1.80
Private insurance	98	29.34
Combination of payment	27	8.08
No response	28	8.38
Total observed for payment method	334	100.00

Table B.2: Summary Statistics of Child Developmental History, January 01, 2001 – May 31, 2005

	Number of Patients (n = 334)	Percent of Total (%)
Average time for doing the following (in months)		
Sat alone		
Not yet	21	6.29
Within 12 months	218	65.27
13-36 months	7	2.10
No response	88	26.35
Walked alone		
Not yet	27	8.08
Within 12 months	148	44.31
> 13 months	85	25.45
No response	74	22.16
Fed self		
Not yet	26	7.78
Within 12 months	121	36.23
> 13 months	71	21.26
No response	116	34.73
Toilet trained		
Not yet	51	15.27
Within 12 months	11	3.29
> 13 months	191	57.19
No response	81	24.25
Dressed*		
Not yet	29	10.28
Within 12 months	3	1.06
> 13 months	158	56.03
No response	92	32.62
Tricycle*		
Not yet	48	17.02
Within 12 months	5	1.77
> 13 months	143	50.71
No response	86	30.49
Tie shoes*		
Not yet	72	25.53
Within 12 months	3	1.06
> 13 months	117	41.49
No response	90	31.91
First word		
Not yet	18	5.39
Within 12 months	123	36.83
> 13 months	62	18.56
No response	131	39.22
Combined two words		
Not yet	35	10.48
Within 12 months	41	12.28
> 13 months	110	32.93
No response	148	44.31

*n = 282.

Table B.3: Selective Summary Statistics of Child Communication/Sensory/Social History, January 01, 2001 – May 31, 2005

	Number of Patient		
	(n = 224)		
	Yes	Sometimes	No
Trouble understanding television programs	23 (10.27%)	21 (9.38%)	179 (79.91%)
Sensitivity to loud sounds	57 (25.45%)	20 (8.92%)	147 (65.63%)
Trouble telling where sounds are coming from	32 (14.29%)	22 (9.82%)	170 (75.89%)
Problems following directions	93 (41.52%)	37 (16.52%)	97 (43.30%)
Easily distracted	12 (5.36%)7	13 (5.80%)	84 (37.50%)
Forgetful	78 (16.52%)	27 (12.05%)	119 (53.13%)
Preference for playing with younger children	39 (17.41%)	19 (8.48%)	166 (74.11%)
Disruptive	39 (17.41%)	22 (9.82%)	163 (72.77%)
Preference for solitary activities	34 (15.18%)	17 (7.59%)	173 (77.23%)
Easily frustrated	117 (52.23%)	14 (6.25%)	93 (41.52%)
Tires easily	38 (16.96%)	19 (8.48%)	167 (74.55%)
Often tense or anxious	50 (22.32%)	18 (8.04%)	156 (69.64%)
Uncooperative	32 (14.29%)	32 (14.29%)	160 (71.43%)
Clumsy	47 (20.98%)	25 (11.16%)	152 (67.86%)
Impulsive	51 (22.77%)	18 (8.04%)	155 (69.20%)
Lacks self-confidence	61 (27.23%)	19 (8.48%)	144 (64.29%)
Easily upset by new situations	53 (23.66%)	16 (7.14%)	155 (69.20%)
Withdraws from touch	7 (3.13%)	21 (9.38%)	196 (87.50%)
Bothered by labels in shirts	37 (16.52%)	14 (6.25%)	173 (77.23%)
Overreacts to small bumps, scrapes, etc	44 (19.64%)	9 (4.02%)	171 (76.34%)
Pinches or bites himself or others	20 (8.93%)	3 (1.34%)	201 (89.73%)
Exhibits poor posture – tires easily	16 (7.14%)	9 (4.02%)	199 (88.84%)
Bored or fussy when eating (poor appetite)	30 (13.39%)	14 (6.25%)	180 (80.36%)
Complains of things "smelling bad"	21 (9.38%)	9 (4.02%)	194 (86.61%)
Experiences car sickness	17 (7.59%)	2 (.89%)	205 (91.52%)
Appears confused in noisy places	49 (21.88%)	16 (7.14%)	159 (70.98%)
Often says "huh" or "what"	119 (53.13%)	19 (8.48%)	86 (38.39%)
Mixes up sounds	67 (29.91%)	16 (7.14%)	141 (62.95%)
Rowdiness	42 (18.75%)	24 (10.71%)	158 (70.54%)
Preference for playing with older children or adults	40 (17.86%)	27 (12.05%)	157 (70.09%)
Headaches	24 (10.71%)	28 (12.50%)	172 (76.79%)
Short attention span	72 (32.14%)	23 (10.27%)	129 (57.59%)
Temper tantrums	57 (25.45%)	20 (8.93%)	147 (65.63%)
Easily flustered or confused	86 (38.39%)	16 (7.14%)	122 (54.46%)
Hyperactive	45 (20.09%)	22 (9.82%)	157 (70.09%)
Disobedient	31 (13.84%)	33 14.73%)	160 (71.43%)
Shy	44 (19.64%)	32 (14.29%)	148 (66.07%)
Irritable	36 (16.07%)	29 (12.95%)	159 (70.98%)
Destructive	19 (8.48%)	14 (6.25%)	191 (85.27%)
Excessive talking	58 (25.89%)	20 (8.93%)	146 (65.17%)
Seeks attention	65 (29.02%)	31 (13.84%)	128 (57.14%)
Is bothered by bright lights	37 (16.52%)	14 (6.25%)	173 (77.23%)
Craves spinning or swinging	13 (5.80%)	14 (6.25%)	197 (87.95%)
Dislikes going barefooted or having arms or legs bare	11 (4.91%)	6 (2.68%)	207 (92.41%)
Appears unaware of the feelings of others	22 (9.82%)	20 (8.93%)	182 (81.25%)

