# A hedonic price analysis of hearing aid technology

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**Abstract**

In this article, we study how technological components affect the price of hearing aids. The main goals are to determine which functional and technological features have the greatest influence on manufacturer-based prices in the hearing aid industry, and to analyze the price-cost margins at the dispenser level using a unique data set that is compiled from a hearing clinic in West Texas. The result shows that style and signal processing scheme are the two most important determinants of hearing aid price. Other characteristics such as directional microphone, noise cancellation, and a certain shell type are also positively related to price. Further, on average, this particular local dispenser has a markup of about 35% per hearing instrument.

*JEL*: I19, L11, L13, O14, O21

*Key Words*: Hearing Aids, Technology, Hedonics, Price-Cost-Margins

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## I. Introduction

Hearing aids are external electronic devices that are designed to either fit in or near the ear(s). The makers 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 23% of the hearing-impaired population has purchased a hearing aid (Kochkin, 2005). Further, there does not appear to have any robust price competition or product innovation in the market. Research has 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[4], who act as the middleman between hearing aid manufacturers and end-users. The result is that various prices exist for hearing aids which typically seem to be fairly standard in their technology. Our research seeks to dissect the components of the list price of hearing aids to better understand the contribution of technology to the determination of price. In addition, we also compute the price-cost margins for a typical dispenser.

[4] Dispensers are most likely audiologists, but retailers like Wal-Mart could also dispensing hearing aids.

We use hedonic price analysis. Following the revival of the hedonic approach to analyze automobile prices[5] in the early 1960's, the regression technique has been applied to study the prices of a wide variety of goods including houses,[6] washing machines,[7] computers,[8] computed tomography scanners (CT),[9] and personal digital assistants (PDA's)[10]. However, to the best of our knowledge, the market for hearing aids has not been studied using the aforementioned hedonic method. This study, therefore, proposes to utilize a unique dataset to examine how functional and technical features affect the price of hearing aids and to analyze price-cost margins at the intermediary level. The data employed in this article has been gathered from a hearing clinic in West Texas.

Our paper shows that signal processing scheme and style of the hearing aid are the two most important drivers of list price in the hearing aid market. More precisely, digital processors contribute the most to cost and 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" does matter for consumers of hearing aids.

The remainder of the paper is organized as follows. Section II gives a brief account of the different types of hearing instruments. Section III provides a description of the data, while Section IV reports the empirical analysis. Section V offers a few summary remarks.

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[5] See Griliches (1961), Adelman and Griliches (1961), Griliches (1964), Berry, Levinsohn and Pakes (1995), and Goldberg (1995) for more on automobile industry.
[6] See Bailey et al. (1963).
[7] See Gavett (1967).
[8] See Berndt, Griliches and Rappaport (1995), Berndt and Rappaport (2001), Chwelos (2003), Pakes (2003), Benkard and Bajari (2005) for more on computer industry.
[9] See Trajtenberg (1989)
[10] See Chwelos et al. (2004).

## II. Hearing Instruments

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

There are five types of hearing aids in terms of style[11]: (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 grow. Canal aids can be 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, our dataset records no such instance.

[11] www.nidcd.nih.gov

The internal mechanisms of hearing aids may vary across devices, even if they have the same external design[12]. A signal processor is essential to a functional hearing device and comes in three types: analog-adjustable (AA), analog-programmable (AP), and digital-programmable (DSP). AA, which is often referred 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 environment. DSP, on the other hand, is typically the most expensive, for 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 price of instruments vary due to style and processor type. However, the outcomes of their analyses seem to be based solely on observation of market trends. This paper, instead, systematically investigates the variation in prices vis-à-vis specific features of technology and style using individual level data.

## III. Data

*Data collection*

Hearing aid cost and pricing data are 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.

