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INTER-MARKET VARIATION IN THE RATE OF NEW PRODUCT DIFFUSION

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This paper examines to what extent diffusion rates systematically vary depending on the type of decision maker involved in adopting the product. The superiority of producers' information-processing ability is considered as one of the most important qualitative differences between producers and consumers as potential adopters. It is found that the speed of adoption is more rapid for producer goods than for consumer goods. The difference in the rate of adoption can be explained by a more rapidly falling price path and more rapid entry into markets for new producer goods. In order to find out why price falls more rapidly for new producer goods, we estimate the learning curve for producer goods and consumer goods. Our analysis shows that learning-by-doing is more extensive for producer goods. Therefore, we conclude that the learning curve is one important source of product diffusion.

JEL Classification: L. Industrial Organization; L6
Keywords: New Product Diffusion, Producer Goods, Consumer Goods

I. INTRODUCTION

The diffusion rates of new products vary across different markets. There are several factors which affect the diffusion rate of a new product. Yet these factors are mentioned in separate and unrelated literatures. First of all, the speed at which information on a new product may vary across different markets (Nelson, 1970; Mueller, 1976; Reinsdorf, 1988). Thus, the efficiency of communication channels can affect the rate of new product diffusion (Rogers and Shoemaker, 1971; Olshavsky,

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1980; Qualls et al., 1981). Second, several factors which affect the rate of falling prices may influence the diffusion rate of a new product. The falling prices of new products affect the diffusion process by allowing more potential adopters to afford these products but also through the anticipation of falling prices on the timing of potential adopters' purchases. For a new durable product which is purchased infrequently by consumers, one explanation for falling prices is "intertemporal price discrimination (Stokey, 1981; Bulow, 1982)." There is a source of decreasing prices on the producer side as well. Referred to as the learning curve, it captures the relationship between unit cost and cumulated experience, typically cumulative output. Since lower production costs translate into lower prices, the learning curve is another source of a declining price path for a new product (Boston Consulting Group, 1972; Fudenberg and Tirole, 1983; Lieberman, 1984). Changes in the intensity of competition among firms can also contribute to falling prices and thereby to the rate of product diffusion (Klepper and Graddy, 1990). In summary, the diffusion rates of new products are affected by the following factors: 1) the dissemination of information; 2) intertemporal price discrimination; 3) the learning curve; and 4) the entry of new firms.

Given these various factors that influence the rate at which a new product is adopted in the marketplace, this paper examines whether diffusion rates systematically vary depending on the type of decision maker involved in adopting the product. This hypothesis is examined by considering two types of markets: consumer good markets, where a producer sells to a consumer, and producer goods markets, where a producer sells to another producer. New products are thus designated as either a producer good or a consumer goods. This paper is unique in several respects: 1) the extensive coverage[1] of new products introduced during the 20th century in the U.S.; 2) the product classification criteria[2] in terms of adopters; 3) the first empirical documentation of differences between producer and consumer good markets in new product diffusion.

In the diffusion process of new products, potential adopters' perceptions of innovation attributes and/or adopters' information-processing ability may differ considerably. Previous studies have not considered the effects that different types of adopters may have on product diffusion processes.

With the qualitative difference in information-processing ability between consumers and producers in mind, our empirical examination begins with the documentation that the speed of adoption is more rapid for producer goods than for consumer goods. The average annual growth rate of producer goods during the initial five years after introduction is almost twice as large as that for consumer goods. We then develop an empirical model to identify the source of this difference. The difference in the rate of adoption can be explained by a more rapidly falling price;

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[1] See Table 1. Some products in our dataset were introduced in the early 20th century, while others were marketed in 1980s.

[2] We will discuss data and product classification in section III.

path and more rapid entry in markets for new producear goods. Finally, we begin an exploration of why price falls more rapidly for new producer goods by estimating the learning curve for producer goods and consumer goods. Our analysis shows that at least one reason for a more rapid price decline for new producer goods is that learning-by-doing is more extensive. Left for future research is explaining why the learning curve should vary between these types of products and why entry should be more rapid in markets for producer goods.