Table B.4: Summary Statistics of Child Speech and Language History, January 01, 2001 – May 31, 2005

	Number of Patients		
	(n = 224)		
	Yes	Sometimes	No
Delay in early speech development	85 (37.95%)	5 (2.23%)	134 (59.82%)
Small vocabulary compared to peers	66 (29.46%)	10 (4.46%)	148 (66.07%)
Poor grammar usage	68 (30.36%)	13 (5.80%)	143 (63.84%)
Problems speaking clearly	88 (39.29%)	17 (7.59%)	119 (53.13%)
Stuttering	8 (3.57%)	13 (5.80%)	203 (90.63%)
Speech therapy now or in the past	83 (37.05%)	0 (.00%)	141 (62.95%)
Problems understanding others*	54 (31.40%)	20 (5.38%)	98 (26.34%)
Problems retelling events at school or stories **	26 (35.14%)	18 (24.32%)	30 (40.54%)
Problems following classroom rules**	18 924.32%)	19 (25.68%)	37 (50.00%)
Problems understanding written language**	26 (35.14%)	10 (13.51%)	38 (51.35%)
Able to write complete sentence**	30 (40.54%)	12 (16.22%)	32 (43.24%)
Problems falling directions**	20 (27.03%)	26 (35.14%)	28 (37.84%)
Problems giving directions**	18 (24.32%)	21 (28.38%)	35 (47.30%)
Problems understanding jokes**	20 (27.03%)	16 (21.62%)	38 (51.35%)
Problems in language arts class**	19 (25.68%)	15 (20.27%)	40 (54.05%)
Asks for help when does not understand**	29 (39.19%)	21 (28.38%)	24 (32.43%)
How does child respond when talking to him? ***			
Babbles	2	3.85	
Coos	0	.00	
Smiles	0	.00	
Talks	3	5.77	
Listens	2	3.85	
Gesture	1	1.92	
Other	4	7.69	
Combination	15	28.85	
Do not respond	4	7.69	
No response	21	40.38	
Total observed	52	100.00	
How does child let know what he wants? ***			
Gesturing	4	7.69	
Single word	0	.00	
Short phrase	3	5.77	
Sentence	1	1.92	
Crying	3	5.77	
Other	0	.00	
Combination	21	40.38	
No response	20	38.46	
Total observed	52	100.00	
Remember a time when child stopped development? ***			
Yes	3	5.77	
No	49	94.23	
Total observed	52	100.00	

* n = 179; ** n = 74; *** n=52.