[12] www.nidcd.nih.gov

Our 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(s) for which the hearing aid(s) is/are 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's selling or list price is sometimes also called "cost of technology to dispenser." Essentially, these manufacturer-to-dispenser invoices are used to determine the inclusive costs for 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 twenty-two electro-acoustic features available in a hearing aid, but a number of them are optional. See Table A2 in the appendix for a thorough explanation of the electro-acoustic features.

We use the hearing aid contracts 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). We also use 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, we confirm ordering and dispensing dates. These sheets contain meticulous details of each clinical visit made by a patient and are used to sort out any confusion that might arise from unclear transactions. Patients' demographic characteristics, such as age and gender, are extracted directly from case history forms for reason of maximum accuracy.

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

*Summary statistics*

After accounting for missing data, we analyzed 254 observations on 9 brands. In Table 1a, we present the distribution of observations across style and signal processor. In terms of style and processor, ITE and digital are the most popular; each has a market share of 54.331% and 51.181%, respectively. Fifty-nine purchases are made over digital ITE—the largest of any processor-style combination. The least sold style is 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 reason of 'vanity,' might therefore be more popular. However, CIC's high cost might be a factor in consumers' purchasing decisions. In Table 1b, we break down the sales of hearing aids by style-processor combinations and brand/manufacturer. The last column of the table represents the market shares of each firm over the period studied. Firm 8 has a predominant market share that accounts for 34.252% 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 our regression analysis.

In Table 2, we present the different components of the average retail price for the 12 style-and-processor combinations. The list price or manufacturer's selling price is the highest for Digital CIC. Digital processors have 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 we can infer that keeping style constant, the digital processor contributes the most to the price of a hearing aid. Further, the summary suggests that these price increments are not the same across processor type. While an AP-ITE costs $63.42 (529.33 – 592.75) less than an AP-BTE, a DSP-ITE costs $98.27 (678.91 – 580.64) more than a DSP-BTE. This irregularity is easy to explain. Besides style and signal processing scheme, there are twenty-two optional functional and technical components that a hearing aid might possess. The same trend continues even in the final retail price which includes hearing aid service or professional fees, besides the shipping and handling fee. 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 pays for the aid out-of-pocket, s/he would be charged a one-time fee of $125 regardless of the number of devices acquired. For someone who pays with Medicaid, the dispensing fee becomes $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. We see this in column 8 where we calculate the average price-cost margin for the dispenser. On an average, more than 30% of the end-user price is made up of the dispenser fee, professional service charges, and shipping and handling fees. This margin is the least for BTE styles across all processor types, although the margins fluctuate in ranking across the other 3 types of styles across the different processor types.

Next, in Table 3, we analyze the movement of nominal list prices over the period of our study, for each of the twelve combinations of style and processor. We note that there is no uniform trend in the prices. If we omit 2001 and 2005 (since the data for these two years contain observations for only a quarter or two), then for the 3 years—2002, 2003, and 2004—for which we have consistent data, we find that for DSP-ITE, the average list price drops from $780 in 2002 to $571.46 in 2004. Likewise, for AA-BTE, the prices drop from $433.38 in 2002 to $307.52 in 2004. An analogous decreasing movement in 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 is no systematic development. A downward trend on prices is to be expected of fast-changing technologies with competitive market structures. The technology for hearing aids, however, is not a very dynamic one. 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. We disclose the different prices by manufacturer in Table A1 in the Appendix.

Description of the various technology variables used in our regression analysis, are p[provided in Table A2. While patient characteristics are not pertinent to the analysis of the manufacturer's list price, they are, however, important in some ways to explain the retail price of a hearing aid. When considering patient characteristics, about 55% of them are males, 75% of them are older than 65 years. Also note that about 60% of the patients are retired and live in urban areas. Additional details could be provided upon request.