This paper is organized as follows. Section II discusses why the rate of diffusion might vary depending on whether it is a producer good or a consumer good. Section III provides empirical evidence of the inter-market variation in the rate of new product diffusion and explains the source of these differences. Given these empirical observations, this section then explains why prices fall faster for producer goods. Section IV is devoted to the estimation of learning curves for consumer and producer goods, and section V concludes the paper.

II. DETERMINANTS OF DIFFUSION RATE VARIATIONS

This section specifies some essential differences that exist between producer and consumer goods markets, and explains how the type of market may affect the rate of new product diffusion.

2.1. Diffusion of Information

Producer goods markets tend to have greater buyer concentration, a higher volume of purchases, and a higher frequency of repeat purchases than consumer goods markets. These differences may result in the following intrinsic differences in information diffusion. When a new product is introduced into the market, potential buyers need information about the price and product characteristics of the good. While characteristics of some goods can be ascertained by consumers before a purchase, those of other goods can only be discovered after a purchase has been made. The former are called "search goods" and the latter are called "experience goods (Nelson, 1970; Nelson, 1974)." In many cases, information on price can be acquired with little effort. Advertisements may often reduce the costs of learning price. However, in general, information on the characteristics of experience goods can only be acquired at much higher cost. These costs will vary across different adopters depending on their prior information and their information-processing and information acquisition skills (Lee, 1974; Chan and Leland, 1982; Burtler, 1991). Potential adopters of producer goods are relatively more knowledgeable about a new product than potential adopters of consumer goods. Relevant information about new producer products can be accessed in advance more readily than information about new consumer goods.

Information about new consumer goods is usually diffused by mass media and/or by word-of-mouth. While advertisements convey information about whether a new consumer product has been introduced, when a new product is an experience good, advertisements cannot convey much more information. In this case, information about the product is mainly diffused by word-of-mouth. In contrast, information about new producer goods is often diffused via brochures on the new products, coupled with product samples. In many cases, these goods can be inspected by buyers through direct contact with manufacturers, and this is feasible because the number of potential buyers is relatively small. In other words, the marketing techniques of sellers are different for producer goods and consumer goods. For example, even though the number of physicians is relatively large among various producers, sellers of medicines often contact doctors directly. In addition, producers can acquire information through professional trade journals that are relatively more technical and detailed than the information that consumers receive through advertisements. In this context, consumers' information about new consumer goods has relatively less content than producers' information about new producer goods.

The apparent superiority of producers' information-processing ability lowers the information costs that a potential producer adopter must pay, relative to consumers. Producers generally have a larger base of knowledge due to making repeated related purchases. This makes information acquisition less costly. Information costs per unit are then lower for the adopter of a new producer good than for the adopter of a new consumer good. The information cost per unit also declines as the quantity purchased becomes larger. Clearly, the average amount purchased is likely to be quite different between producers and consumers. Producers generally buy in large quantities on a regular basis, while consumers tend to buy far smaller quantities, especially when a new product is a durable good. This fact may amplify the divergence in information costs faced by producers and consumers, because the information cost per unit is smaller for the bulk-buying producer.

These differences in information costs may also yield differences in the intensity of competition among manufacturers. According to Reinsdorf (1988), higher consumer information costs make markets less competitive. Less intense competition over time usually implies slower price declines over time. The speed of price decline in turn affects the rate of new product diffusion, because declining prices relaxes consumers' budget constraints and because the reservation values of more consumers are reached. Therefore, differences in the cost of consumer information may affect the speed of new product diffusion.

Better knowledge of a new product implies less uncertainty about the future development of the product's industry (Klepper and Graddy, 1990). Producers are apt to form expectations on future prices and demands more easily than consumers. The initial uncertainty characterizing new industries is likely to restrain the growth of incumbent firms, as well as encouraging potential adopters to wait until such uncertainty has abated considerably. Reduced uncertainty about the future of a new product may therefore result in faster diffusion of it.

2.2. Degree of Product Homogeneity

The degree of product homogeneity also tends to affect the speed of diffusion of new products. One of the main qualitative differences between producer goods and consumer goods is that producer goods tend to be more homogeneous than consumer goods. This difference is particularly prominent in our data sample.

