Patent Litigation As a Leading Market Indicator

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Abstract

The purpose of this paper is to introduce patent litigation as a leading indicator of market growth. We model the intensity of patent litigation and the market growth for the personal computer and cellular phone market in the US. By means of these analytic models, we show that patent litigation is a leading indicator to market growth. We are also able to very precisely delineate discrete stages of the product's market life cycle and demarcate the time when life-cycle transitions are about to take place. We close this paper with a discussion on new lines of patent research that are potentially useful for managerial practice and for investment decisions.

Keywords: patents, patent citations, patent litigation, patent infringement, technology diffusion, innovation, market growth, market forecasting, leading indicators, knowledge spillover, early adopters

Biographical Notes

Victor Tang is at the Center for Innovation for Product Development at MIT in the Sloan School of Management. He is concentrating on product development methodologies and pricing strategies for technology intensive services. Prior to MIT, Victor held various executive positions in IBM in product, systems and services development, corporate strategy, and business development. He has consulted for the United Nations and foreign governments in Europe, Latin America and the Far East. He has advanced degrees in mathematical physics and business policy from Purdue University and Columbia University Business School, respectively. Victor is coauthor of three books in technology management.

Biao Huang is a graduate student in the Technology Management Program at MIT. His main interests are in technology management, knowledge management and diffusion of high technology into industry and the marketplace.

Introduction

Patents have been used to analyze the diffusion of knowledge as a productive asset that creates economic growth [1-5]. Patent renewal information has been a line of research to determine its relationship to economic growth [6-9]. However, the visibility is thin regarding the nature of the mechanisms of knowledge flow. To address this void, a major line of research has been to investigate patent citations as a mechanism of knowledge spillover [10,11]. The literature demonstrates that there are linkages between patent activity and macroeconomic growth through citations across institutional and geographic boundaries [12-14].

The objective of this paper is to address such a direct link and discuss potential new research directions. We show that the intensity of patent litigation is an indicator to determine the timing and rate of market growth. Although patent litigation has a line of investigation [15,16], we are not aware of analysis that uses patent litigation as leading indicator to market growth. We use the personal computer (PC) and the cellular phone markets to test our hypothesis. Using measures of patent litigation intensity (PLI) and market growth, we are able to express their relationship in mathematical form and thus establish the linkage between patent litigation intensity and market growth. We will discuss the limitations of our analysis, as well as, new potential research to develop a unifying framework to connect patent activities to market growth. We close this paper with a discussion of the implications to managerial practice and to financial investments in new and emerging high technology markets.

The fundamental research challenge has been to identify parametric variables that link patent activity to market growth. Although research shows that patent citations is a

useful proxy to indicate that knowledge is being diffused, we seek a more direct indicator to link a specific class of patent activities to economic growth. In addition, patents are not always renewed [6-9]. Our line of thinking is motivated by our experience in high technology industry which tells us that patent citations are activities largely related to research and development, analysis of competitor capabilities, and acquisition of competitive knowledge. As such, they are more indicative of future *expectations* of growth, rather than of *conviction* that growth is imminent, present, or in active progress. Furthermore, citation research is grounded on the presumption that once knowledge is acquired, spillover has begun, and therefore market growth will follow. Recent research shows that citation data is not always accurate [17]. Jaffe, et al., 2000, cite:

> "There is however a large amount of noise in citations data; it appears that something like one half of all citations do not correspond to any perceived communication, or even necessarily to a perceptible technological relationship between the inventions."

Our hypothesis is that the intensity of patent litigation is a promising indicator of market growth. We believe that patent litigation engages the attention and commitment of the firm *precisely* because its economic interests are at stake and because litigation is costly. The average cost for each patent lawsuit is more than $1 million [18]. As such, unlike other patent activity, patent litigation is no longer merely planning, research, or analysis. It is a shot across the bow to warn an adversary. It is a strong signal that the firm's significant economic interests are at stake and that the firm is committed to spend management time and litigation expenses to defend its markets. Patent litigation engages the attention of senior executives of the firm because they have judged that market

growth is emerging, imminent, or visible to the firm. Consider other sides of the litigation issue. Intentional patent infringement clearly indicates that the infringing firm has a strong belief that there is a nontrivial market share it wants to capture, albeit by illicit means. On the other hand, innocent infringement of existing patents can be interpreted as technology reaching a level of maturity. Ideas are now more common and widely diffused because market growth is either imminent or in progress.

PLI and Market Data for the PC Market

Using public data about the PC industry, we collected information of the market size in the US, measured in $, from 1970 to the present, 2000. Table 1 shows these data. Next, we collected patent litigation activity of key PC firms from for the same time interval [19]. We examined the patent litigation activities from these key firms in the PC industry and discarded those we considered not germane to our analysis. Our analysis included firms like Intel, AMD, Texas Instruments, Cypress Semiconductor, Tandy, Cyrix, and NEC. We found a total of 46 relevant suits covering the period under consideration. This is shown in Table 2.

PLI and PC Industry Models

Using the data from Table 1 and by means of regression analysis, the market growth of the PC industry measured in sales $, is expressed by:

$$R^{PC} = \frac{R_m}{1 + e^{-a-bT}} \tag{1}$$

R^{PC} is the PC industry revenue curve in monetary units plotted against time as the independent variable. R_m is the ultimate industry revenue when we expect the market to be saturated. The coefficients, a and b, are obtained from the regression. The variable T is time, which is measured in years. Note that equation (1) takes the form of the logistics

curve. In equation (1), we have: R_m=$180,000 million, a = 402.83069, b = 0.20151339 and R^2 = 0.986. This is illustrated below in Figure 1.