Table B.5: Summary Statistics of School/Education Information for Children of Age 5 – 17, January 01, 2001 – May 31, 2005

	Number of Patients (n = 282)	Percent of Total (%)
Attending school		
Yes	151	53.55
No	111	39.36
No response	20	7.09
Best subject(s)*		
None	13	7.56
Language	17	9.88
Math	31	18.02
Science	6	3.49
Social science	3	1.74
Arts	4	2.33
Physical education	2	1.16
Combination	31	18.02
No response	63	36.63
Poorest subject(s)*		
None	17	9.88
Language	53	30.81
Math	14	8.14
Science	2	1.16
Social science	1	.58
Arts	0	.00
Physical education	0	.00
Combination	31	18.02
No response	54	31.40
Type of therapy or assistance		
None	152	53.90
Reading/speech	59	20.92
Math	1	.35
Social skills	3	1.06
Others	22	7.80
Combination	11	3.90
No response	34	12.06
Has he ever repeated a grade?	48	17.02
Does he like school?*		
Yes	118	68.60
No	24	13.95
No response	30	17.44
Parental satisfaction with school support?*		
Yes	99	57.56
No	22	12.79
No response	51	29.65
Teacher expressed concern for child?*	90	52.33

* n = 172.

Table B.6: Marginal Effects of Independent Variables in the Adult Noise Model: The Severity of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Noise Model					
	Prob (y=1)	Prob (y=2)	Prob (y=3)	Prob (y=4)	Prob (y=5)	Prob (y=6)
Age	-.004*	-.002*	-.001*	.003*	.003*	.002*
	(.001)	(.000)	(.000)	(.000)	(.000)	(.000)
Gender	-.070*	-.035*	-.019*	.045*	.045*	.034*
	(.020)	(.010)	(.006)	(.013)	(.013)	(.010)
Otologic history						
Ear infection	-.035	-.019	-.012	.022	.025	.019
	(.019)	(.011)	(.008)	(.011)	(.014)	(.012)
Special treatment	-.045*	-.026	-.019	.028*	.034	.028
	(.022)	(.015)	(.013)	(.013)	(.019)	(.018)
Surgery	-.045*	-.026	-.019	.027*	.034	.028
	(.023)	(.015)	(.013)	(.013)	(.020)	(.018)
Excessive noise						
Gunfire	.112*	.047*	.014*	-.072*	-.060*	-.040*
	(.033)	(.011)	(.005)	(.021)	(.015)	(.009)
Explosions	.006	.003	.002	-.004	-.004	-.003
	(.036)	(.018)	(.009)	(.023)	(.023)	(.017)
Factory noise	0.027	-.015	-.010	.017	.019	.015
	(.023)	(.014)	(.010)	(.014)	(.018)	(.015)
Power tools	-.038	-.021	-.013	.024	.027	.021
	(.023)	(.014)	(.010)	(.014)	(.018)	(.015)
Heavy equipment	.044	.021	.010	-.028	-.027	-.019
	(.026)	(.012)	(.005)	(.017)	(.018)	(.010)
Motorcycles	-.032	-.018	-.012	.020	.024	.019
	(.031)	(.019)	(.015)	(.018)	(.025)	(.022)
Power lawn mowers	.040	.019	.009	-.026	-.025	-.018
	(.027)	(.012)	(.005)	(.017)	(.015)	(.011)
Aircraft	.083*	.035*	.010*	-.054*	-.045*	-.029*
	(.040)	(.013)	(.004)	(.025)	(.017)	(.010)
Loud music	.041	.020	.009*	-.027	-.025	-.018
	(.025)	(.011)	(.004)	(.016)	(.014)	(.010)
Military tanks	-.048	-.029	-.023	.029	.038	.033
	(.037)	(.026)	(.025)	(.019)	(.034)	(.034)
Other noise	-.001	-.000	-.000	.000	.000	.000
	(.023)	(.012)	(.007)	(.015)	(.015)	(.011)
Family history	-.013	-.007	-.004	.009	.009	.007
	(.017)	(.009)	(.005)	(.011)	(.011)	(.008)
Major health problems	-.014	-.007	-.004	.009	.010	.007
	(.020)	(.010)	(.005)	(.013)	(.013)	(.010)
Other diseases or symptoms	.015	.008	.005	-.010	-.011	-.008
	(.021)	(.012)	(.008)	(.013)	(.015)	(.012)
Medication	.050*	.028*	.019	-.031*	-.037*	-.030*
	(.020)	(.013)	(.010)	(.012)	(.016)	(.014)

