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The Determinants of New Product Diffusion : A Simultaneous Equation Approach

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신제품의 확산 결정요인 : 연립방정식 접근법

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The purpose of this paper is to investigate the determinants of new product diffusion. We seek to document and explain systematic features of product diffusion. In this essay, we examine the well-documented empirical regularity that the speed of diffusion has accelerated during the twentieth century. The empirical results show that the main source of acceleration are faster declines in prices. Faster price declines make the product affordable to more consumers within a given period of time. Based on theories of intertemporal price discrimination and learning-by-doing, the association between the speed of adoption and the speed of price decline was explained. Faster price declines are attributed to several product characteristics as well as changes in income distribution. Above all, the introduction of consumer electronic products in more recent years can be regarded as the most important factor in accelerating price declines. Consumer electronic products are technologically different from non-electronic goods, in that semiconductors are important components. As the price of semiconductors has dropped rapidly, the falling production costs can be rapidly incorporated to the price of consumer electronic goods. Furthermore, most of the recently introduced consumer electronic products have network externalities, and many products with network externalities require complementary products. A complementary product becomes more readily or cheaply available as more people have the main product. One major difference between previous studies and this study is that the former focuses only on the factors that operate directly on the speed of adoption, while this study incorporated factors that work through price changes as well as the factors that work directly on the speed of adoption.

Keywords : New Product Diffusion, Intertemporal Price Discrimination, Learning-By-Doing, Network Externalities

1. Introduction

The diffusion of a new product takes time, typically years if not decades. Even truly innovative products that are superior to existing products will usually take years before they are widely adopted. The question is why it takes a considerable length of time before a new product saturates its market. When a new product is introduced into the market, little is typically known about its attributes by potential adopters. Furthermore, it is often the case that a large proportion of

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potential adopters is unaware of the introduction of the good. The dissemination of information about a new product can be slow. Thus, the efficiency of communication channels can affect the rate of new product diffusion [15, 16].

Even if the dissemination of information is rapid, product diffusion can be slowed by potential adopters' postponment of purchase in anticipation of falling prices. It is well known, for example, that prices of many consumer electronic products, like VCRs and PCs, are falling over time. The declining price of a new product affects the rate of product adoption in two ways. It directly affects the diffusion process by enabling more consumers to afford these products while the anticipation of falling prices affects the diffusion process indirectly by influencing the timing of consumers' purchases.

For new products that are durable, it has been Olshavsky [15] showed the statistical significance of the time coefficient in a regression of adoption rates on the time of introduction. He argued that possible explanations for this phenomenon are improvements in channels of communication, increases in marketing sophistication, and increases in consumer affluence. Qualls et al. [16] also document evidence that the overall length of a product's life cycle has become shorter for products more recently developed. As it is difficult to identify the entire product life cycle for recently introduced products, particularly the lengths of the maturity and decline stages, Qualls et al. [16] test whether the introduction and growth stages are shortening.

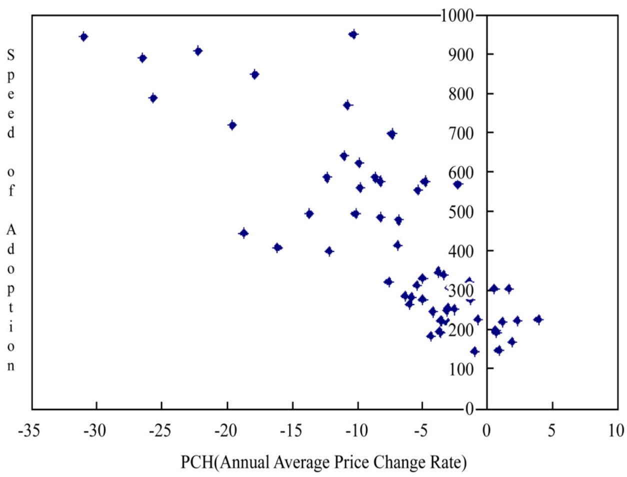
While the marketing literature has been productive in documenting such acceleration, it has done little to explain it. Specifically, those empirical studies in the marketing literature have not explained the interactions that occur among the various determinants of diffusion processes. The key feature of our approach is the development of an interactive empirical model of sales and price and the use of this model to identify the factors driving the acceleration of the rate of adoption of new products.