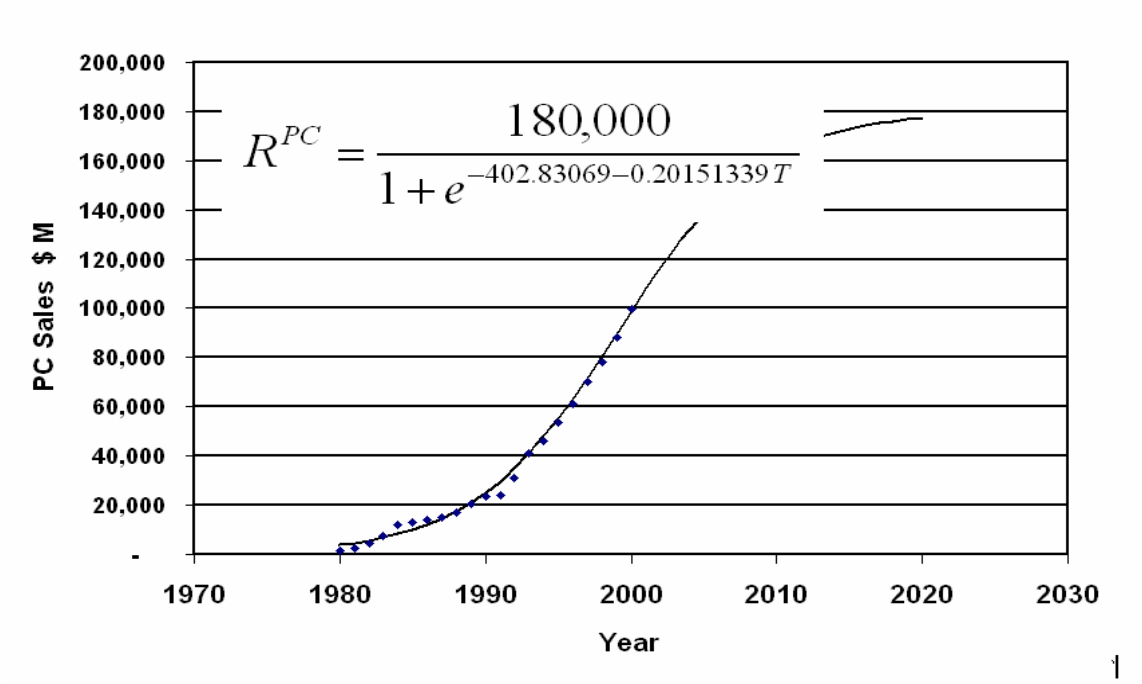


Figure 1. PC Industry Revenues, 1980-2020
(Source: Information Technology Industry Data Book, 2000)

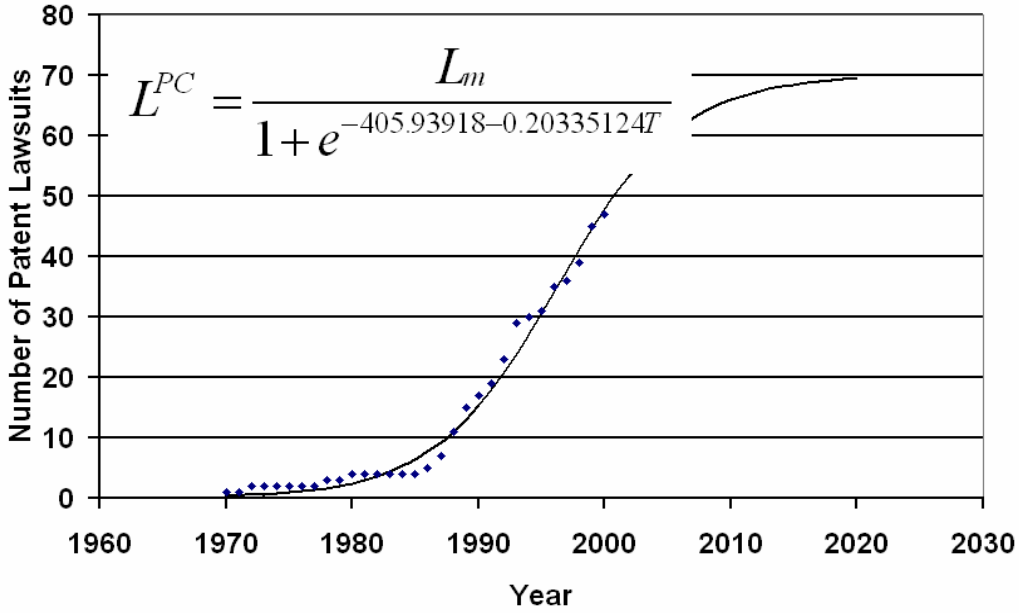


Figure 2. Patent Litigation Intensity (PLI) Curve (PC Industry 1980-2020)
(Source: http://web.lexis-nexis.com/)

Intuitively, the rate of the rise of the PLI curve is indicative of the increasing intensity of the patent litigation. Using the same regression approach, we can express the PLI curve in the following form:

$$L^{PC} = \frac{L_m}{1 + e^{-c - dT}} \qquad (2)$$

L^{PC} is the litigation intensity function for the PC market. L_m is the maximum level of litigation intensity. We obtain the coefficients *c* and *d* from a regression analysis. The independent variable T is time, which we measure in years. In equation (2), we have L_m=70, and obtained c = 405.93918, d = 0.20335124, with R^2 = 0.961.

We plot the functions d^2R^{PC}/dt^2 and d^2L^{PC}/dt^2 as shown in Figure 3. There are three points of specific interest in our analysis:

T_1 where d^2L^{PC}/dt^2= maximum at year 1989.8,

T_2 where d^2R^{PC}/dt^2= maximum at year 1992.5, and

T_3 where d^2R^{PC}/dt^2= 0 at year 1999.0.

We can now segment, with some precision, the PC market life cycle into 4 distinct segments: $T \leq T_1$, $T_1 < T < T_2$, $T_2 < T < T_3$ and $T \geq T_3$ as shown in Figure 3. We show the PLI and the market growth function in Figure 4 with the life-cycle segments delineated by the time periods in discussion where T_1=1989.8, T_2=1992.5 and T_3=1999.0

We call the time period $T \leq T_1$, the period of "market establishment." This is the time when the first movers try to establish their position in the market. In order to protect their investments that helped create this market, firms defend their exclusive rights to innovation by litigation where they are convinced their business interests are being violated. At this time litigation is intense and accelerating driven by their belief that the

market is about to take off. Evidence of market growth helps to strengthen that conviction. In addition, firms use patents as weapons to defend their markets or as instruments to "hem in" in markets led by others [20, 21]. This is a particularly common business practice before the take off stage of new markets. However, eventually litigation intensity slows down to the point where its acceleration reaches a maximum at time T_1.