Table B.7: Marginal Effects of Independent Variables in the Adult Family Model: The Severity of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Family Model					
	Prob (y=1)	Prob (y=2)	Prob (y=3)	Prob (y=4)	Prob (y=5)	Prob (y=6)
Age	-.005*	-.002*	-.001*	.003*	.003*	.002*
	(.001)	(.000)	(.000)	(.000)	(.000)	(.000)
Gender	-.084*	-.043*	-.022*	.054*	.055*	.039*
	(.020)	(.010)	(.006)	(.013)	(.013)	(.010)
Otologic history						
Ear infection	-.043*	-.025*	-.016	.028*	.032*	.025*
	(.018)	(.011)	(.009)	(.011)	(.014)	(.012)
Special treatment	-.038	-.022	-.015	.024	.029	.023
	(.024)	(.015)	(.013)	(.014)	(.020)	(.017)
Surgery	-.046*	-.027	-.020	.029*	.036	.029
	(.022)	(.015)	(.013)	(.013)	(.020)	(.018)
Excessive noise	.075*	.041*	.025*	-.048*	-.053*	-.040*
	(.018)	(.010)	(.008)	(.012)	(.012)	(.011)
Family history						
Father	.060*	.028*	.011*	-.040*	-.036*	-.024*
	(.024)	(.010)	(.004)	(.016)	(.013)	(.008)
Mother	.033	.016	.008	-.022	-.021	-.014
	(.024)	(.011)	(.004)	(.016)	(.014)	(.009)
Sister	-.032	-.018	-.012	.020	.024	.019
	(.026)	(.016)	(.013)	(.016)	(.021)	(.018)
Brother	-.040	-.023	-.016	.025	.030	.024
	(.022)	(.014)	(.012)	(.013)	(.018)	(.016)
Grandmother	-.023	-.013	-.009	.015	.017	.013
	(.035)	(.021)	(.016)	(.022)	(.027)	(.022)
Grandfather	.068	.030*	.009*	-.045	-.038*	-.024*
	(.042)	(.015)	(.003)	(.027)	(.019)	(.011)
Aunt	-.069*	-.045	-.039	.039*	.059	.054
	(.029)	(.023)	(.027)	(.012)	(.032)	(.036)
Uncle	-.050	-.030	-.023	.030*	.040	.033
	(.027)	(.019)	(.018)	(.015)	(.025)	(.024)
Cousin	-.053	-.033	-.026	.032	.043	.037
	(.041)	(.030)	(.031)	(.021)	(.040)	(.041)
Child	-.084*	-.058*	-.055*	.044*	.078*	.076*
	(.021)	(.019)	(.025)	(.007)	(.027)	(.035)
Other member	.043	.020	.008	-.029	-.025	-.017
	(.061)	(.025)	(.005)	(.041)	(.031)	(.019)
Major health problems	-.026	-.013	-.007	.017	.017	.012
	(.020)	(.010)	(.005)	(.013)	(.013)	(.009)
Other diseases or symptoms	.020	.011	.007	-.013	-.014	-.011
	(.020)	(.012)	(.008)	(.013)	(.015)	(.012)
Medication	.043*	.025*	.016	-.028*	-.032	-.025
	(.020)	(.013)	(.010)	(.013)	(.016)	(.014)