Producer goods are usually used as intermediate goods. Thus, in many cases, producer goods become part of the final product. In other cases, they lose their distinct identity in the manufacturing process. As producer goods are often used in further manufacturing, processing, or resale, compatibility and standardization is valued which means that homogeneity is a valued characteristic. Specifically, producer goods are relatively more homogeneous in terms of designs and formats. Producer goods are seldom differentiated horizontally, even though there may be several different quality types. Product differentiation is also dependent on the distribution of buyers' preferences. According to Klepper and Graddy (1990), the more diverse buyers' preferences are, the more difficult it is for the new product to be standardized. In this regard, it can be generally agreed that consumer preferences are relatively more diverse than producer preferences as the number of consumers is far larger than that of producers.

If product A is relatively more homogeneous than product B, price competition in industry A is likely to be more intense than that in industry B. Furthermore, the entry of new firms in industry A would be more rapid than in industry B because of differences in the ease of imitation (Mansfield et al., 1981). Thus, we expect that : 1) the entry of new firms is faster for producer goods than for consumer goods ; 2) price declines faster for producer goods than for consumer goods ; and 3) the rate of diffusion is faster for producer goods than for consumer goods.

2.3. Intrinsic Differences in Technological Aspects

Differences in the speed of diffusion can also be attributed to differences in the technologies of the two types of products. We investigate whether there are significant technological differences by estimating the effect of cumulative sales on price. The so-called "learning curve slope" is used to represent the technological characteristics of a product. It should be recognized that differences in the learning curve slope are only one manifestation of technological differences.

2.4. Concluding Remarks

The sections above have provided the following expectations and hypotheses: 1) the entry of new firms is faster for producer goods than for consumer goods; 2) price declines faster for producer goods than for consumer goods; and 3) the rate of diffusion is faster for producer goods than for consumer goods.

III. EMPIRICAL EVIDENCE OF THE INTER-MARKET VARIATION

This section documents quantitative differences in the rate of diffusion of producer goods and consumer goods. We trace the history of 86 new products, of which 67 are consumer goods and 19 are producer goods.

3.1. Data and Product Classification

Annual data on retail sales, price, and number of manufacturers for eighty-six

Table 1. Classification of the Products

Consumer Goods			
	Data Coverage		Data Coverage
Room air conditioners	1936-1940	Trash compactors	1971-1975
Dehumidifiers	1950-1954	Video cassette recorders	1976-1980
Food disposers	1947-1951	Calculators	1974-1978
Electric clothes dryers	1947-1951	Digital watches	1974-1978
Gas clothes dryers	1947-1951	Answering machines	1975-1979
Freezers	1946-1950	Cordless phones	1980-1984
Electric ranges	1922-1926	Vaporizers	1975-1979
Gas ranges	1930-1934	Personal computers	1980-1984
Refrigerators	1922-1926	Compact disc players	1983-1987
Clothes washers	1922-1926	Video cameras	1978-1982
Vacuum cleaners	1922-1926	Camcorders	1986-1990
Televisions(black and white)	1946-1950	Cellular phones	1984-1988
Blenders	1948-1952	Satellite earth stations	1984-1988
Bed coverings	1947-1951	Fax machines	1986-1990
Can openers	1958-1962	Electronic typewriters	1983-1987
Irons	1922-1926	Scanners	1983-1987
Humidifiers	1963-1967	Intrusion protection systems	1975-1979
Hot plates	1922-1926	Smoke detectors	1975-1979
Heating pads	1922-1926	Electric water heaters	1935-1939
Portable electric heaters	1922-1926	Gas water heaters	1936-1940
Griddles	1959-1963	Corn poppers	1954-1958
Frying pans	1954-1958	Dish washers	1947-1951
Fans	1922-1926	Phonographs	1946-1950
Coffee makers	1922-1926	Tape recorders	1954-1958
Broilers	1947-1951	Slow cookers	1973-1977
Mixers	1933-1937	Automatic dripping coffeemakers	1973-1977
Food slicers	1964-1968	Food processors	1976-1980
Toasters	1922-1926	Fluorescent Lamps	1938-1942
Waffle irons	1922-1926	Pens, Ball Point	1951-1955
Electric tooth brushes	1963-1967	Tape, Recording	1961-1965
Knife sharpeners	1958-1962	Tires, Automobile	1915-1919
Radios	1922-1926	Facial Tissue	1934-1938
Air cleaners	1974-1978	Video Tape	1977-1981
Microwave ovens	1970-1974		

