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The software industry practice of announcing new products well in advance of actual market availability has led to allegations that firms are intentionally engaging in vaporware. The possible predatory and anticompetitive implications of this behavior recently surfaced in the antitrust case *United States v. Microsoft Corporation*. Taking the perspective that a new product announcement is a strategic signal among firms, the authors consider the possibility that intentional vaporware is a way to dissuade competitors from developing similar new products. An examination of empirical data for the software industry suggests that some firms use vaporware in a strategic manner. The authors then formulate and analyze the preannouncement and introduction timing decisions in a game-theoretic model of two competing firms. They find that vaporware can be a way for a dominant firm to signal its product development costs and that intentional vaporware can deter entry. The authors also show that there is a curvilinear relationship between development costs and announcement accuracy; that is, firms with high or very low product development costs make accurate product announcements, whereas firms with intermediate product development costs intentionally engage in vaporware. Empirical support for these theoretical results is also found in the software industry data. Finally, the authors discuss the beneficial and harmful consequences of vaporware and the associated implications.

Truth or Consequences: An Analysis of Vaporware and New Product Announcements

vaporware *n.* 1: a product that the vendor keeps promising is about to arrive "real soon now," but it goes so long past its shipment date that no one believes it will ever really ship (*Jargon: An Informal Dictionary of Computer Terms* by R. Williams and S. Cummings 1993) 2: slang for announced software that may never materialize (*Computer Dictionary* by D. Spencer 1992) 3: a term used sarcastically for promised software that misses its announced release date, usually by a considerable length of time (*Microsoft Press Computer Dictionary* 1991)

Many firms find it beneficial to communicate their development activities to internal and external audiences in advance of a new product introduction (e.g., Lilly and Walters 1997; Rabino and Moore 1989; Wind and Mahajan 1987). In the software industry, for example, preannouncing the future availability of new products is widely practiced (e.g., Singh 1997). Given this pervasive activity of firms, industry pundits have coined the term "vaporware" to describe products that miss their previously announced release date.[1]

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[1]The term "vaporware" has been used in the computer industry for several years. As a tribute to its pervasiveness, the 20th anniversary issue of *Byte* (1995) published a list of famous vaporware products. The term arose when Ann Winblad, a former girlfriend of Bill Gates and now a San Francisco area venture capitalist, visited Microsoft in 1982 demanding to know whether it was really planning to develop a piece of Unix software for her Minneapolis company. Getting nowhere with executives, she asked Microsoft engineers John Ulett and Mark Ursino, who used the term to indicate that the project had run out of steam (Flynn 1995). Later, the term came to have broader connotations (Dyson 1987). *Infoworld* also popularized this term when its editor, Stewart Alsop, presented Bill Gates with the Golden Vaporware award in November 1985 at the Alexic Hotel in Las Vegas (with the speakers blaring "To Dream the Impossible Dream") to celebrate Microsoft's introduction of its first version of *Windows* (Garud 1997; Ichbiah 1993).

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Because of the various uncertainties in any new product development process, some vaporware is certainly unintentional. However, some industry participants allege that certain firms intentionally engage in vaporware to gain a competitive advantage. Therefore, it should not be surprising that the practice of vaporware has recently figured in several headlines (e.g., Jenkins 1988; Johnston 1995; Johnston and Betts 1995; Singh 1997; *Wall Street Journal* 1996) and has been the subject of government scrutiny (e.g., Black and Wylie 1997; U.S. Department of Justice 1995; Yoder 1995).[2]

Despite the importance of this topic, the published literature does not discuss the possible incentives for a firm to engage in vaporware intentionally. The few research papers on this topic conclude that firms have no incentives to lie and thus intentional vaporware does not exist (e.g., Farrell and Saloner 1986; Levy 1997). Unfortunately, this conclusion rings hollow and lacks face validity because of actual marketplace observations of firm behaviors (e.g., Orrison 1997; Prentice 1996). In addition, securities fraud lawsuits involving vaporware have been successful; for example, the mean settlement in securities class action lawsuits between 1989 and 1994 for the dissemination of misleading information on products under development was $7.2 million, and mean damages were assessed at $47.1 million (Carleton, Weisbach, and Weiss 1996).[3] Consequently, the purpose of this article is to offer one possible explanation for this phenomenon that is in agreement with observed industry practice; that is, some firms seem to engage in vaporware intentionally, whereas others do not. Specifically, we show that intentional vaporware can be used to deter entry.