Table B.8: Marginal Effects of Independent Variables in the Adult Disease Model: The Severity of Hearing Loss, January 01, 2001 – May 31, 2005

Variables	Disease Model					
	Prob (y=1)	Prob (y=2)	Prob (y=3)	Prob (y=4)	Prob (y=5)	Prob (y=6)
Age	-.005*	-.002*	-.001*	.003*	.003*	.002*
	(.001)	(.000)	(.000)	(.000)	(.000)	(.000)
Gender	-.061*	-.030*	-.016*	.038*	.039*	.030*
	(.020)	(.010)	(.005)	(.013)	(.012)	(.009)
Otologic history						
Ear infection	-.035	-.019	-.012	.022	.025	.020
	(.018)	(.011)	(.008)	(.011)	(.014)	(.012)
Special treatment	-.041	-.023	-.016	.025	.030	.025
	(.023)	(.015)	(.013)	(.013)	(.019)	(.018)
Surgery	-.055*	-.032*	-.024	.032*	.042*	.037
	(.022)	(.015)	(.014)	(.011)	(.019)	(.020)
Excessive noise	.067*	.035*	.021*	-.042*	-.046*	-.036*
	(.019)	(.010)	(.007)	(.012)	(.013)	(.011)
Family history	-.000	-.000	-.000	.000	.000	.000
	(.016)	(.008)	(.005)	(.010)	(.011)	(.008)
Major health problems						
Diabetes	-.089*	-.055*	-.045*	.049*	.072*	.068*
	(.016)	(.012)	(.013)	(.008)	(.016)	(.018)
High blood pressure	.004	.002	.001	-.003	-.003	-.002
	(.018)	(.009)	(.005)	(.011)	(.012)	(.009)
Heart or kidney disease	-.007	-.004	-.002	.004	.005	.004
	(.020)	(.010)	(.006)	(.012)	(.013)	(.010)
Other diseases or symptoms	.014	.007	.004	-.008	-.009	-.007
	(.021)	(.011)	(.007)	(.013)	(.015)	(.012)
Medication	.067*	.038*	.027*	-.040*	-.050*	-.042*
	(.019)	(.012)	(.011)	(.011)	(.016)	(.015)

Table B.9: Marginal Effects of Independent Variables in the Adult Full Model: The Severity of Hearing Loss, January 01, 2001 – May 31, 2005