Producer Goods

	Data Coverage		Data Coverage
Germanium Transistors	1954-1958	Zippers	1928-1932
Germanium Diodes	1955-1959	Lasers	1963-1967
Polystyrene	1943-1947	Gyroscopes	1963-1967
Polyvinylchloride	1946-1950	Crystals, Piezo	1963-1967
Polypropylene	1961-1965	Benzene	1952-1956
DDT	1944-1948	Ethylene	1953-1957
Penicillin	1945-1949	Nylon	1947-1951
Streptomycin	1946-1950	Silicon Transistors	1954-1958
Styrene	1943-1947	Silicon Diodes	1955-1959
Tubes, Cathode Ray	1948-1952		

products marketed in the U.S. were mostly collected by the author.[3] Data sources of retail sales and price include various summary and special issues of Merchandising Week, Merchandising, Dealerscope Merchandising, and Boston Consulting Group (1972). Price data for each product are adjusted using the 1967 Consumer Price Index. Annual data on the number of producers were obtained from Thomas Register of American Manufacturers.

The products in the dataset were classified as consumer goods or producer goods. Our classification criteria differ from the conventional classification criteria[4] in that it focuses on the type of agent that determines whether or not to adopt a product or technology. In Table 1, penicillin and streptomycin are classified as producer goods in the U.S. because doctors (producers of medical services) rather than patients (consumers) determine whether new medicines should be adopted. Similarly, DDT is classified as a producer good because farmers and exterminators, who can be considered suppliers of agricultural products and extermination services, respectively, determine whether or not to adopt the new chemical product.

3.2. Empirical Evidence

Table 2 shows that the average annual growth rate[5] of the output of new producer goods is far greater than that of a new consumer good. The average annual

[3] Part of the data set was provided by Professor Klepper of Carnegie Mellon University. The data sources were various government publications and trade journals.

[4] A consumer good is a product which is available for immediate use by households so that it does not contribute to future production. In contrast, a producer good is usually used as an intermediate good. Thus, in many cases, producer goods become part of the final product. In other cases, they lose their distinct identity in the manufacturing process.

[5] In our analysis, all the growth rates are listed as percentages. Percentage changes are computed as the first differences in logarithms. For example, when output grows from Q_1 in period 1 to Q_2 in period 2, the output growth rate is $(\ln Q_2 - \ln Q_1) \times 100$ which is equal to $100 \times \ln \frac{Q_2}{Q_1}$. This definition of growth rate is useful in that the rates are consistent with a double-log specification of the learning curve equation in which both the regressand and regressors are in log form.

growth rate of producer goods during the initial 5 years[6] of introduction is almost twice as large as that of consumer goods. Corresponding changes in other variables also indicate that the average annual rate of change of prices and the growth rate of the number of firms for new producer goods are greater than those of new consumer goods.

Table 2. Average Annual Growth Rates During the Initial 5 Years

	Consumer Goods	Producer Goods
Output	27.9	45.2
Price	−8.3	−15.0
Number of Firms	8.4	22.7

Table 3. ANOVA Table For a Comparison of Means

Sources of Variation	d.f.	SS	MS	F
		Growth(output growth rate)		
Between Groups	1	4453.6	4453.6	5.86
Within Groups	84	63836.0	760.0	
		PCH(price change rate)		
Between Groups	1	673.7	673.7	5.21
Within Groups	84	10855.9	129.2	
		NCH(growth rate of the number of firms)		
Between Groups	1	2990.5	2990.5	13.15
Within Groups	84	19097.5	227.4	

Here, we need to check whether the three means (Growth, PCH, NCH) between consumer goods and producer goods are different by performing ANOVA tests. As we can see in Table 3, the values of F (=5.86, 5.21, 13.15) for the three means all exceed the corresponding critical value 3.96 at the 5% significance level. We can conclude that the means between two groups are different.

[6] We use the initial 5 years of introduction of new products in order to avoid the contamination of durable goods data through repeat purchases.

