Hedonic Regressions with Supply and Demand Controls: An Example Using Stereo Receiver Scanner Data*

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Abstract

Standard hedonic regressions estimate price as a function of product characteristics. However, other factors such as the cost of inputs, market structure and product demand also affect price. If supply and demand factors are correlated with product characteristics then estimates omitting them can yield biased coefficient. Such bias is especially problematic if the end use of hedonic characteristic estimates is for the purpose of adjusting for quality in the construction of price indices. We examine this question using U.S. scanner data on stereo receivers. To control for market structure, we use sales information to construct Herfindahl indices and concentration ratios. We use the producer price index for semiconductors to control for production cost. To control for changes in the demand for stereo receivers we use data on sales of DVD players. Our estimates indicate that when supply and demand factors are omitted, hedonic estimates may be overestimating the value of unobserved quality thought to be embodied in brand dummies.

*The views and opinions contained herein are not to be construed as views and opinions of the Bureau of Labor Statistics or the Department of Labor.

1 Introduction

Hedonic models of prices are regularly used to make price adjustments to new products that replace products in the CPI basket of goods. The purpose of this adjustment is to remove the portion of the price change that is due to differences in perceived quality between two goods. This will leave behind the true price change between the two periods. However, if the hedonic model is misspecified then the resulting adjustment will misstate true price changes.

Traditionally, the potential for omitted variable bias has been treated with the inclusion of manufacturer and time dummies. However, the dummies do not differentiate between omitted variables that affect quality from those that affect price. This is an important distinction to make because the coefficients on the brand dummies are frequently used to make adjustments to the CPI. The adjustment is made with the assumption that the manufacturer dummies represent only omitted quality. However, if the coefficients also capture legitimate price chances, due perhaps to supply and demand changes, then the resulting adjustment will bias the CPI.

Typical hedonic models do not control for supply and demand factors.[1] In imperfectly competitive markets, equilibrium prices will depend on product characteristics, demand characteristics and supply characteristics. If either supply or demand characteristics are correlated with the product characteristics then hedonic price regressions that ignore these factors will yield biased coefficient estimates. This is particularly problematic if the coefficient estimates are subsequently used to quality adjust price indices. This point was first made in Feenstra (1995). In a recent paper, Pakes (2002) suggests an alternative method that he calls a "hedonic index"[2] where such bias is not an issue. While

[1] See Griliches (1961) for an early example and Doms and Forman (2001) and Kokoski et al. (2000) for more recent examples.

[2] A.k.a. direct characteristics, imputation and prediction methods.

conceptually this method is quite simple, it is more resource intensive since monthly regressions need to be run using relatively small sample sizes.

We suggest another alternative. We reduce omitted variable bias by explicitly controlling for supply and demand characteristics with variables for industry concentration, cost, and demand. This has the advantage that the data can be pooled over time to increase the sample size. Practically, it would be easier to implement since it is quite similar to procedures currently in place.

Our empirical results occur in three parts. In the first part, we use two baseline regressions: the standard hedonic regression and a regression augmented by industry level supply and demand variables. The stability of hedonic coefficients over the different specifications suggests that our supply and demand controls are capturing changes in market structure occurring within the industry.

In the second part, we interact our supply and demand variables with manufacturer dummies to show that at a more disaggregate level (the level of the manufacturer) supply and demand variables can have a significant impact on estimated coefficients. While the coefficients for coded characteristics again remain fairly stable, the coefficients of brand dummies can may change once manufacturer supply and demand effects are allowed.

The plan of the paper is as follows. In Section 2, we develop a simple model of imperfect competition to illustrate the problems that can arise with hedonic regressions if important supply and demand variables are omitted. In Section 3, we describe the data. The empirical results are reported in Section 4. Finally, we conclude in Section 5.

2 Theoretical implications of (the omission of) supply and demand factors

Assume that there are n firms, for which demand is given by

$$q_i = f_i(\mathbf{p}; \mathbf{x}_i, \mathbf{y}_i) \tag{1}$$

where $\mathbf{p} = (p_1, p_2, \ldots, p_n)$ is the vector of offer prices, $\mathbf{x}_i$ is a vector of each firm's measured product characteristics, and $\mathbf{y}_i$ is a vector demand factors unrelated to its product characteristics. Assume that each firm has constant marginal cost, c_i.