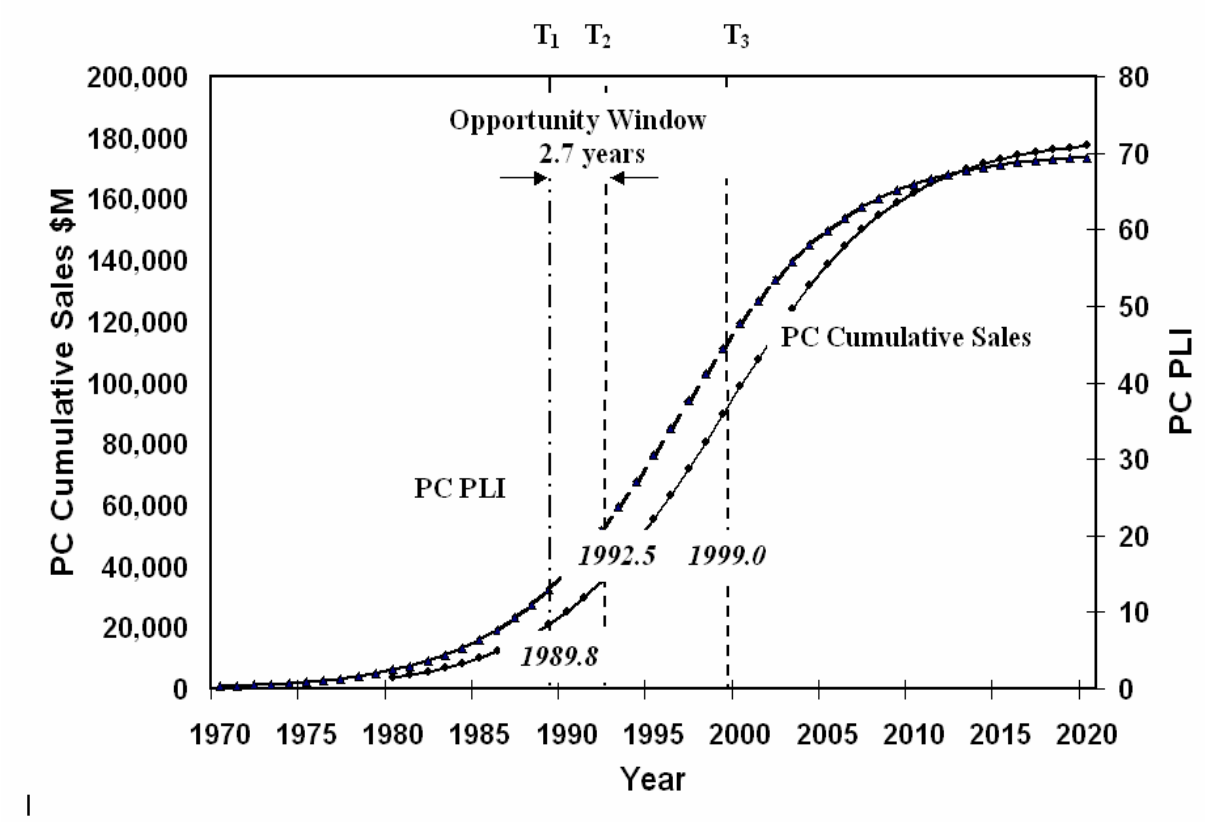


Figure 3. US PC PLI and PC Cumulative Sales

The time between T_1 and T_2 is when litigation is decelerating, but when market revenue are continuously growing and accelerating until it reaches at point T_2, indicating that the risks are now lower than before. Therefore, we call this time the "window of opportunity". We interpret this period as the time when business executives have

determined that knowledge spillover has already taken place and that it is no longer productive to engage in costly patent litigation. The "window of opportunity" is the optimum time for fast-followers to enter the market because the market is growing most rapidly. This is also the time for conservative and risk-averse investors to commit funds in new ventures. However, they should be prepared to face increasingly intensive competition.

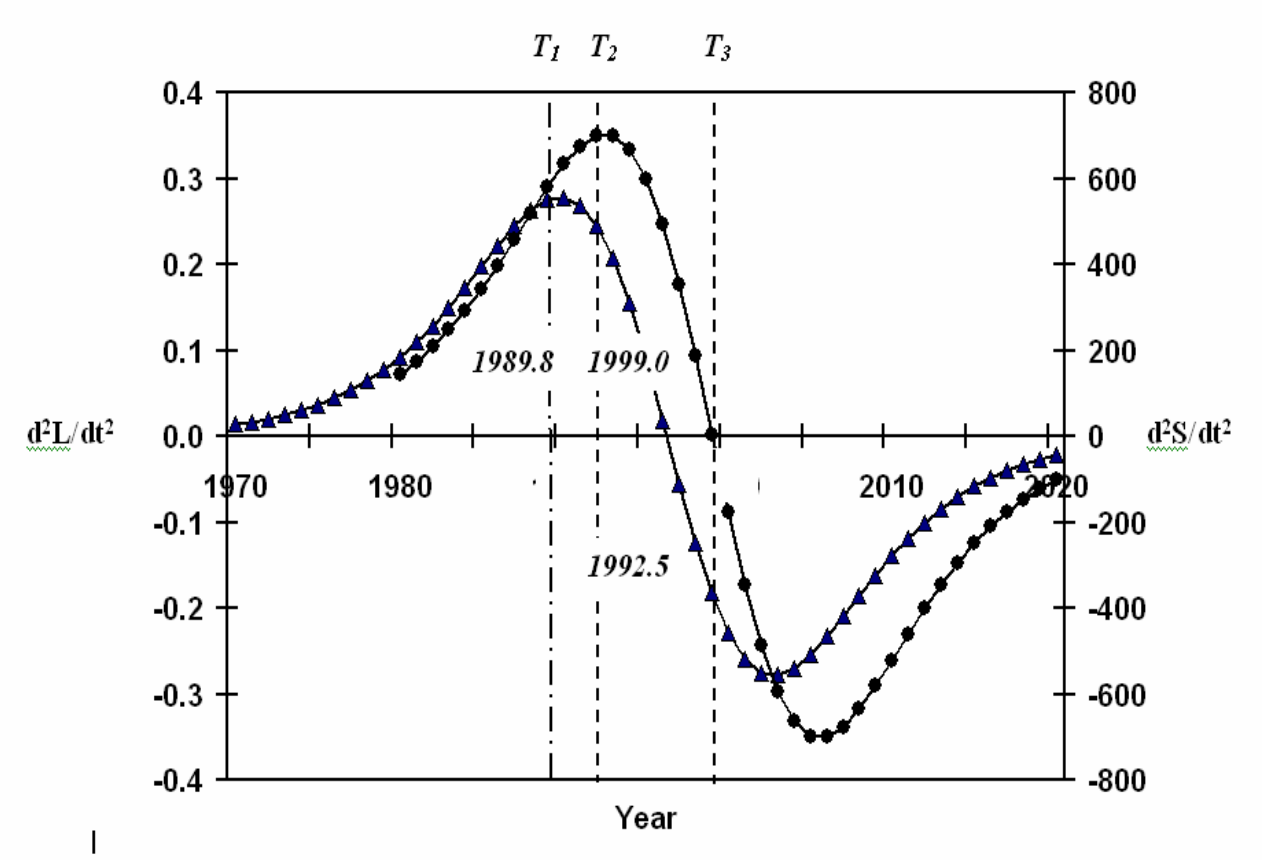


Figure 4. Second Derivative PC PLI and PC Market Growth Model

The time T, $T_2<T<T_3$, we call the "market maturation" period. This is the time when there is steady market growth, albeit, at a decelerating pace until the acceleration of