Among its possible functions, preannouncing behavior by a firm can be used to (1) tell potential competitors that it is working on a new product so that the competitors will back off; (2) signal to potential competitors that it is farther along in product development than they are and therefore the competitors should back off; and (3) in case it already has been beaten to market by a competitor, tell consumers to wait for its product so that the acceptance of the competitor's product will be delayed (for other uses of preannouncements by firms, see Eliashberg and Robertson 1988; Lilly and Walters 1997). Unlike the existing research on this topic (e.g., Eliashberg and Robertson 1988; Farrell and Saloner 1986; Levy 1997; Lilly and Walters 1997), the focus of this article is a firm's use of preannouncements in telling potential competitors about its new product development efforts. Thus, our approach follows the long and rich descriptive and empirical literature, which views product preannouncements as interfirm signals (e.g., Chaney, Devinney, and Winer 1991; Heil and Robertson 1991; Koku, Jagpal, and Viswanath 1997; Porter 1980; Robertson, Eliashberg, and Rymon 1995). However, our work differs from this literature in that we employ a game-theoretic model to examine formally the role of preannouncements in the context of rational firms. Furthermore, in this article we are concerned with the phenomenon of intentional vaporware (i.e., intentionally false preannouncements). We consider a situation in which competitors simultaneously decide whether (and when) to introduce a new product. Our game-theoretic results show that rational firms may want to practice intentional vaporware. This is in sharp contrast to the prevailing thought that firms have no incentives to engage in intentional vaporware.

From a methodological perspective, our article is related to the game-theoretic literature on signaling. This research has examined various mechanisms by which a firm can provide information to either consumers or competitors about a latent variable that has some relevance for decisions. Researchers have considered various signaling tools, such as pricing, advertising, warranty policies, and money-back guarantees, to signal latent variables such as product quality (e.g., Bagwell and Riordan 1991; Kihlstrom and Riordan 1984; Lutz 1989; Moorthy and Srinivasan 1995), network externalities (e.g., Padmanabhan, Rajiv, and Srinivasan 1997), and marginal costs (e.g., Milgrom and Roberts 1982; Srinivasan 1991). An important subset of this literature specifically deals with entry deterrence (e.g., Balachander and Srinivasan 1994; Milgrom and Roberts 1982; Srinivasan 1991). This research has primarily focused on examining the phenomenon of predatory pricing and limit pricing. For example, Milgrom and Roberts (1982) show that rational firms can use limit pricing to deter entry. Our research differs from the extant game-theoretic research in two ways. First, our article formally establishes the possible role of product preannouncements as a signaling device. Specifically, we show that product preannouncements can be used by firms to signal product development costs (which are not marginal costs). This is important because product development costs are a function of a firm's entry time, which is endogenous in our model. Second, we show that preannouncements can be used to deter entry. This is different from the existing models of entry deterrence, which have primarily focused on the role of price in deterring entry.[4]

To provide a specific context for our research, in the next section we discuss the role of new product announcement behavior in the personal computer software industry and present some descriptive data on vaporware over the ten-year period between 1985 and 1995. These data suggest that firms use vaporware in a strategic manner (i.e., firms miss their announced shipment dates in a nonrandom fashion). This implies that intentional vaporware may be practiced by some firms.

Then, in the following section, we formulate and analyze a model that can account for these empirical observations. Consistent with industry usage of the term as well as the usual definitions, we consider preannouncements to be concerned only with the timing of the future availability of a new product. In contrast to the existing research literature (e.g., Farrell and Saloner 1986; Levy 1997), we do not limit our attention to the situation in which a product announce-

[2]Because there are possible predatory and anticompetitive implications associated with false product announcements, there might be a violation of antitrust laws (i.e., there is a potential violation of the Sherman Act that carries a treble damage judgment; see Dratler 1996; Heil and Langvardt 1994; Prentice 1996).

[3]In another notable vaporware lawsuit involving the Lisa computer and Twiggy disk drive, Apple Computer was hit with a jury verdict of $100 million and was fortunate to settle the case out of court later for only $16 million. For a discussion of this case and others, see Prentice and Langmore (1994).

