Diffusion and experience curve pricing of new products in the consumer electronics industry

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ABSTRACT

The existence of experience curve is documented in a wide range of industries (Boston Consulting Group, 1975). However, relating experience curve pricing to diffusion of new products is rarely addressed in the empirical literature, with the exception of Bass (1980). This paper adds to the literature by empirical calculation of the experience curve for a larger set of products and relating it to the introductory stages of these products from the Consumer electronics industry. The gradual price erosion observed in many consumer electronics products is consistent with cumulative production learning curve. Results show excellent fit of data to experience curve models. Comparison of the slope of experience curves for several consumer electronics products with those from other industries is provided. The results should benefit the consumer electronics and related industries in setting long term pricing strategies.
Keywords: experience curve, pricing strategy, consumer electronics industry, diffusion.

INTRODUCTION

Pricing a new product is an intricately difficult task, especially in industries such as consumer electronics where it is common to see rapid technological changes and consequently sharp price erosions soon after the launch of a new product. Manufacturers are cautious about adopting a pricing strategy that will allow wide and sustained diffusion of the product all the way to the maturity level. Although there are other notable pricing strategies considered for new products, such as penetration and price skimming (Dean, 1955), implementing such pricing strategies based on data is extremely difficult. This difficulty arises partly from the tremendous need of data it places on managers. Determining experience curve pricing, on the other hand does not require as extensive data while offering valuable clues for pricing strategies in industries where the supply side related cost reductions are prominent (Ghemawat, 1985). Consumer electronics industry represents one such industry. Yet, to the author's knowledge, there is no empirical paper that documented the experience curve effects in this industry. There are several advantages of choosing this industry to study experience curve effects. First, the industry stands out in terms of the abundance of new products introduced in different historical periods. For example, color television goes back to the 1950s, VCR to 1970s and flat panel televisions to most recently. Second, historical data in consumer electronics industry presents a unique blend of high and low introductory prices for new products and varying degrees of price erosion that follows introduction. The combination of these factors offers a rare opportunity of observing what amounts to a naturally occurring experiment of various rates of price depreciation and their impact on consumers' adoption of these products. The resulting data originating from such a natural experiment should offer testable clues about the pricing practices that might have been adopted in the industry.

Despite its important managerial implications, studies on experience curve pricing stagnated in the marketing literature since Day and Montgomery (1983). Other disciplines have picked up the pace in estimating experience curve effects in industries such as renewable energies (Papineau, 2006; Nemet, 2006), natural gas liquefaction (Greaker and Sagen, 2008), natural gas boiler (Weiss et al., 2009), medical devices (Brown et al., 2007), and semiconductors (Gruber, 1996). Studies in these diverse disciplines report the importance of experience curve modeling as a measure of technological change and the resulting implications on pricing many industrial products. Research focusing on consumer products and their pricing implications using experience curve has been nonexistent for some time. This paper aims to contribute to this gap in the literature.

THE NOTION OF EXPERIENCE CURVE

The concept of experience curve goes back to the aircraft industry in the 1920s when it is observed that the number of hours needed to manufacture decreased at a uniform rate as the quantity of airframes produced increased (Yelle, 1979; Alchian, 1963). According to these studies, the efficiency gained from cumulative job experience results in higher productivity of workers, and thus a reduction in per unit cost of production occurring within a given manufacturing plant. The fixed plant size differentiates this cost reduction from decreasing unit costs arising from economies of scale. Of course, there are other sources of learning in a firm other than cumulative production, such as organizational learning (Bahk and Gort, 1993). The notion of experience curve encapsulates these sources of cost reduction unrelated to economies of scale.

The existence of such a relationship between unit cost and cumulative volume is extensively documented by the Boston Consulting Group (1972). The mathematical expression for the experience curve is given by (Day and Montgomery, 1983, p 44):

$$C_n = C_1 n^{-\lambda} \qquad (1)$$

Where,
C_n=cost of the nth unit
C_1 = cost of the first unit
n = cumulative number of units
λ = elasticity of unit costs with respect to cumulative volume.

The above expression suggests that cost per unit will fall by a constant rate of $1\text{-}2^{-\lambda}$. For example, when λ=1, we are dealing with a 50% experience curve, suggesting that cost (or price) will fall to 50% of their original value as experience (measured by cumulative units produced) doubles.