market revenue reaches zero at time T_3, i.e., where $d^2R^{PC}/dt^2 = 0$. Typically late followers enter the market at this time, when the risk is lowest and when the acceleration has already peaked. No acceleration means that the growth is beginning to decline. This is an indicator of market maturation. Consequently the time $T \geqq T_3$ we call the period of "market saturation."

According to our analysis, we note that the "window of opportunity" for the PC market is between 1989.8 and 1992.5, a time interval of 2.7 years. The "market maturation" period is between 1992.5 and 1999.0, a time interval of 6.5 years. These time intervals are consistent with our intuition and historical development. According to IDG, the US PC market will reach saturation in 2001. The PC established itself in the market rapidly and created for itself a long lasting market period to the point where it is now widely adopted in virtually every walk of life. (Note that is important to carry out the years to one decimal place. In a fast moving business like high technology months can mean the difference between a profitable or a non-profitable quarter.)

Data and Model for the Cellular Phone Industry

In the US, Motorola has been the key creator, innovator and driver of the cellular phone market. Relative to the PC market, the cellular phone business is younger, which is the reason why we collected Motorola's patent litigation activity from 1975 up to the present, 2000. Consequently, whereas in the case of the PC we had 30 years of data, for the cellular phone market we have only have a track of 25 years. Table 4 shows details of the litigation intensity for the cellular phone market. Next we collected information of the US market size, measured in terms of total subscribers, for the same period of time, illustrated in Table 3.

We plot the data from Table 3 and a regression, the market growth of cellular phone is expressed by:

$$S^{CP} = \frac{S_m}{1 + e^{-h-kT}} \tag{5}$$

where S_m=170 million, h=817.69779, k=0.40901375, and R^2=0.99. The interpretation of this equation is analogous to (1). And as in the previous example of the PC market, we plot the data from Table 4 as a function of time. This is the PLI curve for the cellular phone market. The mathematical expression of that is:

$$L^{CP} = \frac{L_m}{1 + e^{-f-gT}} \tag{6}$$

where L_m=70, f=333.11908, g=1.66852027, with R^2=0.94. We combine the PLI curve and the market growth curve of the cellular phone market in Figure 5.

As in the PC market, we now segment the cellular phone market life-cycle into 4 distinct segments: $T \leqq T_1$, $T_1 < T < T_2$, $T_2 < T < T_3$ and $T \geqq T_3$ as shown in Figure 5. We show the PLI and the market growth function in Figure 5 with the life-cycle segments delineated by the time periods in discussion where T_1=1988.6, T_2=1996.5 and T_3=1999.2. Note that in this case the "window of opportunity" is 7.9 years. Recall that this is longer than PC market. We interpret this to mean that the patent litigation activity started earlier in the market life cycle because firms recognized the promise of the cellular phone market. Note that its maturation period is much shorter. Once people started to become comfortable communicating with cellular phones, it became widely accepted very quickly. The interpretation and discussion of the business implications follow similar lines, which have already been discussed in the section for the PC market.

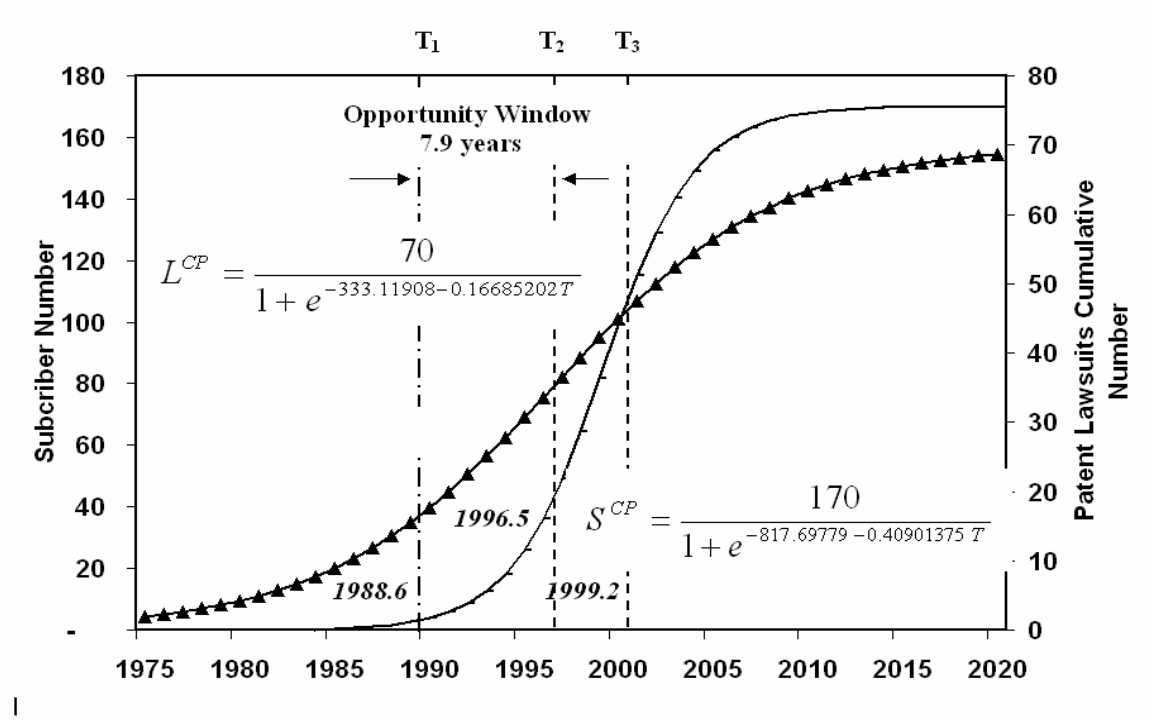


Figure 5. US PLI and Market Growth Model for Cellular Phones
(Source: http://web.lexis-nexis.com/, and CTIA)