Firm i's profits can be written as:

$$\pi_i = (p_i - c_i)q_i. \tag{2}$$

Assuming that product characteristics have been fixed, each firm maximizes profits through choice of p_i. Equilibrium prices will be functions of product characteristics $\mathbf{X} = (\mathbf{x}_1, \mathbf{x}_2, \ldots \mathbf{x}_n)$, firm level demand factors $\mathbf{Y} = (\mathbf{y}_1, \mathbf{y}_2, \ldots \mathbf{y}_n)$ and cost $\mathbf{c} = (c_1, c_2, \ldots c_n)$. I.e., equilibrium price can be written as $p_i(\mathbf{X}, \mathbf{Y}, \mathbf{c})$. Moreover, price also depends on what might be vaguely termed "market concentration." Market concentration depends on n, $\mathbf{X}$, $\mathbf{Y}$ and $\mathbf{c}$.

In a typical hedonic regression, price is regressed only on $\mathbf{x}_i$ with important price determining variables such as $\mathbf{X}_{-i}$, $\mathbf{Y}$ and $\mathbf{c}$ omitted. If omitted variables are correlated with $\mathbf{x}_i$ then these regressions will yield biased coefficients. To best illustrate the problem of omitted supply and demand variables, consider the following stylized example. Suppose there are two firms with demands:

$$q_i = a_i - bp_i + dp_j \tag{3}$$

where $a_i = a + a_x x_i + a_y y_i$ and where $a, a_x, a_y, b, d > 0$ and $b > d$.

Solving each firm's profit maximization problem, equilibrium prices can be written as

$$p_i^* = \frac{2b}{4b^2 - d^2} a_i + \frac{d}{4b^2 - d^2} a_j + \frac{2b}{4b^2 - d^2} c_i + \frac{bd}{4b^2 - d^2} c_j \tag{4}$$

Consider a case where firm 1's product has characteristic $x_1 > x_2$ but where firm 1 has a cost advantage so that $c_1 < c_2$. Assume that d is relatively small so that omission of rival variables will have little impact on regression estimates. Letting all else be equal, it is straightforward to see that for appropriately chosen parameter's $p_1^* < p_2^*$. In other words, with this simple example, if the only independent variable is characteristic x, a hedonic regression will yield a negative coefficient even though x has a strictly positive impact on price. More generally, even with this simplified example where concentration has to some extent been fixed, as long as $y_1 \neq y_2$ and $c_1 \neq c_2$, estimates over product characteristics will typically be biased.

3 The Data

We use scanner data purchased by the Bureau of Labor Statistics from NPD on stereo receivers. The data range from September of 1999 through August of 2001.[3] Each observation includes the average price, number of units sold, total expenditures and physical product characteristics (including brand name) of a single model of stereo receiver sold in the US in a given month. These data are collected from various retail outlet chains across the nation, and then adjusted to make them representative of total national sales.[4] Some summary statistics are given in Table 1.

[3]Data is available until February of 2002, however, because Wal-mart is such a large player in the market and ended its relationship with all U.S. scanner data vendors, we chose to end our analysis in the last month in which Wal-mart participated.

[4]For a more detailed discussion of the NPD data, see Kokoski et al. (2000).

Using the number of units sold, we compute various concentration ratios (three firm up to six firm) and the Herfindahl Index to control for market concentration. The BLS's Producer Price Index for semiconductors is used to control for industry level fluctuations in costs since semiconductors are one of the most important inputs to the production of virtually all consumer electronics. Monthly U.S. sales of DVD players[5] is used as a control for industry demand fluctuations on the premise that the advent of DVD players increased the demand for new stereo receivers due to innovations in stereo receiver technology (particularly surround sound and video switching). Summary statistics for these variables are given in Table 2.

4 Hedonic regression results

Our basic regression model is:

$$\ln p_i = \alpha \mathbf{x}_i + \beta \mathbf{y}_i + \gamma c_i + \delta t_i + \varepsilon_i \tag{5}$$

p_i is the price of observation i, $\mathbf{x}_i$ is a vector of product characteristics for observation i, $(\mathbf{y}_i, c_i)$ is a vector of supply and demand variables, t_i is set of dummy variables for the time period and ε_i is the error term.

We also include a variable controlling for the age of the stereo receiver model. The rationale for use of the age variable is similar in spirit to Kokoski et al.'s use of a vintage variable. The basic idea is that new features may not be observed in the data but may nevertheless affect consumers' valuation of a product.