	Full Model					
Variables	Prob (y=1)	Prob (y=2)	Prob (y=3)	Prob (y=4)	Prob (y=5)	Prob (y=6)
Age	-.004*	-.002*	-.001*	.003*	.003*	.002*
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
Gender	-.089*	-.050*	-.027*	.064*	.061*	.040*
	(.020)	(.011)	(.007)	(.015)	(.014)	(.009)
Otologic history						
Ear infection	-.026	-.016	-.010	.019	.020	.013
	(.018)	(.012)	(.008)	(.013)	(.014)	(.010)
Special treatment	-.034	-.022	-.016	.025	.028	.020
	(.023)	(.016)	(.013)	(.016)	(.020)	(.016)
Surgery	-.056*	-.038*	-.031	.039*	.049*	.037*
	(.020)	(.016)	(.016)	(.013)	(.021)	(.019)
Excessive noise						
Gunfire	.076*	.038*	.015*	-.056*	-.046*	-.028*
	(.030)	(.013)	(.004)	(.021)	(.016)	(.009)
Explosions	.029	.015	.007	-.021	-.019	-.012
	(.038)	(.019)	(.007)	(.028)	(.023)	(.013)
Factory noise	-.026	-.016	-.011	.019	.020	.014
	(.022)	(.015)	(.011)	(.016)	(.018)	(.013)
Power tools	-.028	-.017	-.011	.020	.021	.014
	(.023)	(.014)	(.010)	(.016)	(.018)	(.013)
Heavy equipment	.059*	.031*	.014*	-.044*	-.038*	-.023*
	(.027)	(.013)	(.005)	(.020)	(.015)	(.009)
Motorcycles	-.039	-.026	-.019	.028	.032	.024
	(.027)	(.020)	(.018)	(.018)	(.026)	(.021)
Power lawn mowers	.027	.015	.008	-.019	-.018	-.011
	(.025)	(.013)	(.006)	(.019)	(.016)	(.010)
Aircraft	.088*	.040*	.011*	-.063*	-.048*	-.027*
	(.040)	(.015)	(.004)	(.028)	(.017)	(.009)
Loud music	.058*	.030*	.013*	-.042*	-.036*	-.022*
	(.026)	(.012)	(.004)	(.019)	(.014)	(.008)
Military tanks	-.044	-.030	-.023	.031	.038	.029
	(.035)	(.028)	(.027)	(.023)	(.036)	(.032)
Other noise	.003	.002	.001	-.002	-.002	-.001
	(.022)	(.013)	(.007)	(.016)	(.015)	(.010)
Family history						
Father	.051*	.027*	.012*	-.038*	-.032*	-.020*
	(.023)	(.011)	(.004)	(.017)	(.013)	(.008)
Mother	.034	.019	.009	-.025	-.022	-.014
	(.024)	(.012)	(.005)	(.017)	(.014)	(.008)
Sister	-.013	-.008	-.005	.010	.010	.007
	(.027)	(.017)	(.012)	(.020)	(.021)	(.015)
Brother	-.044*	-.029*	-.022	.031*	.037	.027
	(.020)	(.015)	(.014)	(.013)	(.019)	(.016)

Table B.9. Continued.

Grandmother	-.026	-.017	-.011	.019	.021	.015
	(.033)	(.022)	(.018)	(.023)	(.028)	(.022)
Grandfather	.067	.032*	.011*	.049	-.039*	-.022*
	(.041)	(.016)	(.003)	(.029)	(.019)	(.010)
Aunt	-.078*	-.059*	-.058	.048*	.078*	.069
	(.024)	(.023)	(.032)	(.009)	(.033)	(.039)
Uncle	-.074*	-.055*	-.051*	.048*	.072*	.061*
	(.021)	(.020)	(.025)	(.010)	(.027)	(.030)
Cousin	-.010	-.006	-.004	.007	.007	.005
	(.052)	(.032)	(.021)	(.038)	(.040)	(.028)
Child	-.087*	-.068*	-.070*	.050*	.091*	.085*
	(.019)	(.019)	(.028)	(.008)	(.028)	(.036)
Other member	.055	.027	.009*	-.040	-.032	-.019
	(.063)	(.026)	(.004)	(.045)	(.030)	(.016)
Major health problems						
Diabetes	-.085*	-.060*	-.051*	.056*	.077*	.063*
	(.015)	(.013)	(.014)	(.010)	(.017)	(.017)
High blood pressure	.018	.010	.006	-.013	-.013	-.008
	(.018)	(.010)	(.006)	(.013)	(.013)	(.008)
Heart or kidney disease	-.003	-.002	-.001	.002	.002	.001
	(.020)	(.011)	(.007)	(.014)	(.014)	(.009)
Other diseases or symptoms	.003	.002	.001	-.002	-.002	-.002
	(.021)	(.012)	(.007)	(.015)	(.015)	(.010)
Medication	.036	.022	.015	-.026	-.028	-.019
	(.019)	(.013)	(.010)	(.014)	(.016)	(.012)

Note: Y=1 (normal); Y=2 (Mild), Y=3 (Moderate), Y=4 (Moderately Severe), Y=5 (Severe), Y=6 (Profound).