[4]This focus of prior literature on price as a signaling tool is understandable because these articles were interested in pricing issues, specifically, predatory and limit pricing. It is important to note, however, that in the context we study (i.e., new product preannouncements in which both firms may be entrant firms), prices cannot be used to deter entry because firms cannot commit to prices in advance of product launch.

ment is used only in response to a competitive product introduction, and consequently, we do not emphasize the possible role of intentional vaporware in eliminating a rival's first-mover advantage. Instead, we study the situation in which (1) a preannouncement occurs before the market introduction of a new product; (2) preannouncements are used to signal product development cost information between firms; and (3) intentional vaporware occurs when, having used a preannouncement to deter entry, a firm introduces its new product at an optimal time later than originally announced. In our model, preannouncing serves the function of signaling that a firm has low product development costs (possibly as a result of starting its product development earlier than its competitor) and therefore a competitor should refrain from developing its own similar new product. Thus, the goal of the preannouncement is to provide information that will tell a potential entrant that competition will be unprofitable for it and therefore it would be better to forgo entry and save development costs. Because there are penalties for false announcements (e.g., potential legal expenses associated with an antitrust investigation, losses in reputation that will negatively affect future sales of the firm), a firm with low product development costs can credibly engage in intentional vaporware to signal to competitors that its development costs are indeed low. The reason the signal works is that it is not profitable for a firm with high product development costs to mimic the announced early entry time. Therefore, a firm with low product development costs successfully deters entry and can then introduce its product as a monopolist at a later time than originally announced if this is optimal. We also show that firms with very low product development costs can deter entry but do not need to engage in vaporware.

In the Discussion section, we revisit the vaporware data from the software industry to obtain empirical evidence supporting our analytical results. We conclude by discussing the beneficial and harmful consequences of vaporware and the associated implications. We also offer some promising directions for further research.

SOME EMPIRICAL OBSERVATIONS

The Software Industry

Software is one of the largest and fastest-growing industries today, with global sales of packaged software more than $100 billion (Anderson 1996). Competition in the software industry occurs among large, dominant firms as well as several small, entrepreneurial firms. For example, a casual search of computer trade magazines indicates that competition in the spreadsheet market since 1984 has been among large, dominant firms such as Microsoft (*Excel*) and Lotus (*Lotus 1-2-3*), as well as smaller firms such as Interface Technologies (*Farsight*), Paperback Software International (*VP-Planner*), Ontio Computer Products (*Ontio 259*), Mosaic Software (*The Twin*), Daybreak (*Silk*), Indian Ridge Enterprises (*THE Spreadsheet*), ButtonWare (*PC-Calc*, a shareware program), and Tidestone Technologies (*Formula One*, a Java-based program). Informal discussions with industry participants also suggests that the smaller firms often base their new product development efforts around the new product announcements of their more dominant competitors (e.g., smaller firms may decide to "get out of the way" of a larger firm such as Microsoft by concentrating their limited development efforts in other markets; see Prentice 1996; Prentice and Langmore 1994).

Software development is a complex venture that is laden with uncertainty. Software is a systems product that is generally composed of several interacting components or features that are assigned to different programmers or teams of programmers. Although each software component may independently accomplish its designed task, it is difficult to anticipate how the component will interact with other features in the complete program. Software development is still thought to be largely an art form.[5] Fixing the resulting computer bugs and software glitches is thus an important and ongoing part of the software development process (see, e.g., Cusumano and Selby 1995; Mossberg 1995; Rigdon 1995). Whereas the planning stage in software development can take between 3 and 12 months, development, debugging, and internal/external testing often lasts between 6 and 20 months (Cusumano and Selby 1995; *Soft-Letter* 1991). Thus, there are often legitimate reasons for delays in software development (Jenkins 1988; McConnell 1996; van Genuchten 1991).[6] However, there is some evidence that software development is maturing and firms are better able to plan their development efforts (e.g., Blackburn, Hoedemaker, and van Wassenhove 1996; Carmel and Becker 1995; Cusumano 1991; Cusumano and Selby 1995; Iansiti and MacCormack 1997).