## IV. Empirical Model and Estimation

*The empirical model*

We use a log-log model that has been traditional in most hedonic regression studies. Since the purpose of this study is to determine how technology and perceived characteristics of hearing aids affect manufacturers' wholesale prices, we employ two specifications of this model: the base case specification that includes only the 7 (= 4+3) technology variables that we have coded as style and processor types, and the more elaborate specification that embraces a host of other technology variables. 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:

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

where $P_{\mathrm{iyt}}$ is the base price of hearing aid $i$ from manufacturer $y$ in 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, $\varepsilon$, 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 as specified for a hearing instrument, to Equation (1).

*Estimation results*

Hearing aid style and signal processing scheme are two main variables that a manufacturer might deem valuable in terms of their role in contributing to the consumer's willingness to pay. Style is especially important if one considers the perception of stigma associated with wearing a visible and chunky device. Research validates the assumption that purchasers of hearing aids are more willing to accept these devices as they become smaller (Kochkin, 2002). The processing scheme has also become increasingly vital in view of the fact that manufacturers are replacing the outdated analog lines with more technologically advanced DSP product lines. In Table 4, we report the results from the regression analysis. The reference processor type is analog while the reference style is BTE. In Model 1, we merely include the seven most basic technology variables, namely, the four types of style (BTE, ITE, ITC, CIC) and the three kinds of signal processing schemes(AA, AP, DSP). As expected, both DSP 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 increased prices. As mentioned before, we suspect vendor effects to be present in the hearing aid market. Thus, in Model 2, we incorporate the firm as well as time-quarter effects. The F-test for the joint-restriction of no vendor and time effects is rejected. Hence, we retain the vendor and time effects subsequently (F (23, 225) = 6.86), although only two out of nine firms have significant coefficients, while 14 out of the 17 time-quarters are statistically significant. Next, in Model 3, we add all the other technology variables. 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 signals 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 goes up from .541 in Model 2 to .767 in Model 3. Among the other significant technology variables, noise-cancellation and directional microphone are terms which lend themselves to easy comprehension by the consumer and, thus, it is not surprising that their presence allows a manufacturer to increase the price. The fact that most style variables lose their significance on addition of the other technology variables indicates that the technology variables which we have added are perhaps, in a way, components of the style variables themselves or that style is not independently valued by the consumer. Hence, in Model 4, we ran the full model but used the style and processor interaction terms instead of controlling them individually. Here, we find that given an AP, both ITE and ITC styles have reduced prices compared to the reference group AA-BTE. The coefficients for AP-BTE and ITE also show a similar pattern. For the remaining DSP scheme, all styles have positive coefficients but only CIC is statistically significant. Thus, for an AP processor, a CIC style increased the manufacturer price by 20.7%, while an ITC increased it by 20.3% over the reference category, AA-BTE. Likewise, there was a similar ranking in the impacts for DSP over ITC and CIC styles. Overall, it appears that if a BTE style is being chosen, then manufacturers can charge the maximum for a DSP than for either an AA or AP. If a CIC style is chosen, then DSP commands a greater premium than AP. The quarterly indicator variables are largely negative, as in the other two models. We graph these time coefficients in Figure 1, which indicates an average negative price drift in hearing aids over the period of our study.

## V. Conclusion

The aim of the analysis is to determine whether there is any systematic relationship between technology and prices. We apply the conventional hedonic price method to a unique dataset of 254 observations acquired from a local audiological clinic and find that, not controlling for any other technological features, from among the different styles and processor types available to a consumer, the DSP tends to increase prices. Equally, the smaller the hearing aid, as reflected by ITC and CIC styles, the greater the upward pressure on prices. Another objective of the study is to provide a summary description of pricing behavior in the secondary market within the hearing aid industry. We discover 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 that the few manufacturers of hearing aids charge for what seems to be a fairly standard device. In our study, we identified two sets of drivers of the list price of hearing aids. First, there are technology variables, in which we showed that the smaller the style and the more “advanced” the processor type, the higher the premium a firm can charge. Secondly, there are joint vendor effects, indicating that firms charge high premiums for some reasons other than the technology variables for which we controlled. Perhaps these firm effects are proxy for their unique marketing channels or advertising efforts. We could not identify such efforts in our data and we contend that, with our analysis, we can only see that firms in the hearing aid market have a substantial influence on price besides the technology itself.