3.3. Regression Analysis

The following regression analysis identifies the source of the variation in the rate of output growth that exists between the two classes of new products. The raw data consist of multiple observations of average price, the number of manufacturers, and cumulative output for each product by the initial 5 years of introduction for each product. Then, change rates are computed for each variable, for each year, for each product. This gives us 344 observations for each of the growth rate variables as we have 4 years of growth rates for the 86 products. The rate of output growth is then regressed on a constant, the growth rate of prices, the growth rate of the number of producers, and several dummy variables. We make the following specification:

$$G_{it} = \alpha_1 + \alpha_2 PCH_{it} + \alpha_3 NCH_{it} + \alpha_4 D_p + \alpha_5 D_p \times (PCH_{it}) + \alpha_5 D_p \times (NCH_{it}) + U_{it} \quad (1)$$

where G_{it} = output growth rate, during period t for product i; PCH_{it} = price growth rate, during period t for product i; NCH_{it} = growth rate of the number of firms, during period t for product i; $D_p = 0$ for consumer goods, 1 for producer goods; U_{it} = a random error term.

The estimated coefficient of the interaction term $D_p \times (PCH)$ measures how much more responsive the growth of producer goods is to PCH, than is the growth rate of consumer goods. The dummy variables, D_p, $D_p \times (PCH)$, and $D_p \times (NCH)$ thus allow for differences in each of the coefficients between consumers and producers. The regression results of the model specified above are as follows (Figures in parentheses are t-ratios.):

$$\underset{(0.59)}{G_{it} = 2.316} \underset{(-5.45)}{- 0.952 PCH_{it}} \underset{(1.89)}{+ 0.272 NCH_{it}} \underset{(0.33)}{+ 9.951 D_p} \underset{(-0.94)}{- 0.027 D_p \times (PCH_{it})} \underset{(-0.63)}{- 0.097 D_p \times (NCH_{it})}$$

For both consumer goods and producer goods, PCH is negatively related to G, while NCH is positively related to G, as we would expect. However, the differences in the coefficients of both PCH and NCH are not significant as t-values of both $D_p \times (PCH)$ and $D_p \times (NCH)$ are small. Thus, the responsiveness of output growth to changes in both price and the number of firms does not seem to vary between producer and consumer goods.

The estimated coefficients of both of the constant term and D_p are not significant, either. Therefore, differences in output growth rates can be explained mainly by differences in growth rates of price and the number of firms. A significant negative relationship between the growth rate of output and the rate at which prices change indicate that it is worthwhile exploring the determinants of the change in prices. This avenue is pursued in the next section by estimating the slopes of the learning curves.

An alternative specification of the preceding equation includes a time trend (T). The rationale for the inclusion of a time trend is that sales of a new product might grow over time as information about the new product diffuses over time, irrespective of changes in price and the number of firms. Thus, output of a new product could grow over time even without changes in price and the number of firms. The regression results of the alternative model are as follows:

$$\underset{}{G_{it}} = \underset{(-0.99)}{-8.915} \underset{(-5.46)}{-0.944PCH_{it}} + \underset{(2.15)}{0.319NCH_{it}} + \underset{(1.46)}{4.361T_{it}} + \underset{(1.17)}{22.54D_p} - \underset{(-0.15)}{0.053D_p \times (PCH_{it})}$$

$$\underset{(-0.72)}{-\ 0.147D_p \times (NCH_{it})} - \underset{(-0.80)}{4.991D_p \times (T_{it})}$$

While the t-values of the NCH coefficient has risen slightly, the results of the alternative model are more or less comparable to the previous regression results in that at the 5 % significance level only the coefficients of PCH and NCH are significant. Although there seems to be a positive relationship between the dissemination of information about new products (as reflected in the inclusion of the time trend) and output growth rates, the relative importance of information in the diffusion of new products seems rather weak in comparison with that of changes in price or the number of firms. The insignificance of all the interaction terms D_p, $D_p \times (PCH)$, $D_p \times (NCH)$, and $D_p \times (T)$ indicates that most of the variation in output growth rates can be explained by both PCH and NCH, rather than by differences in other intrinsic factors between producer and consumer goods.