We begin by constructing an original data set of new product diffusion which includes annual data on retail sales, price, and the number of manufacturers for 61 products. The data set is unique in several respects : (1) an extensive coverage of consumer appliances introduced during the 20th century in the U.S.; (2) the use of retail sales data; and (3) an extensive coverage of changes in the number of manufacturers of each good over time. With this data set, we provide additional documentation of the empirical regularity that the speed of adoption has accelerated during the twentieth century. Furthermore, our interactive model provides a much better fit of the data than do previous non-interactive models. The main source of this acceleration is found to be a more rapidly declining price path for products introduced later in the twentieth century. This acceleration of price declines is found to be strongly associated with two product characteristics-use of semiconductors and network externalities- and changes in the distribution of income.

2. Determinants of the Speed of Adoption

2.1 Simultaneous Determination of the Speed of Adoption and Price Change Rate

Products with faster diffusion rates seem to have faster price change rates. <Figure 1> shows that the speed of adoption is associated with the speed of price decline. As is apparent in the scatter diagram, SPD (speed of adoption) and PCH (the rate of price change) are negatively correlated.



<Figure 1> Scatter Diagram of SPD and PCH

The source of this association could be due to factors including the learning and intertemporal price discrimination. Consider the diffusion process of a new consumer durable good with learning-by-doing. Faster declines in the price of a new product make the product affordable to more consumers at a faster pace. From the viewpoint of a seller, the faster diffusion of the product makes the seller cut prices faster because the seller has to reach lower valuation consumers as the market for the new product is saturated more quickly. By selling to higher and lower valuation consumers at different points in time the producer is practicing intertemporal price discrimination. If the product is adopted more quickly, the producer accumulates production experience more quickly, and, because of learning-by-doing, this implies a faster decline in production costs. In turn, this may result in faster price declines. Thus, the effects of accelerating price change and accelerating new product adoption mutually reinforce each other. The two factors, intertemporal price discrimination and learning-by-doing, thus simultaneously determine the speed of product adoption and the rate of price decline.

Given the hypothesis that the rate of price change and the speed of adoption of a new product are simultaneously determined, we have to estimate a simultaneous equation system in order to take account of the interaction effects between the two variables. As previous empirical studies have not taken account of the interaction effects between these various factors due to their single equation specifications, the implementation of a simultaneous equation specification is one of the main contributions of this research.

2.2 Exogenous Factors

Apart from the simultaneous price-diffusion relationship (to be precise, the price change rate-speed of adoption relationship), we also consider several exogenous factors that contribute to the acceleration of product adoption and price change rate. These exogenous factors can directly affect the product adoption rate or the rate of price decline.

2.2.1 Trends

There are various exogenous factors that affect the speed of adoption. First of all, there have been improvements in various information channels, which enable sellers to respond quickly to changes in markets. The improvements in information channels also contribute to the faster diffusion of information on new products. For example, computerization of various office and factory activities have accelerated business activities. Second, innovations in financial institutions such as the introduction of electronic funds transfer systems and credit cards may have loosened consumers' liquidity constraints and accelerated transactions. Third, changes in the distribution of income in the economy can affect pricing behavior. For example, if the middle class has a larger share of total income, one would anticipate larger price changes. If national income is concentrated in a small proportion of the total population, continuous price declines of a new product would probably have minimal effects on the diffusion of the product. Fourth, the increasing competitiveness of imported products might have contributed to faster price declines of new products. Furthermore, the fact that new consumer electronics products are mostly produced by foreign manufacturers, but distributed by domestic sellers, may have intensified competition. This, in turn, may have accelerated price changes.

2.2.2 Product-Specific Factors

Other than the factors with trends, there are several factors intrinsic to each product, which probably determine the rate of price change. We characterize those factors as follows. First of all, there are tremendous variations in price level relative to income level at the time of introduction of a new product. A higher priced good in absolute value tends to show faster price change rate over time probably because there is greater scope for learning-by-doing and price discrimination over time. Second, network externalities arise in the diffusion of some type of products. As the network grows, complementary products can often be supplied at a lower price or with greater diversity if there are increasing returns to scale. This kind of benefit may have contributed to the faster speed of adoption for many consumer electronics products such as VCRs and PCs. Third, there are technological differences, in that electronic components are an increasingly important part of modern goods. Because technological advances in these components have occurred so rapidly it is possible for them to have a significant impact on the production costs of new goods, hence on their price and subsequent diffusion. For example, in the semiconductor industry, production costs have declined so rapidly that it has been difficult to maintain a stable pricing policy. This may be a factor in explaining why consumer electronics products have progressed through the product life cycle so quickly.