[5] `http://www.thedigitalbits.com/articles/cemadvdsales.html`

4.1 Baseline regressions

We begin with two baseline regressions to use as points of reference. The first is a variant of the regression used by the BLS for quality adjusting audio products (Kokoski et al., 2000). This includes time dummies and a model age variable. Our results cover a different sample period but are broadly in line with Kokoski et al. (column 0 of Table 3).

For the second baseline, we estimate a hedonic regression that includes several industry wide supply and demand factors. As an indicator for demand, we use a three-month moving average of the monthly change in U.S. DVD player sales starting with $t-1$ and ending with $t+1$. The rationale for this particular MA structure is that it is not clear whether DVD player purchases lead or lag stereo receiver purchases. As a proxy for market structure, we use the three firm concentration ratio lagged one month.[6] To control for production cost we use the producer price index for semiconductors lagged two months.[7] Lags of the supply factors are used to minimize potential endogeneity and because price stickiness should delay the impact on prices. We exclude the time dummies here since they are perfect predictors of our industry wide variables. The signs of the supply and demand variables are all positive as should be expected. The moving average of ΔDVD player sales is not significant, the three firm concentration ratio- is significant at the 5% level and the PPI for semiconductors is significant at the 1% level (Table 3).

For these model specifications the coefficients for product characteristics and brand dummies remain fairly stable. Since the structure of the time dummies provide a great deal of flexibility to capture market-wide changes in prices that are not captured by the product characteristic variables, we infer that our aggregate supply and demand variables perform well as proxies for market factors. Moreover, the use of supply and demand

[6] Four, five and six firm concentration ratios with lags of between zero and three months also performed well. The Herfindahl index produced significant results at the aggregate level but in our more disaggregate exercises performed poorly.

[7] Lags of between zero and three months we also tried with similar results.

factors has at least two advantages over the use of time dummies. First, the number of regressors falls significantly resulting in a much higher F-statistic (352.95 vs 643.52). Second, these supply and demand variables have an economic meaning with clearly interpretable coefficients.[8]

With the exception of dummy variables for the remote control and Dolby Pro Logic dummy variables, characteristic coefficients have the anticipated signs and relative magnitudes and as we will see, all statistically significant characteristic coefficients remain stable over various regression specifications. The unusual sign for the remote control dummy appears to be a result of the fact that fewer than 2% of all stereo receivers come without a remote control. Given our regression result, one would suspect that certain high end stereo receivers tend to not have a remote control. The negative sign attached to the Dolby Pro Logic dummy variable may be due to the method used by NPD to code surround sound features and moreover, given this coding procedure may be wholly appropriate. In particular, a system coded as having Dolby Digital and DTS may also have Dolby Pro Logic and Dolby Pro Logic II. Since systems often come with multiple surround sound decoders, a system with only Dolby Pro Logic may indeed be considered to be of low quality.

4.2 Manufacturer level supply and demand controls

Since aggregate supply and demand variables could be predicted to perform no better than time dummies, we need to use manufacturer specific variables that better reflect the vagaries of the market. To do so, we interact our aggregate market variables with brand dummies to to get firm specific supply and demand characteristics variables. More accurately, these interaction terms represent individual manufacturer's reaction to market

[8]Time dummies are sometimes used for measuring price change with the somewhat vague interpretation that they capture price changes not embodied in product characteristics, i.e., price changes due to market forces.

level supply and demand factors. For example, differences in the coefficients on the interaction with DVD player sales will represent different firms' ability to change their prices in response to changes in market level demand. We begin by interacting only a single S&D variable at a time to evaluate the efficacy of individual interactions, the results of which are reported in Table 4. We then evaluate the use of all three sets of interactions simultaneously.

We begin with our three month moving average of the change in DVD player sales interacted with all of the brand dummies. For the model omitting the brand dummies, the interaction variables are largely significant, however, the coefficients of the product characteristics change greatly. On the other hand, when the brand dummies are included, with the exception of Onkyo and Harmon Kardon, the interaction variables are insignificant while the coefficients for product characteristics and brand dummies are quite similar to both of our baseline regressions. An F-test cannot reject the hypothesis that the coefficients of the interaction variables are all equal.[9] That is, our baseline supply and demand model cannot be rejected as the true model. This would seem to suggest that there are no significant interaction effects between brands and DVD player sales. Thus, while the growth in DVD player sales does affect the price for receivers as a whole, the growth does not impact manufacturers heterogeneously.