3.4 Concluding Remarks

Bringing together the documented differences in average growth rates (of output, price and the number of firms) and the regression results, it is possible to conclude that producer goods diffuse faster than consumer goods. The source of the difference appears to be that prices fall faster and the number of firms grows faster for producer goods. Given these documented differences, the next issue is to understand what factors are responsible for these empirical results. To explain variations in price paths, we estimate learning curves for consumer and producer goods. It is predicted that the learning curve effects for new producer goods are significantly larger than those for new consumer goods.

IV. ESTIMATION OF LEARNING CURVES

4.1. An Empirical Model

In the estimation of the slopes of learning curves, price data rather than cost data are usually used because cost data are generally proprietary. This paper also uses price data to estimate learning curve slopes, though the learning curve actually represents the relationship between production cost and a measure of accumulated experience. One of the questions this raises is under what conditions we can use price as a proxy for cost.

As Lieberman (1984) explained, one of the following conditions should be met in order to use price data instead of cost: 1) price/cost margins change, but in a manner controlled for by the analysis; 2) price/cost margins remain constant; or 3) changes in margins are small relative to changes in production cost. Lieberman (1982) also showed that large information spillovers, by reducing the proprietary "investment value" of additional output, shift the firm's optimal pricing policy towards one of maintaining constant profit margins. Thus if there are large spillover effects, it is legitimate to use price data to estimate the slope of the learning curve.

Using the proprietary data on its clients' firm-specific cost, market price, and industry cumulative output, the Boston Consulting Group (1972) found that in most industries prices decline as learning proceeds, and profit margins remain approximately constant. It also argued that information acquired through learning diffuses across firms. Further, it predicted that products may have stable price/cost margins when industries are very competitive and grow rapidly and are subject to fast technological developments.

However, it should be noted that there are a number of scenarios in which margins become unstable. For example, entry and changes in capacity utilization may influence margins. With regard to learning spillovers, Jarmin (1994) criticized the assumption that experience is close to a public good. If there are significant differences in geographical location, in the ability to gather information, in R&D expenditures, and other idiosyncratic firm-specific characteristics, then different firms may benefit from spillovers asymmetrically. In this case, price/cost margins will not remain constant. Jarmin used firm-specific data from the early years of the rayon industry in order to obtain better estimates of the slopes of learning curves and to analyze some implications of learning-by-doing.

Nonetheless, as more relevant data (firm-specific data on production cost, plant size, firm-specific output, and market share) for the meaningful estimation of learning curves are difficult to obtain, we may have to rely on the relatively strong assumption that the price-cost margin does not change systematically between producer goods industries and consumer goods industries. Instead, in this paper, we use a proxy variable for market structure with the data on the number of firms in order to control for changes in the level of price/cost margins which may result from changes in market structure. Thus, in the following model, average market price is regressed on cumulative output, current output, and the number of firms.

In this section, we consider two common models for time series-cross section data: (a) the Fixed Effects Model; and (b) the Random Effects Model. While the Fixed Effects Model has industry specific constants, the Random Effects Model has an overall constant.[7]

The empirical strategy for estimating the slope of the learning curves for producer goods and consumer goods is comprised of four steps:

(1) the Breusch-Pagan Lagrange Multiplier test is used to choose an appropriate alternative between the classical regression model and the Random Effects Model;

(2) the Hausman test is used to choose between the Fixed Effects Model and the Random Effects Model;

(3) a Chow test examines whether there is a structural difference between producer goods and consumer goods as only if there is such a difference can a comparison be made between the estimated learning curve slopes of the two groups;

(4) the estimated coefficients of cumulative sales for the two groups are compared.

a. Fixed Effects Model (The Dummy Variable Model)

$$\ln P_{it} = a_{1i} + b_1 \ln N_{it} + c_1 \ln X_{i,t-1} + d_1 \ln Q_{it} + u_{it} \quad (3)$$

$$\ln P_{jt} = a_{2j} + b_2 \ln N_{jt} + c_2 \ln X_{j,t-1} + d_2 \ln Q_{jt} + u_{jt} \quad (4)$$

where P_{it} = average price of product i during year t; N_{it} = number of manufacturers; X_{t-1} = cumulative output at the end of period t-1 for product i; Q_{it} = output during period t for product i = 1, ……, 67 (67 consumer goods), and j = 1, ……, 19 (19 producer goods).