In any event, it is clear that some software ships very close to its announced release date, whereas other software ships long after the first announced release date. For example, the announced release date and actual ship date for *Lotus Notes* was December 1989, whereas the actual ship date for Microsoft *Windows* was 18 months after its announced release date of May 1984. This behavior of announcing a new software product well in advance of its market introduction has led to allegations of intentional vaporware. In the software industry, the antitrust implications of vaporware recently surfaced in the case *United States v. Microsoft Corporation*. In rejecting the U.S. Department of Justice's proposed settlement with Microsoft, U.S. District Judge Stanley Sporkin repeatedly chastised the government for not questioning Microsoft's new product announcement practices. According to Judge Sporkin, "Vaporware is a practice that is deceitful on its face and everybody in the business community knows it" (Yoder 1995, p. B1). (For a discussion of this investigation, see Clark and Novak 1995; Lopatka and Page 1995.)

Data and Analysis

In this section, we empirically explore the vaporware activity of software firms. We assembled information on a sample of new product announcements and introductions in the software industry from *P.C. Letter*'s "Official Vapor List."[7] To obtain products for this list, the newsletter's edi-

[5]For example, it is generally believed that "the best code is still done by small teams of young American coders eating pizza and drinking Coca-Cola" (Dvorak 1993, p. 95).

[6]Not everyone agrees. For example, Eric Dickstein, a leading technical analyst at Continental Grain Corp. of New York, believes that "Microsoft can ship a complete product on time if they choose. They were able to turn the entire organization around to get Internet products out the door within a year" (Jacobs, Blodgett, and Didio 1997).

[7]We thank *P.C. Letter*, and particularly Barbara Newton, for making all the back issues between January 1985 and May 1995 available to us.

tor, Stewart Alsop, solicited nominations from key industry participants (which have included Bill Gates and other prominent chief executive officers) and used his extensive experience and knowledge of the industry. All products on this list have been announced and are believed to be important and influential. We assembled information on the date first announced, the announced release date, and the actual ship date for 123 software products spanning the ten-year period 1985–95. Frequency distributions for the times between various dates appear in Table 1, which indicates that more than 50% of all the software products in this sample were shipped within three months of the announced release date (of the 123 products in our sample, only 6, or 5%, were introduced before their announced release date). In addition, the time between first announcement and actual shipment is less than nine months for more than 75% of these software products. And for more than 50% of these software products, the time between first announcement and announced release date was less than six months. Therefore, if we accept the industry viewpoint that delays of more than three months between the announced release date and actual ship date represent intentional vaporware (e.g., Foundyller 1993; Papows 1992),[8] more than half of all the software products in this sample correspond to vaporware that is not intentional. We note that this is consistent with Eliashberg and Robertson's (1988) cross-industry survey results.

Table 1
PRODUCT ANNOUNCEMENT BEHAVIOR OF SOFTWARE COMPANIES (n = 123)