APPENDIX C

CHAPTER IV

SUPPLEMENTARY DATA

Table C.1: Summary Statistics of Patient Characteristics, June 01, 2001 – May 31, 2005

	Number of Patients	Percent of Total
Gender		
Male	141	55.51
Female	113	44.49
Total observed for gender	254	100.00
Age group		
Birth to 5	2	.79
6-10	15	5.91
11-18	8	3.15
19-29	7	2.76
30-39	7	2.76
40-49	10	3.94
50-59	16	6.30
60-69	40	15.75
70-79	78	30.71
80-89	56	22.05
90-99	12	4.72
No response	3	1.18
Total observed for age group	254	100.00
Employment status		
Employed	38	14.96
Self-employed and farmer	6	2.36
Child and student	32	12.60
Disabled	10	3.94
Homemaker	1	.39
Retired	153	60.24
Unemployed	14	5.51
Total observed for occupation	254	100.00
Location		
Urban residence	154	59.84
Rural	67	27.17
No response	33	12.99
Total observed for location	254	100.00
Ear		
Left	131	51.58
Right	123	48.43
(Both)	72	
Total observed for ear	254	100.00

Table C.2: Technical Variable Definitions

Variables	Description
Style	
Behind-the-ear (BTE)	Designed so that it can be placed behind the ear; this style is modular in nature
In-the-ear (ITE)	Custom-built shell that allows for the device to be placed in the ear canal with a large part flush with the auricle portion of the ear
In-the-canal (ITC)	A miniaturization of the ITE devices; can be placed mostly in the canal.
Completely in-the-ear (CIC)	A miniaturization of the ITE devices; can be placed entirely in the ear canal
Signal Processing Scheme	
Analog-adjustable (AA)	Based on simply increasing the voltage of the input analog signal (e.g., microphone)
Analog-programmable (AP)	Type of hearing aid whose internal controls are manipulated through digital signal processing and its output uses analog signal processing.
Digital-programmable (DP)	Based on converting an analog input signal into a set of binary digits before converting the signal back to analog; also referred to as digital signal processing (DSP) technology

APPENDIX D

CHAPTER V

SUPPLEMENTARY DATA

Table D.1: Summary Statistics of Average Manufacturer Selling Prices, June 01, 2001 – May 31, 2005

Manufacturer	AA				AP				DP			
	BTE	ITE	ITC	CIC	BTE	ITE	ITC	CIC	BTE	ITE	ITC	CIC
1	750.00 (---)								824.50 (86.03)	780.00 (.00)		
2		477.47 (23.62)				857.98 (202.68)	919.97 (---)			670.51 (344.73)	937.48 (25.00)	849.98 (.00)
3	336.76 (45.64)				771.00 (---)				509.95 (113.09)	936.75 (.00)	834.75 (.00)	
4	340.00 (17.99)	314.90 (---)					653.98 (28.25)		661.49 (389.58)	1309.00 (47.34)	679.50 (104.50)	940.81 (55.65)
5		275.00 (.00)							524.00 (98.73)	274.82 (46.52)		
6		352.82 (62.80)				459.67 (180.46)	857.00 (25.40)	876.50 (117.20)		917.00 (668.92)		889.00 (.00)
7									400.00 (.00)			
8	394.77 (154.53)	326.02 (45.13)	349.65 (90.53)		533.33 (202.07)	359.65 (65.64)	324.97 (---)		372.49 (102.51)	722.11 (292.60)	887.48 (141.45)	1214.98 (410.54)
9		532.00 (---)							349.00 (.00)	537.89 (109.61)	341.33 (73.54)	768.00 (.00)