b. Random Effects Model

$$\ln P_{it} = \alpha_1 + \beta_1 \ln N_{it} + \gamma_1 \ln X_{i,t-1} + \delta_1 \ln Q_{it} + \varepsilon_{it} + u_i \quad (5)$$

$$\ln P_{jt} = \alpha_2 + \beta_2 \ln N_{jt} + \gamma_2 \ln X_{j,t-1} + \delta_2 \ln Q_{jt} + \varepsilon_{jt} + u_j \quad (6)$$

where $E[u_i] = 0$, $Var[u_i] = \sigma_u^2$, $Cov[\varepsilon, u_i] = 0$.

Logarithms have been taken for all variables. Thus, bs in the Fixed Effects Model and βs in the Random Effects Model are the estimated elasticities of price with respect to the number of producers. While cs in the Fixed Effects Model and

[7] For more detailed discussion, see Greene (1990).

γs in the Random Effects Model are the estimated elasticities of price with respect to cumulative output, ds and δs may represent the extent of economies of scale.

4.2. Regression Results

The values of Breusch and Pagan's Lagrange Multiplier statistic, for the consumer goods learning curve equations and the producer goods equations, are 631.4 and 176.2, respectively. These numbers are very large. As large values of the LM statistic argue in favor of the Random Effects Model against the classical regression model with no group-specific effects, the null hypothesis, that the classical regression model with no group-specific effects is an appropriate alternative to the random effects model, is easily rejected. Specifically, the classical regression model with no group-specific effects is rejected at the 5% significance level for both the consumer goods model and the producer goods model.

The values of Hausman's chi-squared statistic for the consumer goods learning curve equations for consumer goods and for producer goods are 14.92 and 9.58, respectively. These numbers are large enough for us to reject the null hypothesis, that the random effects models are appropriate alternatives to the Fixed Effects Models for the data sets that were used, because large values of the Hausman statistic support the Fixed Effects Model over the Random Effects Model. Thus, at the 5% significance level the Random Effects Models for both the consumer goods model and the producer goods model are rejected.

Following the results of both the Breusch and Pagan test and Hausman's specification test, we focus on the regression results of the Fixed Effects Model only. The regression results of the Fixed Effects Model are summarized in Table 4.

The estimated coefficient of cumulative output for producer goods is -0.029,

Table 4. Regressions of: Fixed Effects Model

	Pooled	Consumer Goods	Producer Goods
$\ln N$	−0.189***	−0.063	−0.244***
	(−4.94)	(−1.35)	(−3.20)
$\ln X_{-1}$	−0.012***	−0.013***	−0.029**
	(−5.73)	(−6.78)	(−2.61)
$\ln Q$	−0.162***	−0.150***	−0.178***
	(−8.64)	(−8.08)	(−3.73)
Adjusted R^2	0.992	0.988	0.991

** significant at .05 level.
*** significant at .01 level.
Figures in parentheses are t-ratios.

while that for consumer goods is -0.013. Both of the coefficients are statistically significant at the 5% significance level. In addition, the estimated coefficient for the number of manufacturers for producer goods is -0.244 and is significant at the 1% significance level. For consumer goods, it is -0.063, but is not significant at the 5% significance level. We conclude that learning curves for producer goods have steeper slopes than the learning curves for consumer goods, and the entry effects of new firms on the rate of price change is stronger for producer goods. The main source of difference in the rate of diffusion between consumer and producer goods is that price falls faster for producer goods, and it appears empirically that a steeper learning curve slope for producer goods is an important explanation of why price falls faster for producer goods.

4.3 Test of Difference Between Coefficients

For Fixed Effects Model, sum of squares for consumer goods and producer goods are 8.679 and 6.575, respectively. As $F(2, 340)$ is 3.85 at the 1% significance level, we can conclude that there is a structural difference between producer goods and consumer goods. In other words, the results of the Chow test indicate that the estimated coefficients are different in the two sub-samples. Therefore, it is legitimate to estimate separate sets of coefficients for the two sub-samples. This rationalizes a comparison of the parameters found for each sub-sample. It is still necessary to test whether the estimated learning curve slope is different between the two sub-samples, because the Chow test conducted in the previous subsection was a test of structural difference - it did not test whether there was a difference in a specific parameter.