Once plotted the relationship between variable unit cost and cumulative output in logarithmic scales, a linear line that best fit the data is considered the experience curve. An 80% experience curve is considered normal, which bears the following interpretation: every time experience doubles, cost per unit will fall to 80% of their original value (Kortge, et al.,1994). In other words, cost is expected to fall by 20% for each doubling of cumulative volume produced. (Kortge, et al. 1994, p. 222). The slope of the experience curve varies widely from product to product and from industry to industry. For example, Ghemawat (1985) compiled empirical estimates of experience curves for over 100 products that shows the average slope at 85%, while 15% of the products displayed slope under 70%. Boston Consulting Group (1975) also showed varying rate of learning experience for various sizes of motor cycle engines produced in United Kingdom.

EXPERIENCE CURVE AND DIFFUSION

Although prior work on experience curves spans many product categories in many industries, typically the estimation proceeded without concentrating on the stage of the product life cycle or the role of experience curve pricing in driving diffusion. The relationship between cost reduction gained from cumulative production and diffusion of new products is intuitive because experience curve allows marketers more freedom in pricing products to achieve desired market share. Bass (1980) combined the experience curve effects with the social contagion effects model of diffusion (imitation and innovation) and found that experience effects on price reduction sped up the rate of adoption. The focus of this paper is to estimate the experience curve effect on price and the resulting effect on household adoption of consumer electronics products. This paper improves upon previous studies by including a larger number of products (20 versus 4 included in Bass (1980)) and focusing on the introductory/growth stages of these products launched at various points of time. Kortge et al. (1994) suggested that “the experience curve is best used during the growth phase of the product life cycle” (p. 224). Bass (1980) justifies growth stage because most purchases are for first time owners and replacement purchase is yet to be a major part of sales. The repeat purchases do not expand the adoption of the product in question.

DATA AND METHODOLOGY

This paper uses time series secondary data on 20 consumer electronics products purchased from the Consumer Electronics Manufacturers Association (CEMA). The data set covers the first seven years of data since the introduction of each of the products. CEMA's FastFacts, as the data base is called, provides a one-stop source for historical price, volume, and household level adoption (penetration) data. FastFacts lists about 50 products, but complete data on manufacturers' shipped units, average price, and household penetration are available for less than half of those listed. Once the data is screened for completeness and definition of consumer electronics, only 20 products remained in the sample used in this study. One particular characteristic of this data is that the price reported is the average price charged to dealers and volumes represent shipment to dealers. For the purpose of experience curve estimation, this poses no problems as Bass (1980) used similar industry average data, although the potential bias of aggregation is acknowledged. However, this data base is the only source known in industry to report historical household penetration levels for most consumer electronics products starting with their early years of introduction. CEMA data offers one more advantage: the data is reported directly by manufacturers to the CEMA and hence enjoys wider coverage and better reliability. Only the first seven years of historical data on each product is included in order to capture the introductory and growth stage (after visual specification) of each product, recalling that experience curve is best suited for this period of the product life cycle.

Once taken logarithm of prices and cumulative units, the experience curve model becomes

$$\ln C_n = \ln C_1 - \lambda \ln n \qquad (2)$$

Where, *ln* implies natural logarithm. Model (2) is the so called log-log model that represents the experience curve. Estimation by ordinary least squares regression provides the constant cost elasticity estimate, λ and the first part of the right hand side representing a constant. It is noteworthy that this model does not preclude including other factors that are likely to influence the experience curve. Among these factors that are tested in other research includes degree of product standardization, and economies of scale (Stobaugh and Townsend, 1975), however, cumulative experience showed the most predictive power in explaining price changes. Further, it is common in literature to use either cost or average industry price as the dependent variable, depending on data availability (Day & Montgomery, 1983, p 48; Brown et al., 2007).

RESULTS

Estimates of Learning Curves

Ordinary least square regressions are applied to the log-log specification (equation 2) to derive the slope of the curve. Table 1 presents the slope parameters as well as the experience curve. A graphical representation of experience curve for selected products is provided in Figure 1. For instance, 86% experience curve for camcorders implies that every time cumulative production doubles, cost decreases by 14%. Of all four products depicted, DVD players exhibit the strongest experience curve effect.