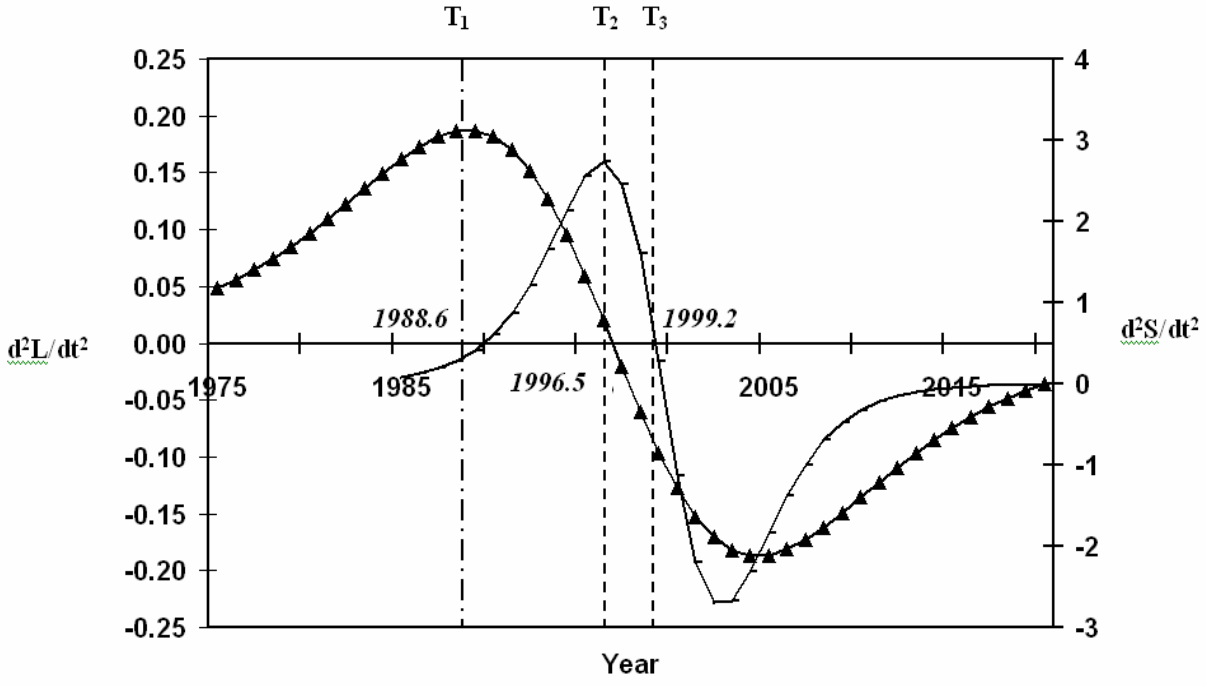


Figure 6. Second Derivative of US PLI and Market Growth Model for Cellular Phones

Discussion

In this paper we have presented analysis for two markets to show that patent litigation intensity (PLI) is a useful indicator of market growth. Patent citation analysis has been a fruitful arena of research using a specific patent activity to demonstrate that knowledge diffuses into the economy to subsequently create economic growth. We have shown the existence of another specific patent activity, patent litigation, as a more direct indicator of market growth.

We have argued that patent citations are indicative of research, learning and expectations of market growth. In contrast, patent litigation is more akin to a declaration of war motivated by unambiguous commitment and a clear conviction that the firm's economic interests are being violated. As such PLI is a more direct indicator of market growth than other patent activities. We believe that this kind of patent analysis offers new avenues of research. For example, we are analyzing software copyright violations to determine its effectiveness as an indicator of market growth. Theoretical economic research suggests that this may be case [22].

Pursuing this line of thinking further, we propose that patent activity analysis be partitioned into three classes of activities, 1) completely legal activities such as patent citations and licensing, 2) disputed activities such as patent infringements, patent litigation and reverse engineering, and 3) illegal patent activities, such as theft of patent embodiments. This suggests that it would be useful to develop an integrated framework that combines a closed of patent activities $L=\{l_i, i=1,\ldots,n, n>0\}$, $D=\{d_j, j=1,\ldots,m, m>0\}$, $P=\{k, k=1,\ldots,r, r>0\}$, such that 1) $L \cup D \cup P=\{\text{patent activities}\}_z$, where $z \leq n+m+r$, $L \cap D=\varnothing$, $L \cap P=\varnothing$, $D \cap P=\varnothing$, and 2) the elements spanning each set are orthogonal and

complete. We claim that, at least, L admits l_1=patent citations and D admits d_1=patent litigation, and set P admits p_1=piracy.

We are currently engaged in efforts to combine patent citations and patent litigation as first step to determine whether we can find an equation for market growth of the form $\psi=\psi(L,D,P,T)$ where T is time.

