Brand Dummy Variables in Hedonic Regressions: A Study Using Stereo Receiver Scanner Data*

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Abstract

Time and brand dummy variables are typically used as controls for omitted variables. The operating assumption made is that time dummies control for unobserved factors affecting price and brand dummies control for unobserved factors affecting quality. We investigate the validity of the latter assumption by explicitly controlling for supply and demand factors in hedonic regressions for stereo receiver scanner data. We find that the characteristic and brand coefficients remain roughly unchanged if industry level supply and demand variables are used in place of time dummies. We interact industry level variables with brand variables to produce manufacturer level controls for supply and demand. Although the coefficients for physical product characteristics are not significantly changed, the coefficients for brand variables become quite unstable. We conclude that brand dummy variables are poorly specified and their use for quality adjustment may introduce errors into price index calculations.

Keywords: hedonic, price measurement, market structure
JEL classification codes: L1, D1, L6

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1 Introduction

A price index measures the price change of a given basket of items. However, in any dynamic economy, this basket of items will change as new items are consumed. If the prices of the new items are not linked to the prices of the old items, then a price index would not account for price changes that occur during the introduction of new items. In other words, differences in price levels would be attributed to changes in the quality of products in the basket. Conversely, if the link is made directly, then all difference would be attributed to "true" price changes.

Moulton and Moses (1997) effectively describes the different methods the BLS has used to link prices to account for the portions of the price change that is due to the "price effect" and "quality effect." Of interest for this paper is direct quality adjustment, which imputes a previous period price for a new item. Because this price is not collected (often because this good is not sold in the previous period), hedonics have been increasingly used to price a hypothetical item composed of the same characteristics as the new item.

In practice, the direct quality adjustment uses the previous period price of an old item to account for most of the imputed price level. The remaining "quality effect" is quantified by pricing out the difference in characteristics between the two items. As such, a measure of the accuracy of a hedonic model becomes its ability to quantify differences in quality (either perceived or real) between two items. 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 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 brand dummies also capture pure price changes, due perhaps to supply and demand changes, then the resulting adjustment will introduce errors into the CPI.

We examine the use of brand dummies in hedonic regressions using explicit controls for supply and demand variables. In imperfectly competitive markets, equilibrium prices will depend on product characteristics, demand characteristics and supply characteristics, however, typical hedonic models control only for product characteristics.[1] If either supply or demand characteristics are correlated with 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) and more recently in Pakes (2002).

To control for supply and demand characteristics, we construct variables for market concentration, cost and demand. Our empirical results are twofold. We begin with two baseline regressions: the standard hedonic regression using time dummies and a regression augmented by industry level supply and demand variables. The hedonic coefficients over these two specifications appear to be quite stable, suggesting that our supply and demand controls are in fact capturing changes in market structure occurring within the stereo receiver industry.

Next, 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 observable characteristics again remain fairly stable, the coefficients of brand dummies change significantly once manufacturer supply and demand effects are allowed. In

[1]See Griliches (1961) for an early example and Ioannidis and Silver (1999), Kokoski et al. (2000), Nelson et al. (1994) and Silver (1999), for more recent examples.

particular, for the specification where firm concentration is interacted with brand dummies and for the specification where the PPI for semiconductors is interacted with brand dummies there are sizeable changes in many of the coefficients for the brand dummies. This suggests that brand dummy variables may be poorly specified and may not be good controls for unobserved quality. We therefore urge caution in their use for quality adjustment.

The plan of the paper is as follows. In Section 2, we describe the data. The empirical results are reported in Section 3. Finally, we conclude in Section 4.

2 The Data

We use NPD's scanner data for stereo receivers purchased by the Bureau of Labor Statistics. The data ranges from October of 1999 through September of 2001.[2] Each month contains a single observation for a specific stereo receiver model sold in the US. Each observation includes the average price, number of units sold, total expenditures and physical product characteristics (including brand name). NPD collect these data from various retail outlet chains across the nation, and then adjust them to make them representative of total national sales.[3] Some summary statistics are given in Table 1.