2.2.3 Market Structure

The rate of price change can be affected by changes in the market structure. It is believed that increases in the number of firms can accelerate the rate of price change. In general, prices are likely to change more quickly when the number of firms change faster.[1)]

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1) See Klepper and Graddy [10].

3. The Empirical Model

3.1 Data

Annual data on retail sales, price, and number of manufacturers for sixty-one consumer durable products marketed in the U.S. were collected by the author. Retail sales for major appliances, housewares, and home electronic products as reported in various summary and special issues of *Merchandising Week*, *Merchandising*, and *Dealerscope Merchandising* were assembled. 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*. Data on other important exogenous variables determining the diffusion processes of new products were compiled from various issues of *Annual Statistical Abstracts of the United States*.

3.2 Measurement

We fit the historical data on the diffusion of the various new durable products to the logistic function. The logistic function characterizes the typical S-shaped diffusion curve. This approach was taken by Mansfield [13] and Olshavsky [15] in measuring the speed of adoption of a new product.

Data availability varies quite significantly between different products. Therefore, we focus on the introduction and growth stages in terms of unit shipments of each product while controlling for the number of households over time. The end of the growth stage is the year when the number of household-controlled unit shipments reaches its maximum. In short, we measure the "steepness" of the S-shaped diffusion curve as the rate of adoption. As we never know what the ceiling or equilibrium value would be for each different product, we substitute the cumulative sales at the peak of unit shipment for the ceiling. Thus, we analyze the time period from the introduction of a new product to the year when unit shipment reaches its global peak, while controlling for changes in number of households. The estimated speed of adoption[2)] is in <Table 1>, where YEAR represents "year of introduction", i.e. the first year that a product was introduced.

In order to test whether a product's speed of adoption is positively related to its year of introduction, we run a regression of the speed of adoption on the year of introduction. The estimated linear equation[3)] is

2) For the definition of the Speed of Adoption, see the Appendix.

3) $\widehat{\Phi}_i$ is just propotional to SPD (Spead of Adoption). $SPD_i = 1000 \times \widehat{\Phi}_i$. See the Appendix.

<Table 1> Classification of Products in the Data Set (Year of Introduction is the First Year when the Data for a New Product are Available)

Products	SPD	D	NE	TECH	YEAR
Room air conditioners	285	0	0	0	1936
Dehumidifiers	315	0	0	0	1950
Food disposers	186	0	0	0	1947
Electric clothes dryers	195	0	0	0	1947
Gas clothes dryers	341	0	0	0	1947
Freezers	197	0	0	0	1946
Electric ranges	144	0	0	0	1922
Gas ranges	224	0	0	0	1930
Refrigerators	308	0	0	0	1922
Clothes washers	200	0	0	0	1922
Vacuum cleaners	199	0	0	0	1922
Televisions (black and white)	478	1	1	0	1946
Blenders	224	0	0	0	1948
Bed coverings	323	0	0	0	1947
Can openers	585	0	0	0	1958
Irons	223	0	0	0	1922
Humidifiers	570	0	0	0	1963
Hot plates	283	0	0	0	1922
Heating pads	253	0	0	0	1922
Portable electric heaters	193	0	0	0	1922
Griddles	323	0	0	0	1959
Frying pans	276	0	0	0	1954
Fans	148	0	0	0	1922
Coffee makers	245	0	0	0	1922
Broilers	305	0	0	0	1947
Mixers	201	0	0	0	1933
Food slicers	249	0	0	0	1964
Toasters	227	0	0	0	1922
Waffle irons	228	0	0	0	1922
Electric tooth brushes	264	0	0	0	1963
Knife sharpeners	577	0	0	0	1958
Radios	334	1	1	0	1922
Air cleaners	349	0	0	0	1974
Microwave ovens	492	1	1	1	1970
Trash compactors	277	0	0	0	1971
Video cassette recorders	720	1	1	1	1976
Calculators	448	1	0	1	1974
Digital watches	790	1	0	1	1974
Answering machines	400	1	0	1	1975
Cordless phones	642	1	0	1	1980
Vaporizers	576	0	0	0	1975
Personal computers	587	1	1	1	1980
Compact disc players	909	1	1	1	1983
Video cameras	949	1	0	1	1978
Camcorders	772	1	0	1	1986
Cellular phones	892	1	1	1	1984
Satellite earth stations	493	1	1	1	1984
Fax machines	945	1	1	1	1986
Electronic typewriters	696	1	0	1	1983
Scanners	417	1	1	1	1983
Intrusion protection systems	561	1	0	1	1975
Smoke detectors	622	1	0	1	1975
Electric water heaters	306	0	0	0	1935
Gas water heaters	255	0	0	0	1936
Corn poppers	168	0	0	0	1954
Dish washers	219	0	0	0	1947
Phonographs	225	1	1	0	1946
Tape recorders	410	1	1	1	1954
Slow cookers	484	0	0	0	1973
Automatic dripping coffeemakers	556	0	0	0	1973
Food processors	847	0	0	0	1976