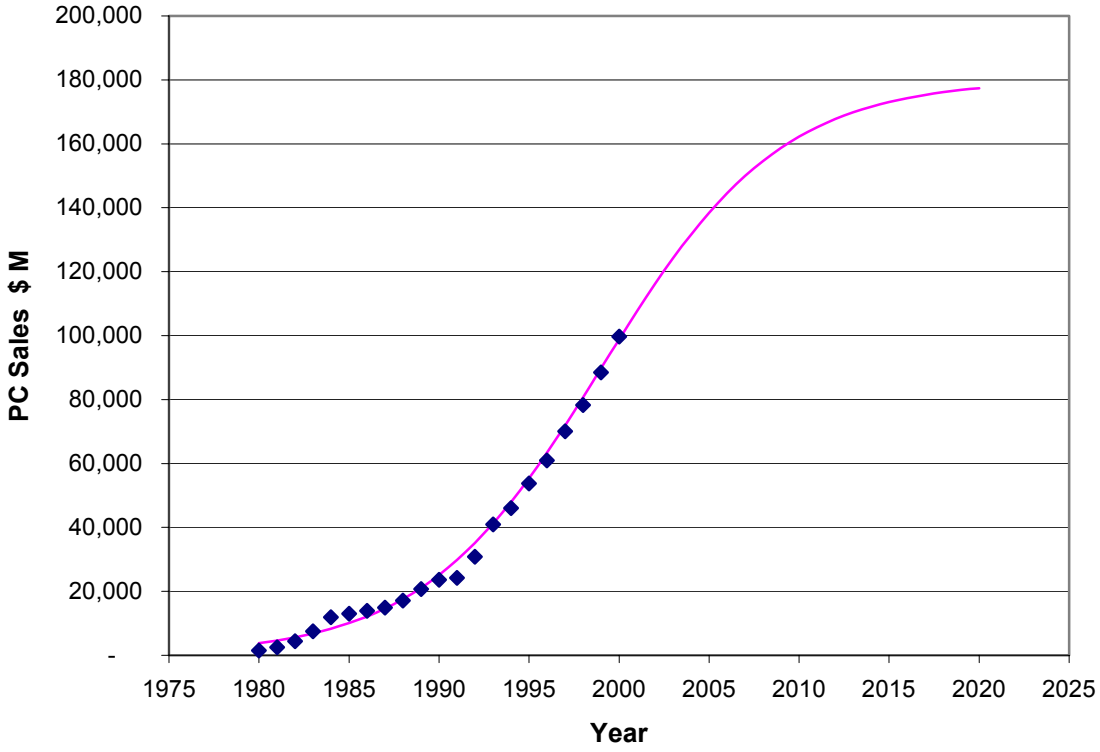
It is appropriate to point out some limitations of our model. We have applied our patent litigation analysis to new markets prior to its take-off stage in only two markets in the US. Extending this analysis to other technology intensive markets in, such as bioengineering, and pharmaceuticals, will shed more light on the timing of market take-off. Research shows that technology moves in waves, i.e., new S-curves ride on top of maturing S-curves [23, 24]. It is reasonable to expect that market growth when approaching its asymptote, will move additively on a new S-curve spurred by new technology. We also did not consider the resolution of litigation. The number of suits does not reach an asymptotic level and remain at that level. At some point while the PLI approaches its asymptote, PLI should begin to attenuate rapidly as dominant technologies assert themselves in the market. The point at which this occurs relative to the market growth curve is another area that merits further investigation.

In spite of its embryonic form, we believe that PLI is a potentially useful indicator to investors in new technology-intensive markets and industries. For venture capitalists, angels, or other investors, PLI can serve as additional confirmation to other indicators they may use. For example, a financial investment firm seeking to commit funds to a new business venture may want to adopt PLI as an indicator in its risk analysis.

Acknowledgements

The authors gratefully acknowledge the useful and insightful discussions with attorneys Ling-Fong Chung and Micheline Tang about the issues and observations in this paper. However, we are responsible for any errors and other shortcomings.