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. Since semiconductors are one of the primary inputs to the production of virtually all consumer electronics, the BLS's Producer Price Index for semiconductors is used to control for industry level fluctuations in costs. The three month moving average of the change in U.S. sales of

[2] Although more recent data is available (through February of 2002), we chose a monthly two-year sample ending in September of 2001 because Wal-mart ended its relationship with all U.S. scanner data vendors beginning in October of 2001 and is such a large player in the retail market.

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

DVD players[4] 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.

3 Hedonic regression results

Our basic log-linear hedonic regression model is:

$$\ln p_i = \alpha \mathbf{x}_i + \beta \mathbf{y}_i + \gamma c_i + \delta t_i + \varepsilon_i \tag{1}$$

p_i is the price of observation i, $\mathbf{x}_i$ is a vector of product characteristics (in practice, this includes brand dummy variables) for observation i, $(\mathbf{y}_i, c_i)$ is a vector of supply and demand variables, t_i is a set of dummy variables for the time periods and ε_i is the error term. We assume that ε_i has all of the standard properties.

3.1 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). 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

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

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.[5] To control for production cost we use the producer price index for semiconductors lagged two months.[6] Lags of the supply factors are used to minimize potential endogeneity and because price rigidities 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 significant at the 5% level, the three firm concentration ratio and the PPI for semiconductors are 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 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 (370.69 vs 677.56). Second, these supply and demand variables have an economic meaning with clearly interpretable coefficients.[7]

With the exception of dummy variables for digital tuner, the remote control and Dolby Pro Logic, characteristic coefficients have the anticipated signs and relative magnitudes and as we will see, all of the statistically significant characteristic coefficients remain stable over various regression specifications. The unusual sign for the digital tuner and

[5]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.

[6]Lags of between zero and three months were also tried with similar results.

[7]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.

remote control dummies appear to be a result of the fact that fewer than 5% and 2% of all stereo receivers come without a digital tuner and a remote control. Given our regression result, one would suspect that certain high-end stereo receivers tend to not have digital tuners or remote controls. 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. Moreover, given this coding procedure, the negative sign 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.

3.2 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 get firm specific supply and demand characteristics variables. Specifically, the coefficients of these interaction terms represent manufacturer reactions to market 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 (including the reference brand, JVC). Including the brand dummy variables and the remaining, uninteracted market variables (model 3), we find that 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.[8] That is, our baseline supply and demand model (2) 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, this growth does not impact on manufacturers heterogeneously.

We next interact the PPI for semiconductors lagged two months (model 4). Here the coefficients on the interaction variables are all significant. An F-test rejects the hypothesis that the coefficients of the interaction variables are all equal ($F(12, 4481) = 8.20$). Moreover, the coefficients on the physical 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 more than 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 (4). 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 (Harman Kardon). Moreover, the large downward shift in the constant term from -0.4943 to -2.2153 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

[8] $F(12, 4481) = 0.52$ with a p-value of 0.9032.

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. The only brand dummy with any statistical significance is Denon and then only at the 10% level. Of the interaction variables, only three are statistically significant (Kenwood, Sony and Yamaha at the 5% level). An F-test cannot reject the hypothesis that the coefficients of the interaction variables are all equal.[9]

Nevertheless, it is interesting to note that based on market shares averaged over the sample period, Sony, Yamaha and Kenwood are among the five largest manufacturers and during the last several months, they are among the top four.[10] This is consistent with the economic story that the biggest firms are best able to exercise market power. If one accepts 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 large firms to exert market power.

Finally we estimate a hedonic regression including all interacted supply and demand variables. As a group, the independent variables are highly significant with an R^2 of 0.7855. As a group, the producer price index interaction variables are significantly different from one another at the 1% level. However, the DVD interaction variables are not significantly different from one another nor are the three firm concentration ratio interaction variables. Thus in some sense, column 4 of Table 4 represents the parsimonious hedonic model for stereo receivers. As an additional exercise, we add the three-firm concentration interaction terms for Sony, Yamaha and Kenwood. Among the characteristic,

[9] $F(12, 4481) = 0.61$ with a p-value of 0.8326.