$$\widehat{\Phi}_i = -14765 + 7.767YEAR, \quad \overline{R}^2 = 0.583$$
$$(-8.97) \quad (9.22)$$

(Figures in parentheses are t-ratios.)

The above result strongly indicates that the speed of adoption has accelerated over time and is consistent with previous empirical work.

3.3 Proxies for Exogenous Variables

A number of exogenous factors are likely to be important determinants of the new product diffusion process : 1) Improvements in communications technology may have accelerated the speed of product diffusion. 2) Innovations in financial institutions may have loosened consumers' liquidity constraints and may have accelerated transactions. 3) Changes in income distribution, such as an increase in the share of total income by the middle class, may have accelerated price changes. 4) An increase in the competitiveness of imported products may have intensified price competition. In this section, we discuss possible proxies for these exogenous factors affecting price changes and diffusion processes.

One explanation for the acceleration of the rate of product adoption is improvements in marketing techniques and communication channels. The diffusion of information about a new product through communication channels as well as pricing, advertising, and promotion strategies on the side of sellers can critically affect the degree of the diffusion of a new product. There have been remarkable improvements in marketing techniques; the advent of electronic transactions and the availability of extensive and detailed data bases enable firms to detect and respond to competitors' pricing and promotion actions. Since the main avenue for these advances is advertising on television, we use TV saturation rates as a proxy for the level of information channels.

A second explanatory factor which may be related to the time trend in the diffusion of a new product is the loosening of liquidity constraints resulting from such financial innovations as the credit card. The income velocity of money is used as a proxy for this factor. The velocity of money is derived from the quantity of money equation : V = PY/M where V is the income velocity of money, P is price level, and Y is real income. We observe that V has increased over time. This suggests that people now hold less money relative to their incomes over time, i.e. less money is used to support a greater volume of transactions.

During the period of interest there have also been significant changes in the distribution of income. The share of income earned by people in the middle portion of the distribution has increased dramatically. Changes in income distribution may have affected price paths which in turn have influenced the speed of adoption. In this research, the thickness of the middle class is more meaningful in the growth of a new product than measures of income inequality. However, we use the percentage of aggregate income received by the top 5% of the population because it is available for all the years covered by our data set.

The phenomenon that we seek to explain may also be attributable to a technological factor noted by Gort and Klepper [8] : "The interval required for successful imitation has systematically declined over time." Increases in the competitiveness of imported products reflect this technological factor.

3.4 Empirical Model

As mentioned in section II-a, the two factors, intertemporal price discrimination and learning-by-doing, result in the simultaneous determination of speed of adoption and price change rate. Furthermore, the information level and velocity of money directly affect the rate of adoption, while income

<Table 2> Description of Variables

Variable	Description
SPD	speed of adoption of a new product
PCH	average annual price change rate of a product during its introductory and growth stages, in terms of unit shipment (number of households held constant) over the period from the introduction of the good to its peak adjusted sales
P_0	initial price divided by average household income
D	Dummy variable for "consumer electronic products" (D = 1 for consumer electronic products; 0 otherwise)
YEAR	year of the commercial introduction of a good
NCH	average annual change rate of the number of firms during the introductory and growth stages
N_0	the number of firms in the year of commercial introduction
INF	the saturation rate of televisions
V	income velocity of money [current dollar net national product (NNP) divided by money supply (M1 = currency+ demand deposits)]
IDS	index of income distribution (percent of aggregate income received by top 5 percent of families)
IMP	imports relative to GNP [imports divided by GNP]
u, V	random error terms

distribution and the competitiveness of imported products affect the rate of price change. The main empirical model consists of the following simultaneous equation system, in which both of the equations are identified.[4)]

$$SPD = aYEAR + bINF + cV + dPCH + u \quad (1)$$

$$PCH = \alpha P_0 + \beta D + \gamma N_0 + \delta NCH + \omega IDS + \theta IMP + \rho SPD + v \quad (2)$$