All the products show excellent fit except the model for CD Boom box which registers an adjusted R-square of 0.34. Models for majority of the products display adjusted R-squares over 0.80 and several products register over 0.90. The average experience effect hovers around 90%, suggesting that cost will diminish by 10% every time cumulative output is doubled. The average estimates compare at about the same level found by the Boston Consulting Group (1975) which found the experience rate at 88%, 76%, and 81% for sizes under 50 cc, 126-250 cc and 51-125 cc motorcycle engines. The color television in Bass (1980) using data for the first 10 years stood at 95% versus 96% in this study. Note that the other products tested in Bass (1980) were refrigerator, air conditioners, dishwashers, and clothes dryers—clocking within 80% to 90% experience curve. See Figure 1 in the Appendix.

However, the products show tremendous variation in experience rates. For instance, Satellite TV equipment shows the steepest experience curve—at 75%, whereas projection TV shows the slowest. Several factors could be contributing such variations. First, the products originated at different historical times, carrying time specific factors with the data. Second, there are product specific factors such as the level of standardization and the number of product models carried that could affect experience curve. More products in a product line dilute the cumulative production in each for a given size of the market. For instance, color televisions come in various sizes whereas telephone answering machines were sold in much fewer variations. Another potential source of variation is the state of technology prevailing around the time period the products had their growth cycle. In addition, camouflaged in the numbers is the quality improvement over time in many of these products. Color television was broken into a separate product after introduction of stereo sound and improved color reproduction (e.g. digital comb filter) in the mid 1980s, however, the television sets in either category most likely went through improvements in features. See Table 1 in the Appendix.

Relationship between Experience Curve and Diffusion

One key question the experience curve raises is if steeper experience curve helps achieve higher level of diffusion. Diffusion is best measured by household penetration rate, that is, the percentage of households owning at least one unit of the product. Unit sales are biased estimate of diffusion because some households might own multiple units (e.g. television sets in bedrooms and living rooms). The consumer electronics association data comes with household penetration information that helps us to estimate another regression model linking estimated experience rates and penetration. Based on results reported in Table 2, it appears the relationship is not statistically significant given this data set. There are several plausible explanations for this. Decreasing price does not necessarily translate into consumer awareness or fulfilling consumers' need at a commensurate level. Other potential explanatory variables that are omitted here could also contribute to this loss of significance. For example, the general economic conditions prevailing at these various product introductions and consumer sentiments might also play a role. Unless more data such as marketing expenditures and macro economic conditions are included in the model, this relationship may remain under explored. See Table 2 in the Appendix.

CONCLUSION

This study presented experience curve estimates for 20 consumer electronic products and found that majority of the products strongly display experience curve effect. This paper revives the experience curve modeling in marketing literature by providing evidence from a consumer products perspective and diffusion of new products. Price erosion has plagued the consumer electronics industry for a long time; yet, product and brand managers need to know to what extent price erosion is generated by experience built by cumulative production. The findings reported in this study demonstrate excellent fit of the data. Majority of the 20 products studies register R-square over 0.80.

The model is estimated in its classic form because of data limitation to include possible additional factors such as the number of competitors in the industry. Many of the advantages of the classic model are also it's disadvantages, according to critics (Monroe & Della Bitta, 1978). Among the shortcomings are the static nature of the model and the lack of scale effects. In other words, the rate of experience is monotonic in levels of output, regardless of timing or competitor reaction. Further, blindly following the experience curve as a guide for strategic pricing have proved erroneous in certain cases because the expected cost reductions did not materialize (Ghemawat, 1985, p 143). The appeal of simplicity in calculating experience curve has led to its abuses (Henderson, 1984). Nevertheless, the simplistic model provides product managers a benchmark on which to base pricing and output decisions. The model can be updated as new cost data is realized from additional production. Further, observing experience curve for several related factors provide a possible range to consider in decision making. Incorporating macro economic data (e.g. per capita income and unemployment rate) and competitive structure of the market will provide excellent extension to the current study.