Our summary statistics of patient characteristics suggest that the traits of the sampled population are comparable to those of national and international clinics. Therefore, we are confident that our paper 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, DSP and miniaturizations have a consequential effect on pricing behaviors, while the dispenser markup also adds significantly to the final retail price of hearing aids. Consequently, hearing aid consumers have to absorb extremely high costs for their hearing aids independent of technology.

Finally, note that Aaron (1987), Lee and Lotz (1998), and Amlani and De Silva (2005) show that the market for hearing aids is relatively price inelastic. As mentioned before, hearing aids cannot be purchased by consumers over the counter. To purchase, an Audiologist need to recommend a certain type of hearing aid to a patient, based the severity of hearing loss and cost considerations. This makes the final price of hearing aids crucially dependent on clinics. Lee and Lotz (1998) characterize this market as a 'friendly oligopoly' and therefore, in a given region prices among clinics will be similar and market will be shared. Hence, clinics have no interest to reduce prices to marginal cost as in a Bertrand oligopoly. This observation should hold true to any unregulated regional, national, or internationals hearing aid market.

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**Table 1a: Summary statistics of hearing aid style and processor type, June 01, 2001 - May 31, 2005**

| **Processor Type** | **Style** | | | | **Total** | **Percentage of Total** |
|---|---|---|---|---|---|---|
| | **BTE** | **ITE** | **ITC** | **CIC** | | |
| AA | 23 | 49 | 6 | 0 | 78 | 30.709 |
| AP | 4 | 30 | 8 | 4 | 46 | 18.110 |
| DP | 39 | 59 | 16 | 16 | 130 | 51.181 |
| Total | 66 | 138 | 30 | 20 | 254 | 100.000 |
| Percentage of total | 25.984 | 54.331 | 11.811 | 7.874 | 100.000 | |

**Table 1b: Total number of hearing aids sold by manufacturer, June 01, 2001 - May 31, 2005**

| Manufacturer | Types of Hearing Aids | | | | | | | | | | | | Total | Percentage of Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Analog | | | | AP | | | | Digital | | | | | |
| | 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 | 2.756 |
| 2 | 0 | 4 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 10 | 4 | 2 | 27 | 10.630 |
| 3 | 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 11 | 2 | 2 | 0 | 24 | 9.449 |
| 4 | 5 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 15 | 4 | 4 | 4 | 35 | 13.780 |
| 5 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 9 | 0 | 0 | 14 | 5.512 |
| 6 | 0 | 11 | 0 | 0 | 0 | 21 | 4 | 4 | 0 | 2 | 0 | 2 | 44 | 17.323 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0.787 |
| 8 | 9 | 30 | 6 | 0 | 3 | 3 | 1 | 0 | 2 | 23 | 4 | 6 | 87 | 34.252 |
| 9 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 2 | 2 | 14 | 5.512 |
| Total | 23 | 49 | 6 | 0 | 4 | 30 | 8 | 4 | 39 | 59 | 16 | 16 | 254 | 100.000 |

**Table 2: Summary statistics of average prices, June 01, 2001-May 31, 2005**

| Types of Hearing Aids | Manufacturer – to – Dispenser Price | | | Dispense – to - End-user Price | Price - cost Margin[13] (5) = [(4) - (3)] / (4) |
|---|---|---|---|---|---|
| | Manufacturer Selling Price (List price) (1) | Discounted Selling price (2) = (1) - Manufacturer Discounts | 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) |
| DSP – BTE | 580.64 | 570.10 | 575.90 | 895.21 | .279 |
| | (279.31) | (270.88) | (271.70) | (525.10) | (.198) |
| DSP – ITE | 678.91 | 582.80 | 590.66 | 925.05 | .336 |
| | (347.50) | (343.78) | (342.47) | (493.33) | (.196) |
| DSP – ITC | 773.12 | 610.32 | 615.94 | 1379.58 | .549 |
| | (212.29) | (165.96) | (165.72) | (220.85) | (.124) |
| DSP – 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 |