In equation (1), the speed of adoption is regressed on the year of commercial introduction, INF, v, and the price change variable. The price change rate captures strategic interactions among different firms as well as between firms and consumers. The variation in the rate of price change, across different products, can be attributed to the following factors: (1) differences in the distributions of consumers' valuations; (2) differences in the potential for learning-by-doing in production; (3) differences in the strategic interactions among firms.

In equation (2), our objective is to capture the following interactive relationships : between learning by doing and the speed of diffusion; between competition among firms and diffusion; and between intertemporal price discrimination and diffusion through price dynamics. Price change rate is determined by the speed of adoption which is closely related to how fast cumulative sales increases. The *NCH* variable reflects the effect of changes in competition. A scatter diagram shows that there is a negative relationship between *NCH* and *PCH*. Changes in the number of firms are considered to affect the rate of price change, not vice versa. For instance, an increase in the number of producers increases the intensity of competition among firms which then accelerates the decline of price. Therefore, a change in the number of firms affects the speed of adoption indirectly through changes in price.

The variable *SPD* in the *PCH* equation captures the combined effects of the learning curve and intertemporal price discrimination, which come from (a) the learning curve literature [3, 6, 11] and (b) the durable good literature [17, 4]. The estimated coefficient of *NCH* reflects the effect of changes in competition on the rate of price change, while the estimated coefficient of N_0 reflects the impact of the initial market condition on pricing strategy. The *YEAR* variable controls for any time trend.

4) The SPD equation (Equation 1) has YEAR, INF, and Vas its own predetermined variables, while the PCH equation (Equation 2) has P_0, D, N_0, NCH, IDS, and IMP as its own predetermined variables. Therefore, both equations (1) and (2) are overidentified.

Previous theories provide us with expectations of the signs of the coefficients of each variable. Putting together various literatures, we summarize expected signs of variables in <Table 3>.

<Table 3> Expected Signs of Variables

Equation	Variables						
SPD	*YEAR* 0	*INF* +	*V* +	*PCH* -			
Equation	Variables						
PCH	P_0 -	*D* -	N_0 0	*NCH* -	*IDS* +	*IMP* -	*SPD* -

If the factors elaborated so far explain the acceleration of the speed of adoption of a new product, the *YEAR* variable should be insignificant. One anticipates that the inclusion of a proxy for the level of communicative efficiency would reduce the effect of the year of introduction significantly, as *YEAR* and *INF* move together. Improvements in communicative efficiency, as reflected in TV saturation rates, could accelerate the speed of adoption. Thus, *INF* and *SPD* may also have a positive relationship. Increases in the speed of transactions and the relaxation of liquidity constraints may also accelerate the speed of adoption. Thus, *V* and *SPD* could be expected to have a positive relationship. The effect of *PCH* on *SPD* is expected to be negative as faster price declines enable more consumers to purchase a new product by relaxing the capital constraint.

While the variable *NCH* in the *PCH* equation should be negative, the variable N_0 in *PCH* equation is expected to be insignificant because the inclusion of the effects of changes in market structures would be considered to be more important for change (as opposed to level) of price.

We believe that changes in income distribution may influence firms' price discrimination strategies. A decrease in the share of aggregate real income received by the top 5% of the population may cause prices to decline more rapidly as firms seek to sell to the middle class. Therefore, the percent of income received by top 5% of the population is expected to be positively related to the rate of price change. The larger the share of total income by the middle class, the larger price changes would be. Thus, *IDS* and *PCH* are anticipated to have a positive relationship. Increases in the competitiveness of imported products or increases in the ease of imitation may also accelerate price declines. Thus, it is likely that *IMP* and *PCH* have a negative relationship.