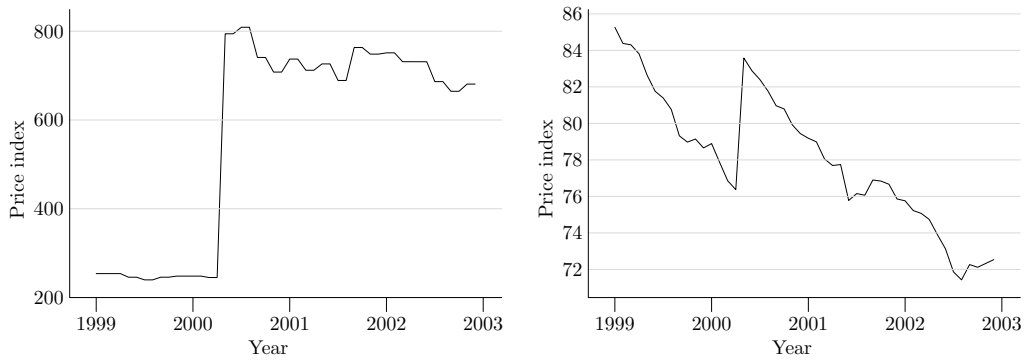
[10] Indeed, we run a regression with just the Sony, Yamaha and Kenwood interaction variables and include the lagged three firm concentration ratio to capture the common effect. A test of the hypothesis that the interaction variables are different from zero cannot be rejected at the 5% level ($F(3, 4490) = 2.58$). That is, restricting the remaining interaction coefficients to be the same, the interaction terms for Sony, Yamaha and Kenwood are significantly different from the common effect.

brand and PPI interaction coefficients, most are not significantly different that those from model 4. Of the three concentration interactions, only Kenwood is statistically significant but Sony, Yamaha and Kenwood are jointly significant at the 10% level.

Generally, 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 concentration, manufacturer dummy variables may upwardly bias these same estimates. The clear conclusion that we can draw is that while the coefficients for physical characteristics remain fairly stable over different model specifications, the brand dummies are quite sensitive. In this exercise we've experimented with different specifications to capture market forces, so this sensitivity suggests that brand dummies are poorly specified and are unable to accurately measure unobserved quality. This is problematic because these brand dummies are used to make quality adjustments when the BLS substitutes across brand. For example, from January 2001 through December 2003, brand substitution in the BLS's data for its hedonically adjusted products ranged from just over 3% (washers and dryers) to nearly 50% (audio products) of all product substitutions (see Table 5).

The brand dummy issue can become more of a problem when combined with historical small sample issues in the CPI.[11] One extreme anecdotal example occurred in May 2000. The single quote representing Audio Products in San Diego made an across brand substitution. The hedonic stated that the new brand was only worth 30% of the old brand. The adjustment resulted in a price increase for the Item-Area of 325% (Figure 1(a)), which

[11]Many of these issues are artificially created due to the Item-Area structure of the CPI. This structure results in a two-stage price index calculation—one to create indices for every combination of item stratum and geographical sampling unit, and the second to aggregate these indices into various published indices. In this aggregation process, each Item-Area index is given a predetermined expenditure weight appropriate to the expenditure on the item stratum in the geographical area. If the sample has depleted, then a disproportionately small number of quotes can represent a high level of expenditure.



(a) San Diego

(b) National

Figure 1: Example of problematic dummy variable use: Audio products (1999–2002)

when combined with the weight, resulted in a noticeable impact on the aggregated US Audio Product price index (Figure 1(b)). While this is an example of the worst that can happen and is, as we have emphasized, due in large part to the structure of the U.S. CPI, our analysis suggests more generally that the use of brand dummy variables for quality adjustment is problematic, at best introducing unnecessary noise to price index calculations.

Three potential solutions to the brand dummy issue 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 brand in order to minimize the use of these less than reliable hedonic coefficients. The final measure would be to use a different adjustment procedure for across brand substitutions. Future research will analyze the impact of different treatments of this issue.