Dummy variables are used to allow for differences in the coefficients between consumers and producers. Pooling the data for the two groups of products, we estimated the following equation.

$$\ln P_{it} = \sum_{k=1}^{86} a_i D_{kit} + b \ln N_{it} + c \ln X_{i,t-1} + d \ln Q_{it} + e D_p \times (\ln N_{it}) + f D_p \times (\ln X_{i,t-1}) + g D_p \times (\ln Q_{it}) + u_{it} \qquad (7)$$

where $D_{kit} = 1$ if $k = i$; 0 if $k \neq i$.

The coefficients of $D_p \times (\ln N)$ and $D_p \times (\ln Q)$ measure, respectively, the difference in the slope of entry effects and the difference in current output. The coefficient of $D_p \times (\ln X_{-1})$ measures the difference in the slope of learning curve effects. The following regression results indicate the differences in the estimated coefficients that exist between each separate group.

$$\ln P_{it} = \underset{(-1.15)}{0.063\ln N_{it}} - \underset{(-5.78)}{0.013\ln X_{it-1}} - \underset{(-6.88)}{0.150\ln Q_{it}} - \underset{(-2.35)}{0.181 D_p \times (\ln N_{it})} - \underset{(-1.94)}{0.016 D_p \times (\ln X_{it-1})}$$

$$- \underset{(-0.70)}{0.028 D_p \times (\ln Q_{it})},$$

Degrees of freedom = 338, Adjusted $R^2 = 0.992$

As both the LM statistic(= 177.3, p value = 0.000000) and the Hausman statistic(= 64.0, p value = 0.000000) are significantly large, we conclude that the Fixed Effects Model is the most appropriate model. The marginal significance levels (p-values) of the coefficients of both $D_p \times (\ln N)$ and $D_p \times (\ln X_{-1})$ are smaller than 5.2%. Thus, even by a conservative standard, both of the differences are significant. We conclude that producer goods have steeper learning curve slopes than consumer goods and the entry effects of new firms on the rate of price change is stronger for producer goods.

Earlier, this paper documented inter-market variation (i.e. between producer and consumer goods) in the rate of new product diffusion. The underlying differences were also discussed. Quantitative analysis was used to quantify the differences between these types of markets. Regressions of the output growth rate indicated that the source of the difference between the two markets is that prices fall faster and the number of firms grows faster for producer goods. The differences in the rate at which prices fall were explained by estimating a learning curve for producer and consumer goods. These regressions indicated that the learning curves for producer goods have steeper slopes. At least in part, this accounts for the faster decline in producer good prices. Furthermore, as consumer goods in the sample are relatively more durable, the actual learning curve slope is much lower for consumer goods than for producer goods. This is because the coefficients of cumulative sales may incorporate both learning effects and intertemporal price discrimination.

There is a potential source of bias in the estimated coefficients. As the growth in the number of firms is larger for producer goods, probably due to relative product homogeneity, price-cost margins presumably shrink faster for producer goods. This may bias upwards the absolute value of the coefficient of cumulative sales for producer goods. It is possible that prices drop rapidly even though production costs have not changed much at all.

V. CONCLUSION

This paper documented and explained how the rate of new product diffusion depends upon the types of agents adopting the product. The product classification was based on whether a product is purchased by a consumer or a producer. It was noted that information processing ability and the degree of product homogeneity have a significant impact on the speed of diffusion. Quantitative differences were also examined, and it was found that producer goods diffuse faster than consumer goods. It was shown that prices fall faster and the number of firms grows more rapidly for producer goods.

For both consumer and producer goods, the rate of output growth is negatively related to the rate of price change, but positively related to the rate of change in the number of firms. As output growth is mainly explained by differences in the rate of price change and the rate of change in the number of firms, technological differences are one of the most important sources of variation in growth rates. The regression results indicated that the learning curve slopes for the producer goods in the data sample are on average larger than those for the consumer goods.

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