The estimated coefficient of *SPD* in *PCH* equation should be negative because the larger is learning in production and the more extensive are intertemporal price discrimination practices, the larger one expects the rate of price decrease to be.

3.5 Weaknesses and Limitations

Recognition of some weaknesses in this analysis is in order. First of all, many of the exogenous variables are highly correlated. This is partly because proxies are used for certain economic variables and many of these proxies are affected by the time trend. One may also question whether the proxies are direct and relevant measures of the economic factors that they are used to represent.

Second, the number of firms is partly endogenous. This is because in the long run firms' entry decisions depend on how profitable it would be to operate in a particular industry. Therefore, potential entrants take account of the expected profit levels in future periods, as well as the profits in the current period. However, we regard price and output as more important endogenous variables than the number of firms, because the number of firms does not change within a short period of time.

Third, we are dealing with only one of several alternative measures of the rate of adoption. One could argue that the saturation rate, rather than cumulative output, should be used in the estimation of the rate of adoption, especially for consumer durable goods. The saturation rate tells us the proportion of consumers (or households) that have adopted a certain new product, while cumulative output tells how many units have been sold. However, because of data availability, most of the previous studies have also used output data.

4. Empirical Results

Using the three-stage least squares estimation method (3SLS),[5] we have obtained the following regression results for equations (1) and (2). Figures in parentheses are t-ratios.

$$SPD = \underset{(1.34)}{0.038YEAR} + \underset{(1.33)}{0.749INF} + \underset{(2.38)}{51.42V} - \underset{(-3.96)}{15.83PCH}$$

$$\overline{R^2} = 0.758$$

$$\begin{aligned} PCH = & -\underset{(-2.93)}{0.394P_0} - \underset{(-2.65)}{3.731D} + \underset{(1.52)}{0.016N_0} \\ & -\underset{(-0.34)}{0.024NCH} + \underset{(2.56)}{0.155IDS} \\ & -\underset{(-0.30)}{0.165IMP} - \underset{(-2.85)}{0.018SPD} \end{aligned}$$

$$\overline{R^2} = 0.728$$

The results show that the factors determining *PCH* indirectly change *SPD*. Besides the indirect factors, direct changes in trend variables also accelerate *SPD*. The results also document the strong and consistent significance of the income distribution. The price of a new product declines more quickly when the middle class possess a larger share of income. The velocity of money was also strongly and consistently significant, however it should be noted that the velocity of money is itself believed to be influenced by the level of communicative efficiency. Improvements in communication channels affect the velocity of money, which in turn influences the speed of adoption of a new product. Thus, *INF* is also found to be an important factor in the determination of the speed of adoption of a new product, but once *V* is included, the coefficient on *INF* decreases dramatically. As was noted in section III, many proxy variables are affected by the time trend. The *IMP* variable turns out to be insignificant. This may be because *D* (the dummy variable for electronic and/or video/audio products) has already explained the competitiveness of imported products over the years. We note that P_0 and *D* are negatively related to *PCH*. This implies that electronic products and products with higher initial prices relative to income level tend to have faster decreasing prices. The estimated coefficient of *YEAR* is insignificant; P_0, *D*, *IDS*, *V*, and *INF* explain both price declines and speed of diffusion very well.

The dummy variable, *D* (consumer electronic products), can also be regarded as the aggregation of a number of other variables with economic implications. Specifically, the products within the group of "consumer electronic products" can be broken down into two subgroups, which are not mutually exclusive. The first is a product group using semiconductors, which represents a technological distinction. Products with

5) The value of the Hausman statistic is x^2 (9) = 6.062 (significance level = 0.734). Thus, we cannot reject the hypothesis that 2SLS and 3SLS estimates are the same. This result suggests that there is no misspecification in the system of equations. Comparing t-values of both 3SLS and 2SLS estimates, we found that standard errors are smaller for 3SLS estimators than for 2SLS estimators. Thus, we report 3SLS estimates.

and without semiconductors are generally differentiated by the following factors : ease of imitation, the number of potential competitors, and differences in learning curves. The second group is composed of products with network externalities, which is a feature of the user side. The dummy variables for each group of products are denoted *TECH* and *NE*, respectively. <Table 1> shows the classification of products in the data set.