We next interact the PPI for semiconductors lagged one month. In the model without the brand dummies, all of the interaction variables are highly significant. With the brand dummies, the coefficients on the interaction variables are all significant, in some cases deviating significantly from the regression without the brand coefficients. In both cases, the coefficients on the product characteristics do not deviate significantly from those from our baseline regressions. However, a number of brand dummies are significant and quite large. For example, according to our results, Yamaha stereo receivers are priced at nearly

[9] $F(10, 4080) = 1.12$ with a p-value of 0.3447.

four times the cost of an observationally equivalent JVC stereo receiver.

This finding seems to be on the high side and a quick informal survey appears to confirm this. Examining prices at Circuit City, we did find considerable dispersion for stereo receivers with "identical" characteristics, however, not to the extent suggested by column (6). For example, a small sample at Circuit City of 5.1 channel Dolby Digital/DTS Surround sound receivers with 100 watts per channel ranged in price from $189.99 (JVC) to $379.99 (Harmon Kardon). Moreover, the large downward shift in the constant term from 0.0174 to -1.2483 is worrying. This suggests that in the presence of the interacted PPI for semiconductors, the brand dummies "borrow" from the constant term. Nevertheless, since many of of the brand dummies are significant at the 10% level or better, the model seems difficult to dismiss. This would seem to suggest that the omission of establishment level cost factors may introduce a downward bias in the measured value of unobserved quality.

Next, we interact the three firm concentration ratio lagged one month with the brand dummies. For the model without the brand dummies (column (7)), a majority of the interaction variables are significant (6 of 11) and the characteristic coefficients remain fairly stable. With the brand dummies included, none of the brand dummies are still significant and four of the interaction variables are significant. Moreover, an F-test rejects the hypothesis that the coefficients of the interaction variables are all equal.[10]

Thus the case can be made that in addition to observed quality attributes, brand dummies also pick up pure price change due to changes in market structure. To do so, note that the coefficients for the Sony, Kenwood, Pioneer and Yamaha interaction variables are positive and significant at at least the 5% level. Based on market shares averaged over the sample period, these are the four largest manufacturers. This is consistent with the economic story that the biggest firms are best able to exercise market power. If one ac-

[10] $F(10, 4080) = 1.62$ with a p-value of 0.0947.

cepts this argument then one must conclude that some of the value being picked up by the brand dummies is due to market concentration and the ability of certain firms to exert market power.

The results of the introduction of interacted market variables is somewhat mixed. Without brand level cost controls, there may be a downward bias in estimates of unobserved quality captured by manufacturer dummy variables. However, without controls for market structure, manufacturer dummy variables may upwardly bias these same estimates. The clear conclusion that we can draw is that the brand dummies are sensitive to model specification. In this exercise we've experimented with different specifications to capture market forces, so this sensitivity suggests that brand dummies are capturing true market price factors in addition to unobserved quality. This is problematic because these brand dummies are used to make quality adjustments when the BLS substitutes across brand. In the BLS's data for audio receivers from August 2001 until March 2003, approximately one third of the quality adjusted substitutions involved a substitution across brand.

Two potential solutions suggest themselves. The first would be to discontinue the use of brand name in making quality adjustments. However, we feel that brand dummies are still capturing unobserved quality that should be accounted for. The second and less drastic measure would be to put a greater emphasis on making substitutions to the same or similar brands (as determined by hedonic regressions) in order to minimize the use of less than reliable hedonic coefficients.

5 Concluding remarks

Time and brand dummy variables are often used to control for omitted variables. Time dummies are proxies for omitted market effects and are sometimes used as a measure of

price change. The brand dummy variables have been taken as proxies for unobserved quality and are often used for quality adjustment purposes. While the use of the "direct time dummy approach" has been dismissed (Schultze and Mackie, 2002, p. 143), the use of brand dummy variables for quality adjustment is quite common (for example, the BLS uses brand dummy variables to adjust for quality change for nearly all of the Consumer Price Index's hedonically adjusted products). Our results suggest that the use of brand names for quality adjustment may warrant more caution either in their application or when making product substitutions.