$$R^{PC} = \frac{180{,}000}{1 + e^{-402.83069 - 0.20151339T}}$$



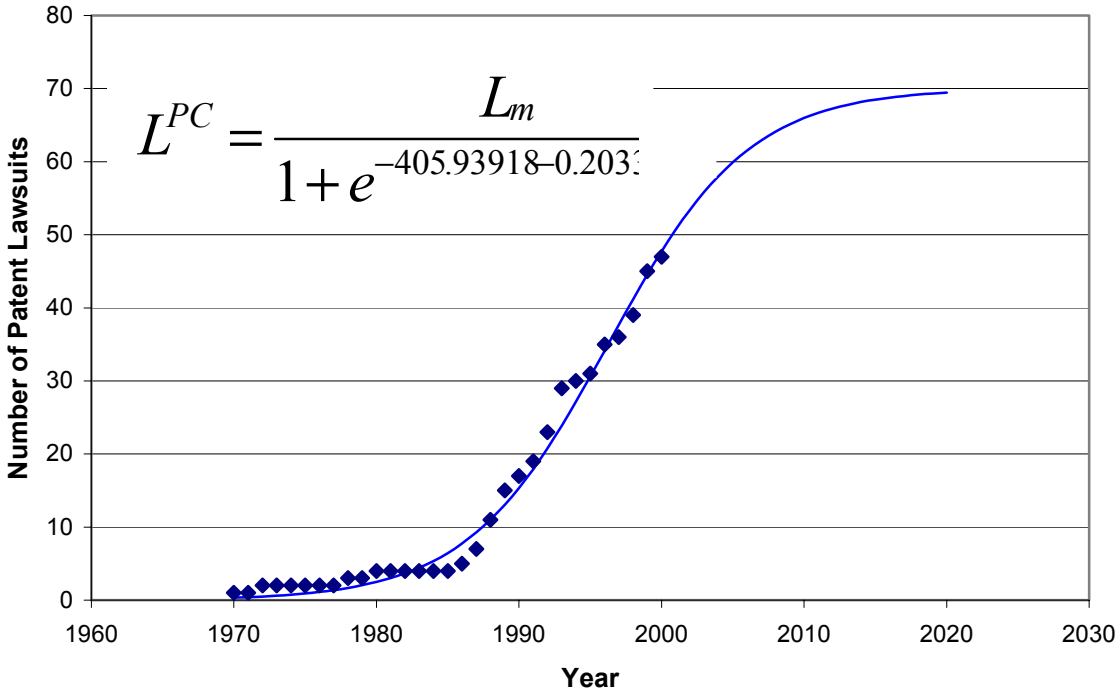


Figure 2. Patent Litigation Intensity (PLI) Curve (PC

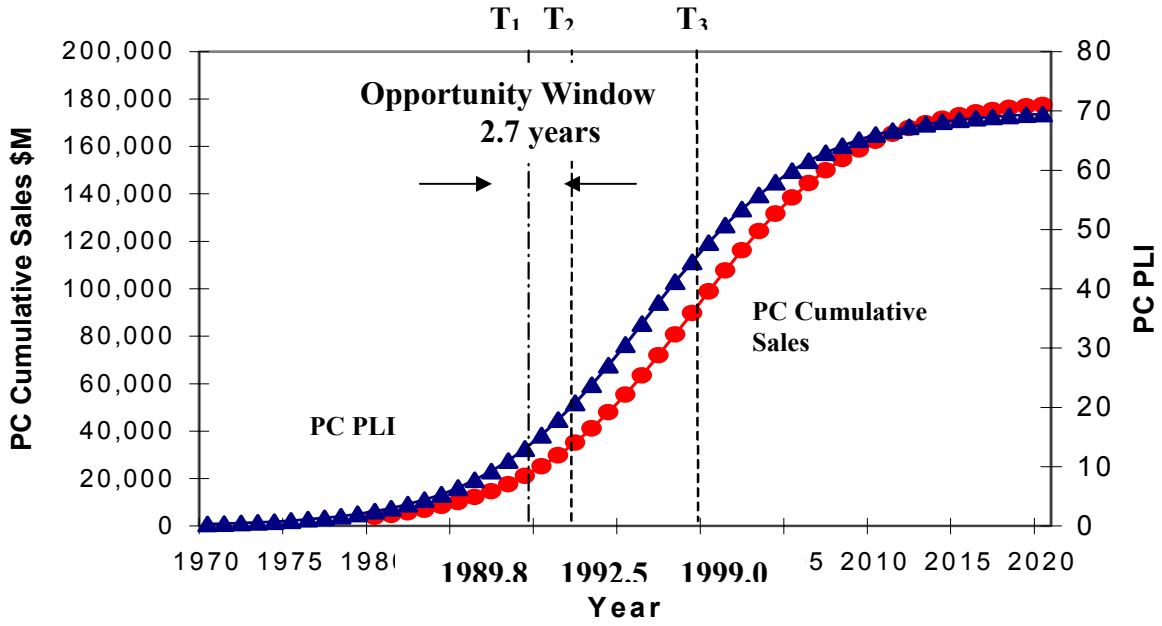


Figure 3. US PC PLI and PC Cumulative Sales

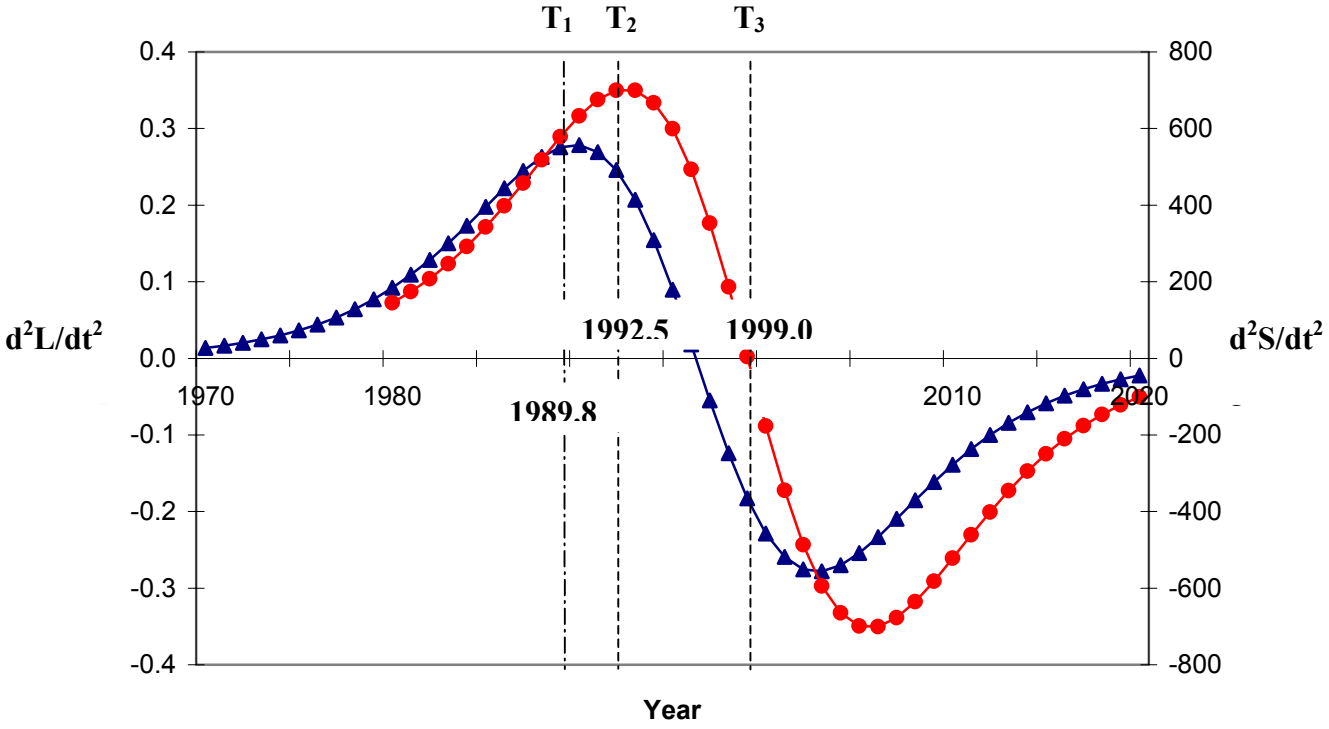
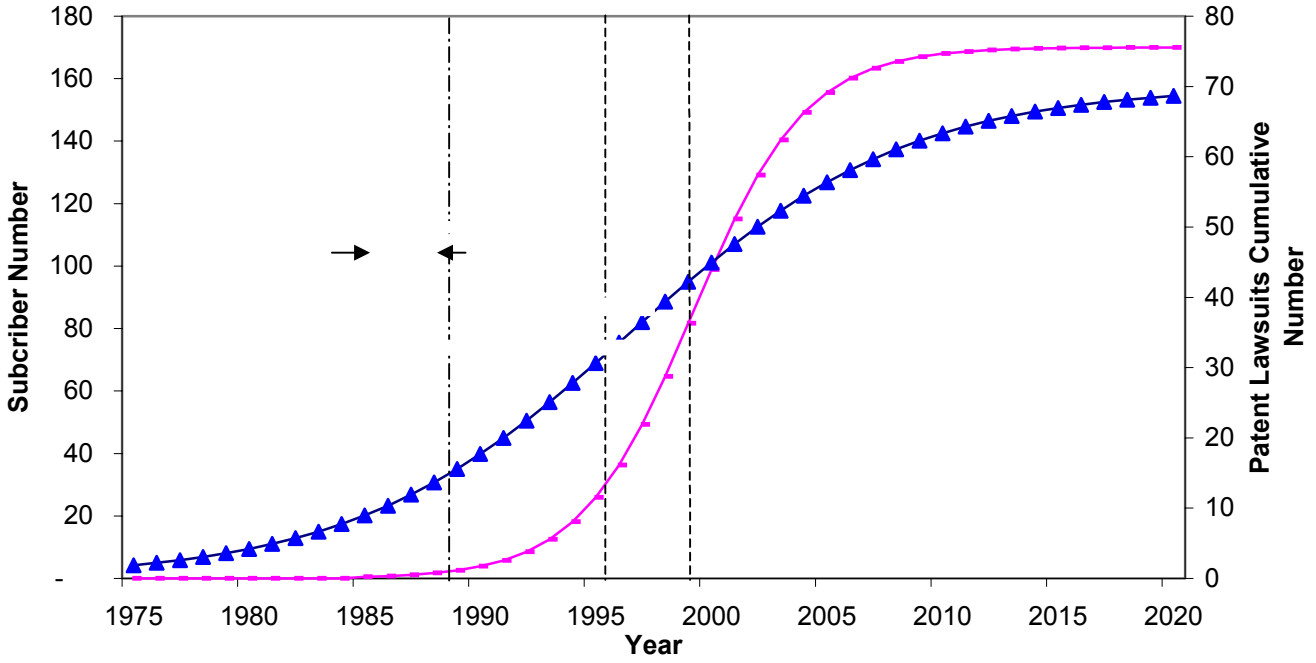