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

**Table 3: Average list prices by year and type of hearing aid**[14]

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

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

**Table 4: Estimation results for log of manufacturers' 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) | |
| DSP | .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*** | | | | Yes |
| ***Manufacturer effects*** | | Yes | Yes | Yes |
| ***Quarterly effects*** | | Yes | Yes | Yes |
| ***Output Limiting*** | | | Yes | Yes |
| ***Circuit*** | | | Yes | Yes |
| ***Shell Material*** | | | Yes | Yes |
| ***Quantity variables*** | | | Yes | Yes |
| ***Other distinct dummies*** | | | Yes | Yes |
| Number of Observations | 254 | 254 | 254 | 254 |
| Adj. R2 | .380 | .541 | .767 | .774 |

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

**Appendix:**

**Table A1: Summary statistics of average manufacturer selling prices, June 01, 2001 - May 31, 2005**

| **Manufacturer** | **AA** | | | | **AP** | | | | **DSP** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **BTE** | **ITE** | **ITC** | **CIC** | **BTE** | **ITE** | **ITC** | **CIC** | **BTE** | **ITE** | **ITC** | **CIC** |
| 1 | 750.00 | | | | | | | | 824.50 | 780 | | |
| | (---) | | | | | | | | (86.03) | (0.00) | | |
| 2 | | 477.47 | | | | 857.98 | 919.97 | | | 670.51 | 937.48 | 849.98 |
| | | (23.62) | | | | (202.68) | (---) | | | (344.73) | (25.00) | (0.00) |
| 3 | 336.76 | | | | 771.00 | | | | 509.95 | 936.75 | 834.75 | |
| | (45.64) | | | | (---) | | | | (113.09) | (0.00) | (0.00) | |
| 4 | 340.00 | 314.90 | | | | | 653.98 | | 661.49 | 1309.00 | 679.50 | 940.81 |
| | (17.99) | (---) | | | | | (28.25) | | (389.58) | (47.34) | (104.50) | (55.65) |
| 5 | | 275.00 | | | | | | | 524.00 | 274.82 | | |
| | | (0.00) | | | | | | | (98.73) | (46.52) | | |
| 6 | | 352.82 | | | | 459.67 | 857.00 | 876.50 | | 917.00 | | 889.00 |
| | | (62.80) | | | | (180.46) | (25.40) | (117.20) | | (668.92) | | (0.00) |
| 7 | | | | | | | | | 400.00 | | | |
| | | | | | | | | | (0.00) | | | |
| 8 | 394.77 | 326.02 | 349.65 | | 533.33 | 359.65 | 324.97 | | 372.49 | 722.11 | 887.48 | 1214.98 |
| | (154.53) | (45.13) | (90.53) | | (202.07) | (65.64) | (---) | | (102.51) | (292.60) | (141.45) | (410.54) |
| 9 | | 532.00 | | | | | | | 349.00 | 537.89 | 341.33 | 768.00 |
| | | (---) | | | | | | | (0.00) | (109.61) | (73.54) | (0.00) |

**Table A2: 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. |
| **Processing Scheme** | |
| *Analog - adjustable* | Based on simply increasing the voltage of the input analog signal (e.g., microphone). |
| *Analog - programmable* | Type of hearing aid whose internal controls are manipulated through digital signal processing and its output uses analog signal processing |
| *Digital - programmable* | 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. |
| *Direct Audio Input (DAI)* | Allows an external source (e.g. television, telephone, computer, CD player) 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. |

**Table A2: Functional and technical variable definitions (cont.)**

| | |
|---|---|
| *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. |

## Figure 1: Quarterly time trend in log of manufacturer prices