To provide a more concrete measure of potential bias, future research will be directed towards calculating price indices for different specifications of the hedonic regressions. Additionally, to judge the overall impact of this issue, similar specifications for other hedonic goods that substitute across brand will be developed.

References

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Table 1: Summary Statistics: Prices and product characteristics ($n = 4116$)

Variable	Mean	Std. Dev.
Av. Price	410.97	463.59
Units	616.35	1442.54
Expenditure	215206.2	449001.6
Watts	93.05	21.97
Digital Tuner	0.962	0.190
Equalizer	0.090	0.287
Remote control	0.986	0.118
Video switching	0.514	0.500
Video switching/s-video	0.437	0.496
THX	0.079	0.269
Dolby Pro-Logic	0.301	0.459
Dolby Digital	0.168	0.374
Dolby Digital/DTS	0.430	0.495
Sony	0.214	0.410
Pioneer	0.159	0.366
Yamaha	0.135	0.341
Denon	0.104	0.306
Kenwood	0.098	0.298
Technics	0.088	0.283
JVC	0.070	0.256
Onkyo	0.041	0.198
Marantz	0.039	0.193
Harmon Kardon	0.033	0.177
Mitsubishi	0.018	0.135

Table 2: Summary Statistics: Supply and demand controls (24 months).

Variable	Mean	Std. Dev.
C3	0.667	0.036
C4	0.766	0.032
C5	0.836	0.028
C6	0.895	0.028
Herfindahl Index	0.193	0.018
One month change in DVD player sales	17237.54	339311
PPI for semiconductors	90.75	3.046

Table 3: Baseline Regressions

Variable	(0) Kokoski et al.	(1) Time dummies	(2) S&D factors
Constant	4.7784^{***}	4.4300^{***}	0.0174
	(0.0757)	(0.0810)	(0.4688)
Watts per Channel	0.0111^{***}	0.0095^{***}	0.0095^{***}
	(0.0003)	(0.0003)	(0.0003)
Digital Tuner	-0.1423^{***}	0.0736^{***}	0.0697^{**}
	(0.0468)	(0.0329)	(0.0330)
Graphic Equalizer	-0.0332	0.0248	0.0187
	(0.0374)	(0.0230)	(0.0230)
Remote Control	-0.0348	-0.2160^{***}	-0.2170^{***}
	(0.0444)	(0.0524)	(0.0524)
Video Switching	0.4433^{***}	0.2554^{***}	0.2545^{***}
	(0.0269)	(0.0344)	(0.0344)
THX Certification	0.8526^{***}	0.8257^{***}	0.8241^{***}
	(0.0337)	(0.0264)	(0.0264)
Dolby Pro Logic	-0.2347	-0.2487^{***}	-0.2462^{***}
	(0.0191)	(0.0269)	(0.0269)
Dolby Digital	0.3395^{***a}	0.1210^{**}	0.1225^{**}
	(0.0234)	(0.0289)	(0.0289)
Dolby Digital and DTS		0.4799^{***}	0.4771^{***}
		(0.0288)	(0.0288)
Technics	0.0011^{b}	-0.0448	-0.0497
		(0.0302)	(0.0303)
Kenwood	0.0946^{b}	0.0823^{***}	0.0775^{***}
		(0.0294)	(0.0294)
Pioneer	0.1340^{b}	0.1360^{***}	0.1320^{***}
		(0.0282)	(0.0283)
Sony	0.2842^{b}	0.3012^{***}	0.2978^{***}
		(0.0266)	(0.0266)
Onkyo	0.6806^{b}	0.5743^{***}	0.5672^{***}
		(0.0374)	(0.0374)
Mitsubishi	0.7817^{b}	0.5994^{***}	0.5969^{***}
		(0.0496)	(0.0497)
Yamaha	0.6666^{b}	0.7981^{***}	0.7916^{***}
		(0.0298)	(0.0298)
Denon	0.8876^{b}	0.8239^{***}	0.8220^{***}
		(0.0299)	(0.0299)
Harmon Kardon	1.0133^{b}	1.0274^{***}	1.0151^{***}
		(0.0425)	(0.0424)
Marantz	1.0576^{d}	1.0356^{***}	1.0319^{***}
		(0.0387)	(0.0387)
Months	-0.2138^{***c}	-0.0092^{***}	-0.0095^{***}
	(0.0110)	(0.0012)	(0.0012)
Months, Squared	0.0144^{***c}	-6.18×10^{-6}	-8.27×10^{-6}
	(0.0024)	(1.82×10^{-5})	(1.82×10^{-5})
3 month MA of			0.0833
Δ in DVD player sales			(0.0533)
PPI for semiconductors			0.0417^{***}
lag 2			(0.0034)