Table D.2: Functional and Technical Variable Definitions

Variables	Description
Style	
Behind-the-ear (BTE)	Designed so that it can be placed behind the ear; this style is modular in nature
In-the-ear (ITE)	Custom-built shell that allows for the device to be placed in the ear canal with a large part flush with the auricle portion of the ear
In-the-canal (ITC)	A miniaturization of the ITE devices; can be placed mostly in the canal.
Completely in-the-ear (CIC)	A miniaturization of the ITE devices; can be placed entirely in the ear canal
Signal Processing Scheme	
Analog-adjustable (AA)	Based on simply increasing the voltage of the input analog signal (e.g., microphone)
Analog-programmable (AP)	Type of hearing aid whose internal controls are manipulated through digital signal processing and its output uses analog signal processing
Digital-programmable (DP)	Based on converting an analog input signal into a set of binary digits before converting the signal back to analog
Output Limiting	
Compression	The output signal is reduced at some rate to prevent peak clipping and distortion.
Peak clipping	The output signal, which is linear, is cut when it reaches the maximum output level of the amplifier, resulting in high distortion.
Circuit	
Class A and B	These types of amplified circuits produce distortion.
Class D	This type of amplified circuit produces minimal distortion.
Other Technology Variables	
Memory	A place in random access memory (RAM) that allows the listener to change how sounds are amplified
Channel	A filter that can be used alone or in conjunction with other filters to provide differing amounts of amplification in different frequency regions
Telecoil	Induction coil in a hearing aid designed to pick up signals from a telephone or a room designed for the hearing impaired
Directional microphone	A type of microphone that attenuates sounds from the sides or rear of the listener. This type of microphone has been shown to improve the listener's ability to hear in noisy situations.

Table D.2. Continued.

Direct audio input (DAI)	Allows an external source (e.g. television, telephone, computer, CD player, etc.) to be directly connected as an input that bypasses the microphone; not available in ITE, ITC, and CIC styles
DAI boot or boot	The adaptor needed between the hearing aid and the DAI
Venting	Hole drilled through an ear-mold or hearing aid shell that allows the passage of air and the modification of sound to reach the eardrum
Volume control	Adjustment feature on a hearing aid that allows for the manual control of amplification
Remote control	A handheld device that allows the listener to control changes in volume and memory
Removal aids	Devices used to assist the listener in removing the hearing aid from the ear
Shell material	The chemical composition used to make the shell of the hearing aid
Gain	The output level of the hearing aid, as determined by the amplifier, minus the input level
Output	The output level of the hearing aid's amplifier
Low-cut	A type of filter that passes high frequencies and attenuates low frequencies
High-cut	A type of filter that passes low frequencies and attenuates high frequencies
Resonance peak	A variable filter that allows for the broadening or narrowing of the filter bandwidth
Crossover	The frequency at which two filters overlap
Threshold kneepoint	The decibel value at which a linear signal becomes nonlinear
Compression ratio	The amount of reduction in the output signal (from linear to nonlinear)
Feedback reduction	An algorithm that can reduce or eliminate the whistling sound sometimes heard in a hearing aid
Noise reduction/cancellation	A digital algorithm used to reduce the amount of gain when noise exceeds speech at the input

Table D.3: Summary Statistics of Patient Characteristics, June 01, 2001 – May 31, 2005

	Number of Patients	Percent of Total
Gender		
Male	141	55.51
Female	113	44.49
Total observed for gender	254	100.00
Age group		
Birth to 5	2	.79
6-10	15	5.91
11-18	8	3.15
19-29	7	2.76
30-39	7	2.76
40-49	10	3.94
50-59	16	6.30
60-69	40	15.75
70-79	78	30.71
80-89	56	22.05
90-99	12	4.72
No response	3	1.18
Total observed for age group	254	100.00
Employment status		
Employed	38	14.96
Self-employed and farmer	6	2.36
Child and student	32	12.60
Disabled	10	3.94
Homemaker	1	.39
Retired	153	60.24
Unemployed	14	5.51
Total observed for occupation	254	100.00
Location		
Urban residence	154	59.84
Rural	67	27.17
No response	33	12.99
Total observed for location	254	100.00
Ear		
Left	131	51.58
Right	123	48.43
(Both)	72	
Total observed for ear	254	100.00