3.3 Sensitivity analysis

We now test the sensitivity of our results to the length of the covered time period and to alternate model specifications. We begin by dividing the two-year sample to two equal one-year samples and re-running our regressions. Although the significance of some of the variables changes, the same basic pattern emerges. After substituting the market variables for time dummies, we see that hedonic coefficients again remain largely unchanged. Using interacted market variables reveals a similar pattern of stable hedonic coefficients and unstable brand coefficients.

We then introduce controls for a model's vintage (as in Kokoski et al., 2000) or model age (i.e., months since introduction). Such controls increase the model's goodness of fit and moreover, all of the results discussed continued to hold. Hedonic coefficients remain stable and brand dummies are unstable. In fact, with the Kokoski et al. vintage variable included, the results are particularly striking. The regressions with either the interacted three-month moving average of the change in DVD player sales or the interacted lagged semiconductor index behave the same as before. However, the regression with the interacted lagged three-firm concentration ratio now has six interaction coefficients that are significant at at least the 10% level.

Finally, we also estimate a linear hedonic regression to see if functional form impacts these findings. Although the fit was not as good, we again find stability of hedonic coefficients and instability of brand dummy coefficients. Due to our eventual use of interactions between our market structure variables and the brand dummies, another commonly used specification, the double-log specification, is not feasible for the purposes of our robustness exercise.

Thus our basic finding that brand dummy variables are poor proxies for unobserved quality appears to be robust to changes in the number of periods covered and to other common hedonic specifications.

4 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. 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.

Since the coefficients of physical product characteristics appear to be fairly stable over various regression specifications, one possible interpretation of our results is a validation of hedonic models where supply and demand factors are omitted. We caution against this interpretation as, although we have confidence in our supply and demand variables as indicators of market structure at the industry level, we are less satisfied with our interacted supply and demand variables. To properly test this proposition, it would be necessary to have manufacturer level supply and demand variables.

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. Finally, to gauge the importance of this issue research will be directed towards the collection of better manufacturer level supply and demand proxies.

Another potential area of research could be delving into an examination of the degree to which time dummies may be poorly specified. In this paper our supply and demand variables are aggregate, industry-wide measures and are thus perfectly collinear with the time dummy variables. Better proxies for market structure (i.e., manufacturer specific variables) would no doubt shed more light on this issue. Nevertheless, since time dummy

coefficients are equally vaguely interpreted as measuring pure price changes, we expect them to have similar problems. In particular, it is natural to expect that unobserved quality varies over time so that some of these quality changes will be picked up by the time dummies. Thus there may be further reasons to hold suspicions against the "direct time dummy approach" (Schultze and Mackie, 2002, p. 143).

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Table 1: Summary Statistics: Prices and product characteristics ($n = 4518$)

Variable	Mean	Std. Dev.
Av. Price	452.58	551.46
Units	618.02	1465.141
Watts	93.84	23.72
Digital Tuner	0.958	0.200
Equalizer	0.103	0.304
Remote control	0.981	0.135
Video switching	0.950	0.218
THX	0.090	0.286
Dolby Pro-Logic	0.275	0.447
Dolby Digital	0.168	0.374
Dolby Digital/DTS	0.450	0.498
Technics	0.085	0.278
Aiwa	.007	.081
JVC	0.066	0.249
Kenwood	0.096	0.294
Pioneer	0.151	0.358
Sony	0.200	0.400
Onkyo	0.051	0.220
Mitsubishi	0.018	0.134
Yamaha	0.128	0.334
Denon	0.114	0.317
Harmon Kardon	0.033	0.179
Marantz	0.036	0.185
Other	0.017	0.128