Figure 4. Second Derivative PC PLI and PC Market Growth Model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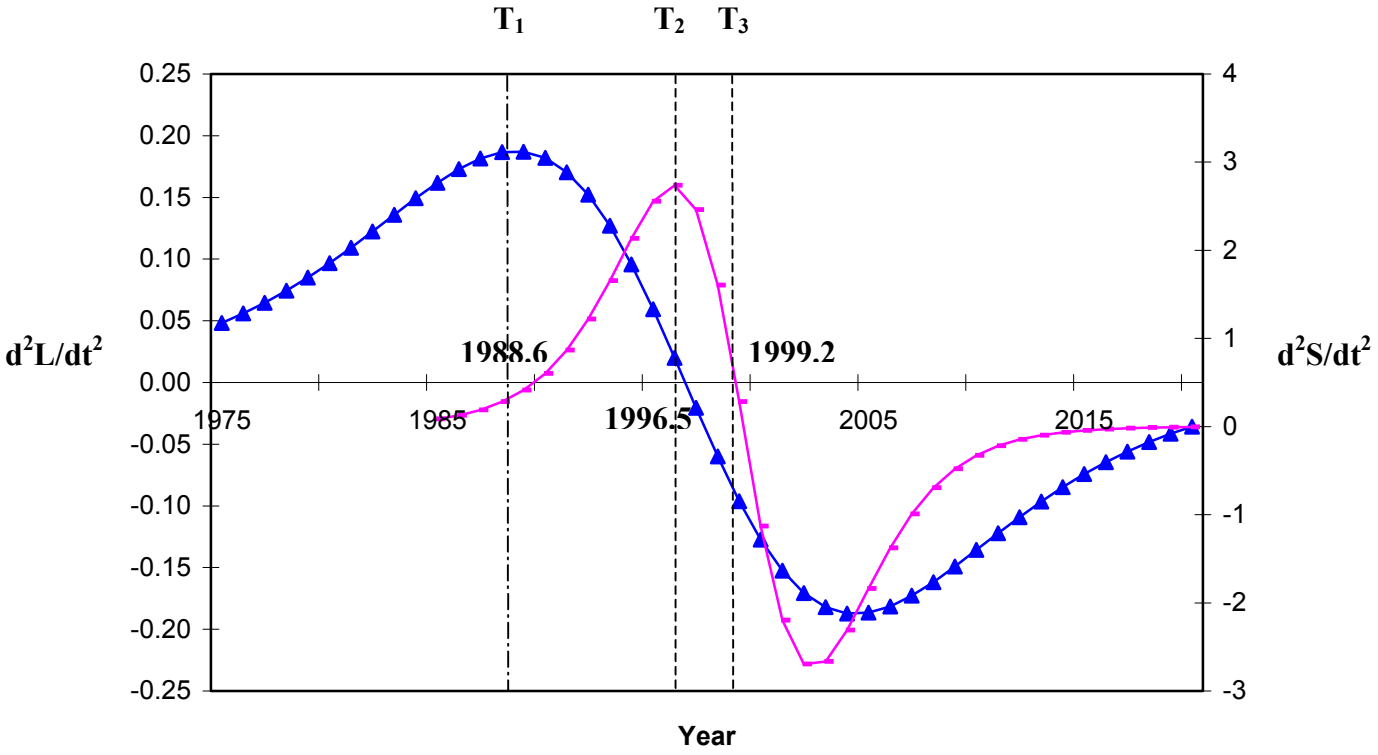

Figure 6. Second Derivative of US PLI and Market Growth Model for Cellular Phones

Table 1. PC Market Revenues 1980-2000

Year	Annual Sale $m
1980	1,550
1981	2,550
1982	4,390
1983	7,470
1984	11,940
1985	13,040
1986	13,940
1987	14,881
1988	17,147
1989	20,707
1990	23,584
1991	24,269
1992	30,833
1993	40,985
1994	46,052
1995	53,706
1996	61,008
1997	70,090
1998	78,240
1999	88,440
2000	99,700

(Source: Information Technology Industry Data Book)

Table 2. PC Industry Patent Litigation Intensity (PLI)

Year	Patent Litigation
1970	0
1971	0
1972	1
1973	0
1974	0
1975	0
1976	0
1977	0
1978	1
1979	0
1980	1
1981	0
1982	0
1983	0
1984	0
1985	0
1986	1
1987	2
1988	4
1989	4
1990	2
1991	2
1992	4
1993	6
1994	1
1995	1
1996	4
1997	1
1998	3
1999	6
2000	2

(Source: http://web.lexis-nexis.com/)

Table 3. US Cellular Phone Subscribers 1985-2000

Year	Subscribers
1985	203,600
1986	500,000
1987	883,778
1988	1,608,697
1989	2,691,793
1990	4,368,686
1991	6,380,053
1992	8,892,535
1993	13,067,318
1994	19,283,306
1995	28,154,446
1996	38,411,446
1997	49,680,446
1998	63,577,446
1999	80,000,000

(Source: Strategy Research Division)

Table 4. Patent Litigation Intensity (PLI) of US Cellular Phone Market 1985-2000

Year	Patent Lawsuits
1975	1
1976	1
1977	0
1978	0
1979	0
1980	4
1981	1
1982	0
1983	0
1984	4
1985	2
1986	1
1987	2
1988	1
1989	1
1990	3
1991	2
1992	0
1993	0
1994	2
1995	1
1996	2
1997	7
1998	2
1999	2
2000	3

(Source: http://web.lexis-nexis.com/)

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