3 firm concentration ratio lag 1			0.6599^{***} (0.2581)
N	3781	4115	4115
R-squared	0.7381	0.7923	0.7906
Adjusted R-squared	0.7346	0.7901	0.7894
F-statistic	210.27	352.95	643.52

Note: Numbers in parentheses are standard errors.
*** Significant at the 1 percent level
** significant at the 5 percent level
* significant at the 10 percent level
[a] Kokoski et al. aggregate Dolby Digital and Dolby Digital/DTS
[b] standard errors omitted
[c] these are coefficients for Kokoski et al.'s vintage variable

Table 4: Regressions using interaction variables

Variable	(3) DVD w/o brand	(4) DVD w/ brand	(5) PPI w/o brand	(6) PPI w/ brand	(7) C3 w/o brand	(8) C3 w/ brand
Constant	1.0098*	-0.0114	0.4298	-1.2483	0.3807	0.5230
	(0.5986)	(0.4693)	(0.4679)	(0.8278)	(0.4680)	(0.5979)
Watts per Channel	0.0024***	0.0095***	0.0095***	0.0095***	0.0094***	0.0095***
	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Digital Tuner	−0.1117***	0.0702**	0.0707**	0.0647*	0.0677**	0.0671**
	(0.0405)	(0.0330)	(0.0330)	(0.0331)	(0.0330)	(0.0330)
Graphic Equalizer	0.0563**	0.0182	0.0179	0.0199	0.0192	0.0188
	(0.0263)	(0.0230)	(0.0230)	(0.0230)	(0.0230)	(0.0230)
Remote Control	−0.0708	−0.2160***	−0.2189***	−0.2138***	−0.2144***	−0.2133***
	(0.0667)	(0.0524)	(0.0525)	(0.0524)	(0.0525)	(0.0524)
Video Switching	0.3239***	0.2535***	0.2538***	0.2538***	0.2561***	0.2543***
	(0.0434)	(0.0344)	(0.0345)	(0.0345)	(0.0345)	(0.0345)
THX Certification	1.0140***	0.8249***	0.8237***	0.8226***	0.8248***	0.8239***
	(0.0298)	(0.0264)	(0.0264)	(0.0265)	(0.0265)	(0.0265)
Dolby Pro Logic	−0.4917***	−0.2463***	−0.2458***	−0.2491***	−0.2487***	−0.2482***
	(0.0331)	(0.0269)	(0.0269)	(0.0269)	(0.0269)	(0.0269)
Dolby Digital	0.0318	0.1225***	0.1213***	0.1200***	0.1228***	0.1202***
	(0.0363)	(0.0289)	(0.0290)	(0.0290)	(0.0290)	(0.0290)
Dolby Digital and DTS	0.4594***	0.4760***	0.4764***	0.4745***	0.4773***	0.4743***
	(0.0360)	(0.0288)	(0.0288)	(0.0289)	(0.0288)	(0.0289)
Technics		−0.0472		-0.2962		0.1494
		(0.0312)		(0.9201)		(0.5191)
Kenwood		0.0746**		1.9160**		−0.8484*
		(0.0308)		(0.8874)		(0.5082)
Pioneer		0.1346***		1.7650**		−0.5155
		(0.0293)		(0.8290)		(0.4674)
Sony		0.3010***		2.1164***		−0.4115
		(0.0276)		(0.7962)		(0.4503)
Onkyo		0.5546***		0.5512		0.4695
		(0.0389)		(1.0315)		(0.6035)
Mitsubishi		0.5966***		2.6278*		−0.2043
		(0.0509)		(1.4703)		(0.8074)
Yamaha		0.7991***		2.8815***		−0.1702
		(0.0308)		(0.8391)		(0.4805)
Denon		0.8256***		1.0033		0.8435*
		(0.0310)		(0.8903)		(0.5092)
Harmon Kardon		1.0056***		2.3661**		0.6209
		(0.0431)		(1.1808)		(0.7039)
Marantz		1.0314***		2.8321**		0.2712
		(0.0396)		(1.1151)		(0.6342)
Months	−0.0095***	−0.0096***	−0.0095***	−0.0095***	−0.0095***	−0.0095***
	(0.0015)	(0.0012)	(0.0012)	(0.0012)	(0.0012)	(0.0012)
Months, Squared	2.04×10^{-5}	9.83×10^{-6}	8.07×10^{-6}	8.45×10^{-6}	9.17×10^{-6}	8.71×10^{-6}
	(2.33×10^{-5})	(1.82×10^{-5})	(1.82×10^{-5})	(1.82×10^{-5})	(1.82×10^{-5})	(1.82×10^{-5})
3 mo. MA of Δ in DVD player sales			0.0836	0.0818	0.0863	0.0822
			(0.0534)	(0.0532)	(0.0534)	(0.0533)
PPI for semi-conductors lag2	0.0433***	0.0418***			0.0419***	0.0418***
	(0.0043)	(0.0034)			(0.0034)	(0.0034)
3 firm conc. ratio lag 1	0.5627*	0.6767***	0.6502**	0.6512**		
	(0.3314)	(0.2584)	(0.2584)	(0.2578)		
JVC × Int. Var.	−0.5446**	0.1281	0.0372***	0.0556***	0.0984	−0.1154
	(0.2442)	(0.1969)	(0.0034)	(0.0082)	(0.2596)	(0.6243)
Technics × Int. Var.	−0.6273***	0.0310	0.0367***	0.0582***	0.0182	−0.4208
	(0.2241)	(0.1778)	(0.0034)	(0.0070)	(0.2602)	(0.5418)
Kenwood × Int. Var.	−0.6441***	0.1980	0.0380***	0.0354***	0.2117	1.2725**
	(0.2104)	(0.1722)	(0.0034)	(0.0065)	(0.2600)	(0.5208)
Pioneer × Int. Var.	−0.5026***	0.0372	0.0386***	0.0377***	0.2930	0.8527**
	(0.1629)	(0.1305)	(0.0034)	(0.0056)	(0.2590)	(0.4234)
Sony × Int. Var.	−0.0108	0.0258	0.0404***	0.0357***	0.5425**	0.9451**
	(0.1395)	(0.1114)	(0.0034)	(0.0049)	(0.2591)	(0.3788)