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.[a]	(1) Time dummies	(2) S&D factors
Constant	4.2288***	4.5782***	−0.4943
	(0.0820)	(0.0757)	(0.3085)
Watts per Channel	0.0108***	0.0088***	0.0088***
	(0.0003)	(0.0003)	(0.0003)
Digital Tuner	−0.2870***	−0.1023***	−0.1038***
	(0.0520)	(0.0333)	(0.0333)
Graphic Equalizer	0.0740	0.0248	0.0210
	(0.0407)	(0.0228)	(0.0227)
Remote Control	0.1164**	−0.2990***	−0.2977***
	(0.0492)	(0.0495)	(0.0495)
Video Switching	0.5062***	0.2060***	0.2025***
	(0.0298)	(0.0356)	(0.0356)
THX Certification	0.9042***	0.8026***	0.8021***
	(0.0377)	(0.0255)	(0.0256)
Dolby Pro Logic	−0.2895***	−0.2088***	−0.2057***
	(0.0207)	(0.0270)	(0.0270)
Dolby Digital	0.4184***[b]	0.2224***	0.2256***
	(0.0258)	(0.0279)	(0.0279)
Dolby Digital and DTS		0.6970***	0.6988***
		(0.0266)	(0.0266)
Technics		−0.0511	−0.0546*
		(0.0317)	(0.0317)
Aiwa		−0.1419*	−0.1322*
		(0.0782)	(0.0781)
Kenwood		0.0434	0.0390
		(0.0308)	(0.0307)
Pioneer		0.0706**	0.0672**
		(0.0295)	(0.0295)
Sony		0.2328***	0.2300***
		(0.0278)	(0.0278)
Onkyo		0.5409***	0.5348***
		(0.0369)	(0.0369)
Mitsubishi		0.4577***	0.4559***
		(0.0507)	(0.0507)
Yamaha		0.7602***	0.7551***
		(0.0310)	(0.0310)
Denon		0.7549***	0.7531***
		(0.0303)	(0.0303)
Harman Kardon		1.0080***	1.0004***
		(0.0433)	(0.0433)
Marantz		1.0114***	1.0093***
		(0.0409)	(0.0409)

Others		1.7226***	1.7184***
		(0.0552)	(0.0552)
3 month MA of			0.1268**
△ in DVD player sales			(0.0514)
PPI for semiconductors			0.0463***
lag 2			(0.0023)
3 firm concentration			0.9264***
ratio lag 1			(0.2242)
N	3781	4518	4518
R^2	0.6710	0.7848	0.7835
Adjusted R^2	0.6668	0.7827	0.7824
F-statistic	158.58	370.69	677.56

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. use a bimonthly sample beginning in Feb/Mar 1997 and ending in Dec 1999/Jan 2000 and report only dummy variable coefficients for the model including model vintage variable. Kokoski et al. dummy variable coefficients are not included here because their sample time period differs from ours and thus has a different set of manufacturers.