The following results show the significance of both network externalities and the technological characteristics attributable to the use of semiconductors in production. The effect of network externalities on the rate of price change is notably stronger than that of the technological factor. This is probably because most of the products with higher proportions of semiconductors in total production costs are products with network externalities.

$$SPD = \underset{(0.98)}{0.029YEAR} + \underset{(1.34)}{0.769INF} + \underset{(2.73)}{60.70V} - \underset{(-3.38)}{13.36PCH}$$

$$\overline{R^2} = 0.755$$

$$\begin{aligned} PCH = & -\underset{(-2.61)}{0.349P_0} - \underset{(-2.35)}{2.885NE} - \underset{(-1.77)}{3.210TECH} \\ & -\underset{(1.56)}{0.017N_0} - \underset{(-0.42)}{0.030NCH} + \underset{(1.87)}{0.117IDS} \\ & -\underset{(0.23)}{0.125IMP} - \underset{(-3.13)}{0.018SPD} \end{aligned}$$

$$\overline{R^2} = 0.754$$

5. Conclusions

This study is the first attempt to use a formal empirical model to investigate the observation that the speed of new product adoption has accelerated over time. Studies of new product diffusion have been done in both the marketing literature and the economics literature. The former is mainly composed of empirical work, while the latter is mainly theoretical. In the marketing literature, the above phenomenon has been frequently documented, but there has been no attempt to understand why it is true. On the other hand, in the economics literature, several strands of research have tried to explain the factors affecting new product diffusion, but there has been relatively little interaction between the different areas. Moreover, empirical studies have been particularly rare in the economics literature. This paper remedies these deficiencies by bringing together the various factors determining diffusion and examining their interactions, and by stylizing the process of product diffusion as an interactive system.

The empirical results show that the main source of acceleration are faster declines in prices. Faster price declines make the product affordable to more consumers within a given period of time. Based on theories of intertemporal price discrimination and learning-by-doing, the association between the speed of adoption and the speed of price decline was explained.

Faster price declines are attributed to several product characteristics as well as changes in income distribution. Above all, the introduction of consumer electronic products in more recent years can be regarded as the most important factor in accelerating price declines. Consumer electronic products are technologically different from non-electronic goods, in that semiconductors are important components. As the price of semiconductors has dropped rapidly, the falling production costs can be rapidly incorporated to the price of consumer electronic goods. Furthermore, most of the recently introduced consumer electronic products have network externalities, and many products with network externalities require complementary products. A complementary product becomes more readily or cheaply available as more people have the main product.

There seem to be a number of variables that explain the changing pace of product diffusion processes. Largely, these variables are related to improvements in marketing techniques and communication channels. In the marketing literature, these factors have been considered as the main source of acceleration of speed of adoption. These factors also turned out to be significant in this study. However, one major difference between previous studies and this study is that the former focuses only on the factors that operate directly on the speed of adoption, while this study incorporated factors that work through price changes as well as the factors that work directly on the speed of adoption.

One of the weaknesses of this analysis is that many of the exogenous variables are highly correlated, as many of the proxies are strongly related with the time trend. Thus, it is likely that certain variables that appeared to be insignificant are in fact significant. This study also treats the number of firms as exogenous. In future work, the interaction effects among the speed of entry of new firms and the speed of price change and the speed of adoption should be further examined.

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<Appendix>

According to the method which we have described in section Ⅲ-b, we measure the rate of adoption of a new product using the following procedure. For product i at time t, we calculate the number of units shipped, D_{it}, and cumulative sales, E_{it}, while holding the number of households constant. Then, we obtain cumulative sales, F_i, where unit shipment reaches its global maximum.

A_t = number of households in year t
B = number of households in year 1967 (base year)
C_{it} = units shipped of product i in year t
$D_{it} = C_{it} \times \frac{B}{A_t}$ = units shipped of product i in year t in constant household numbers

$E_{it} = \sum_{i}^{t} D_{it}$ = cumulative sales from the year of introduction, I, to year t in constant number of households.

F_i = the value of E_{it} where D_{it} reaches a global maximum Having obtained E_{it} and, F_i we use these data to estimate the following logistic function :

$$\ln[E_i/(F_i - E_i)] = \ell + \Phi_i T$$

where T = the time measured in years from 1900.
Having obtained i's, we define the speed of adoption for product i, denoted SPD_i, as follows.

$SPD_i = 1000 \times \widehat{\Phi}_i$.