Onkyo ×	0.5777^{*}	0.5132^{**}	0.0434^{***}	0.0557^{***}	0.9398^{***}	0.0245
Int. Var.	(0.3211)	(0.2602)	(0.0034)	(0.0086)	(0.2620)	(0.7210)
Mitsubishi ×	0.3787	0.1729	0.0437^{***}	0.0334^{**}	0.9875^{***}	1.0862
Int. Var.	(0.4981)	(0.3971)	(0.0034)	(0.0143)	(0.2652)	(1.0754)
Yamaha ×	0.6468^{***}	-0.1094	0.0458^{***}	0.0327^{***}	1.2797^{***}	1.3256^{***}
Int. Var.	(0.1795)	(0.1441)	(0.0034)	(0.0057)	(0.2599)	(0.4571)
Denon ×	0.6814^{***}	0.0187	0.0462^{***}	0.0536^{***}	1.3196^{***}	-0.1512
Int. Var.	(0.1915)	(0.1535)	(0.0034)	(0.0065)	(0.2593)	(0.5169)
H-K ×	1.2296^{***}	0.7503^{***}	0.0484^{***}	0.0408^{***}	1.5991^{***}	0.4756
Int. Var.	(0.3610)	(0.2839)	(0.0034)	(0.0108)	(0.2643)	(0.8886)
Marantz ×	1.1003^{***}	0.1634	0.0485^{***}	0.0358^{***}	1.6422^{***}	1.0222
Int. Var.	(0.3337)	(0.2639)	(0.0034)	(0.0098)	(0.2626)	(0.7719)
N	4115	4115	4115	4115	4115	4115
R^2	0.6552	0.7912	0.7902	0.7919	0.7902	0.7915
Adjusted R^2	0.6531	0.7895	0.7890	0.7902	0.7890	0.7897
F-statistic	323.79	454.74	642.06	456.64	642.03	455.42

Note: Numbers in parentheses are standard errors.
*** Significant at the 1 percent level
** significant at the 5 percent level
* significant at the 10 percent level