[b] Kokoski et al. aggregate Dolby Digital and Dolby Digital/DTS

Table 4: Regressions using interaction variables

Variable	(3) DVD	(4) PPI	(5) C3
Constant	-0.4970	-2.2153***	-0.6562
	(0.3092)	(0.7811)	(0.5926)
Watts per channel	0.0088***	0.0088***	0.0088***
	(0.0003)	(0.0003)	(0.0003)
Digital tuner	-0.1044***	-0.1141***	-0.1034***
	(0.0333)	(0.0337)	(0.0333)
Graphic equalizer	0.0202	-0.0209	0.0223
	(0.0228)	(0.0228)	(0.0228)
Remote control	-0.2975***	-0.2901***	-0.2979***
	(0.0495)	(0.0495)	(0.0495)
Video switching	0.2021***	0.2023***	0.2039***
	(0.0356)	(0.0357)	(0.0356)
THX certification	0.8030***	0.8065***	0.8029***
	(0.0256)	(0.0257)	(0.0256)
Dolby Pro Logic	-0.2052***	-0.2079***	-0.2065***
	(0.0270)	(0.0270)	(0.0270)
Dolby Digital	0.2262***	0.2251***	0.2241***
	(0.0279)	(0.0280)	(0.0279)
Dolby Digital	0.6990***	0.6964***	0.6973***
and DTS	(0.0266)	(0.0267)	(0.0266)
Technics	-0.0568*	0.8300	0.8602
	(0.0332)	(0.9729)	(0.7024)
Aiwa	-0.1443*	-2.0890	0.6680
	(0.0822)	(3.1068)	(1.7263)
Kenwood	0.0368	1.4892	-0.2731
	(0.0327)	(0.9320)	(0.6845)
Pioneer	0.0671**	1.8607**	0.3309
	(0.0310)	(0.8783)	(0.6304)
Sony	0.2270***	2.5087***	0.3668
	(0.0293)	(0.8447)	(0.6078)
Onkyo	0.5208***	1.9076*	0.5274
	(0.0389)	(1.0166)	(0.7945)
Mitsubishi	0.4532***	2.2318	0.3731
	(0.0527)	(1.5004)	(1.0426)
Yamaha	0.7572***	3.3330***	0.6772
	(0.0326)	(0.8891)	(0.6527)
Denon	0.7469***	2.4590***	1.1882*
	(0.0319)	(0.9192)	(0.6666)
Harman Kardon	0.9839***	2.6649**	0.9714
	(0.0449)	(1.2250)	(0.9443)
Marantz	1.0025***	4.6484***	1.1181
	(0.0426)	(1.1915)	(0.8763)
Others	1.7172***	0.3141	1.4004
	(0.0566)	(1.5828)	(1.2159)
3 mo. MA of $\triangle$ in		0.1245**	0.1284**
DVD player sales		(0.0513)	(0.0514)
PPI for semi-	0.0464***		0.0464***
conductors lag 2	(0.0023)		(0.0023)

3 firm conc.	0.9310***	0.9086***	
ratio lag 1	(0.2245)	(0.2241)	
JVC x	0.0599	0.0655***	1.1682
int. var.	(0.1910)	(0.0083)	(0.8145)
Technics x	0.0915	0.0557***	-0.2334
int. var.	(0.1724)	(0.0069)	(0.7078)
Aiwa x	0.3442	0.0871***	-0.0524
int. var.	(0.5565)	(0.0333)	(2.4976)
Kenwood x	0.1045	0.0495***	1.6489**
int. var.	(0.1627)	(0.0063)	(0.6683)
Pioneer x	0.0364	0.0457***	0.7648
int. var.	(0.1275)	(0.0052)	(0.5265)
Sony x	0.1190	0.0404***	0.9599**
int. var.	(0.1099)	(0.0045)	(0.4610)
Onkyo x	0.3860*	0.0503***	1.1815
int. var.	(0.2148)	(0.0077)	(0.9182)
Mitsubishi x	0.1098	0.0459***	1.2972
int. var.	(0.3886)	(0.0142)	(1.3793)
Yamaha x	-0.0042	0.0371***	1.2897**
int. var.	(0.1380)	(0.0055)	(0.5872)
Denon x	0.2079	0.0467***	0.5015
int. var.	(0.1416)	(0.0060)	(0.6220)
H-K x	0.5268**	0.0471***	1.2147
int. var.	(0.2584)	(0.0108)	(1.2008)
Marantz x	0.2408	0.0254**	1.0028
int. var.	(0.2557)	(0.0103)	(1.0764)
Others x	0.0370	0.0809***	1.6604
int. var.	(0.3534)	(0.0154)	(1.6843)
N	4518	4518	4518
R^2	0.7838	0.7846	0.7838
Adj. R^2	0.7821	0.7829	0.7820
F-statistic	451.3	453.52	451.21

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

Table 5: Frequency of change in manufacturer as a percentage of all model substitutions – January 2001 to September 2003

Product Group	Percentage
Men's Athletic Footwear	33.3
Women's Athletic Footwear	38.6
Personal Computers	9.3
Refrigerators	19.9
Clothes Washers & Dryers	3.3
Microwave Ovens	19.6
Televisions	33.7
VCRs, DVD Players & Camcorders	36.0
Audio Receivers*	38.2
Other Audio Products	48.3
All Hedonic Items	**24.7**

* September 2001 – March 2003