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APPENDIX

Figure 1: Experience Curve of Selected Products

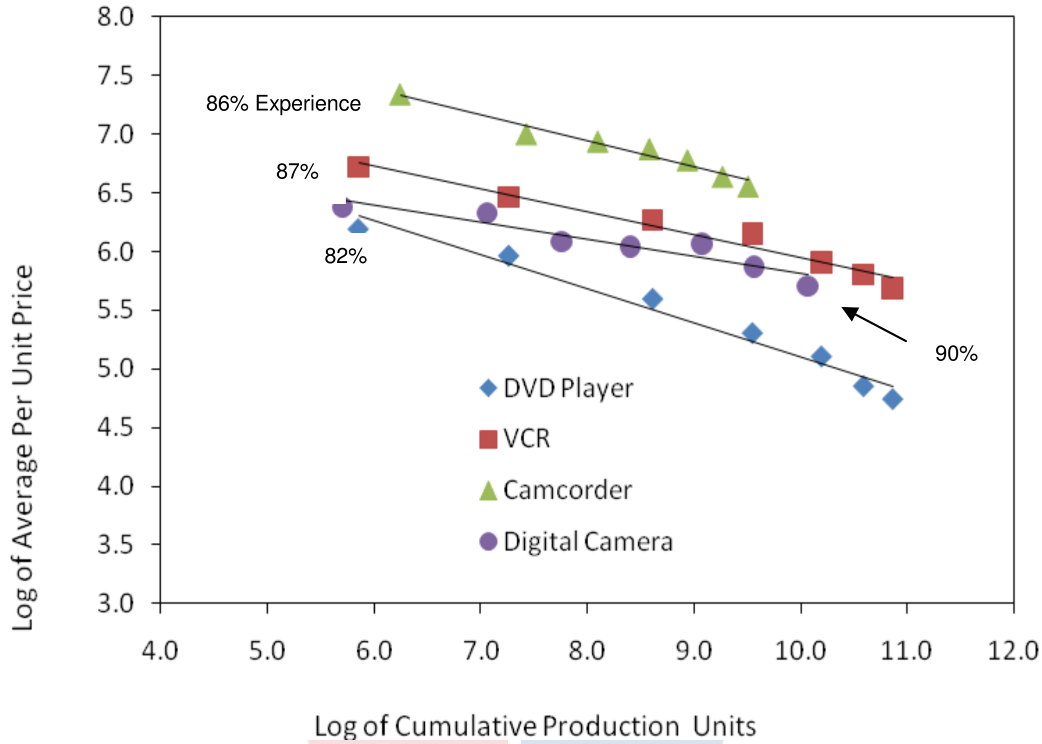

Table 1: Experience Curve and Household Penetration of Consumer Electronic Goods

Product	λ	t-ratio	Adjusted R^2	Experience Curve ($1-2^{-\lambda}$)	Observed Penetration Rate at the end of 7th year
DVD Player	-0.292*	-12.89	0.965	0.183	0.50
VCR	-0.197*	-11.89	0.959	0.127	0.40
Camcorder	-0.222*	-11.8	0.958	0.142	0.15
Digital Camera	-0.147*	-6.41	0.870	0.097	0.28
Digital Television	-0.111*	-13.16	0.966	0.074	0.11
Projection TV	-0.041**	-2.96	0.564	0.028	.06
CD Player	-0.124*	-9.24	0.934	0.082	0.56
Cellular Phone	-0.294**	-3.87	0.700	0.185	0.10
Cordless Phone	-0.118*	-9.36	0.935	0.079	0.14
Facsimile Machine	-0.188*	5.08	0.805	0.122	0.04
Color TV	-0.056*	-29.16	0.993	0.038	0.01
Stereo Color TV	-0.139*	-17.11	0.980	0.092	0.21
Satellite TV	-0.410*	-9.71	0.940	0.246	0.16
Portable CD Player	-0.185*	-12.94	0.965	0.120	0.31
Compact Audio	-0.377*	-4.02	0.716	0.230	0.27
Answering Machine	-0.160*	-6.09	0.857	0.105	0.20
Set-Top Internet Device	-0.133*	-5.62	0.836	0.088	0.06
Digital Video Recorder	-0.117**	-2.98	0.568	0.078	0.04
PC TV	-0.146*	-5.84	0.847	0.097	0.01
Boom box	-0.104	-2.02	0.340	0.070	0.63

*Significant at 1% level
** Significant at 5% level

Table 2: Effect of Experience Curve on Household Penetration

Independent variables	**Parameter Estimates**	**t-statistics**
Intercept	0.16	1.66
Experience Curve Slope (λ)	0.47	0.63
R^2	0.02	