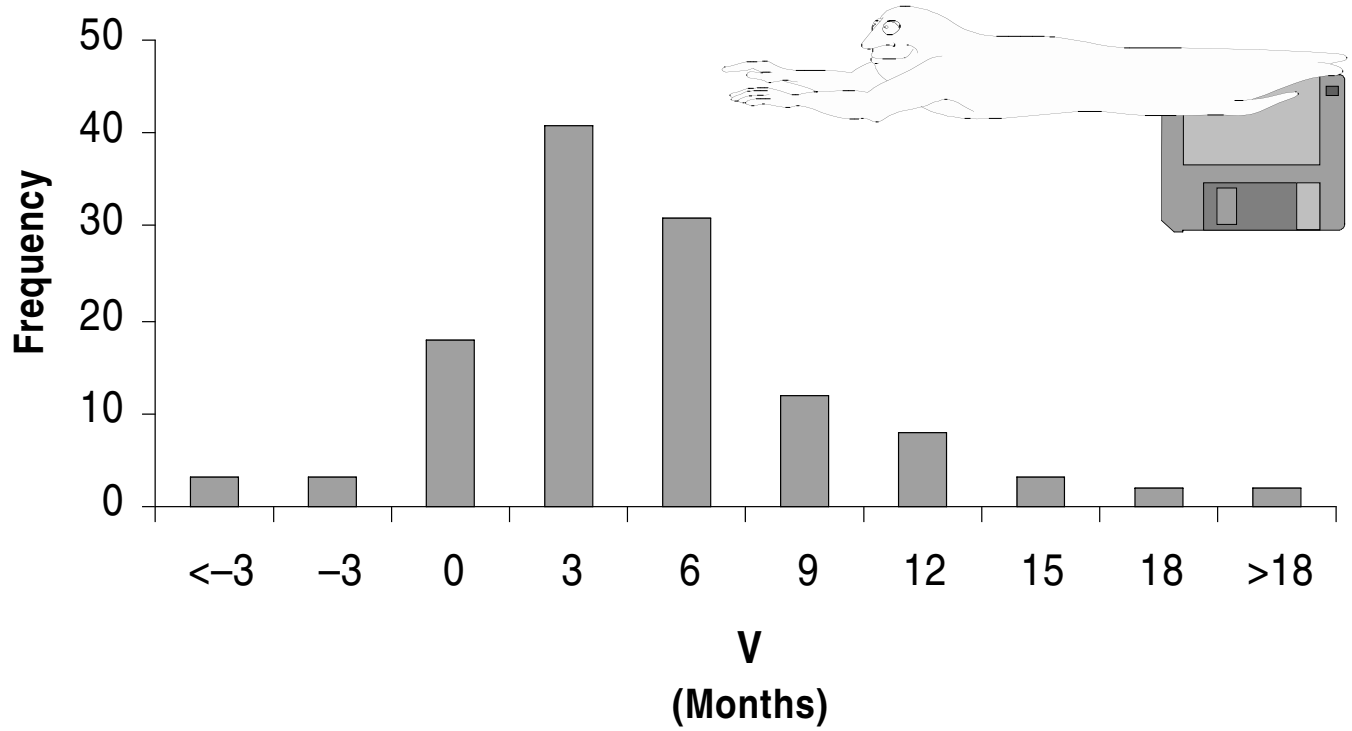
Time (Months)	*Time Between Date First Announced and Announced Release Date*	*Time Between Announced Release Date and Actual Ship Date (V)*	*Time Between Date First Announced and Actual Ship Date*
<3	18%	53%[a]	12%
3–<6	37%	25%	28%
6–<9	15%	10%	36%
9–<12	7%	6%	11%
≥12	8%	6%	22%

Source: *P.C. Letter*'s "Official Vapor List" (1985–95).
[a]Six cases, or 5%, are negative; that is, these products were introduced before their announced release date.

We define V to be the time between the announced release date and actual ship date (i.e., announcement accuracy). Note that V can be negative if the product is introduced before its announced date. Now, consider the histogram of V shown in Figure 1. We note that a symmetric distribution around 0 would suggest that there is no systematic relationship between the announced release dates and the actual ship dates of the firms in our sample (i.e., all vaporware is unintentional). This histogram is not symmetric around 0 (the mean of V is 3.5 months, which is significantly differ-

[8]For example, the now-defunct industry group called the Software Business Practices Council recommended in 1990 that the time between first announcement and availability should be no longer than nine months (Johnston and Betts 1995). Other industry pundits have argued that a 60-day (e.g., Papows 1992) or 90-day (e.g., Foundyller 1993) time between the announced release date and availability (i.e., ship time) is tolerable. An industry study also indicates that the median delay for late software products is three months (*Soft-Letter* 1991).

Figure 1
TIME BETWEEN ANNOUNCED RELEASE DATE AND ACTUAL SHIP DATE (n = 123)



ent from 0; t = 8.18, p = .00). One possible explanation for these results is that some firms use vaporware in a strategic manner (i.e., some vaporware is intentional). In addition, for V > 0, if all vaporware were unintentional, we would expect V to be positively correlated with how far in advance of the release date announcement is made (i.e., the farther the preannounced date is in the future, the more likely a firm will make an error in accurately forecasting its product introduction time). Empirically, however, we find that there is no relationship between V and how far in advance of the release date the announcement was made (Table 1, column 1); that is, r = .02, p = .85. To explore this null result further, we tested whether this conclusion holds when controlling for firm size (i.e., Do the possibly different software development processes of large and small firms matter?), whether the firm was publicly or privately owned (i.e., Do the different incentive structures of public versus private firms matter?), and the year the product announcement was made (i.e., Is there a systematic trend in announcement accuracy over time?). Although not reported here, we find that none of these variables is significant in a regression analysis.

Summary

Our discussion and empirical analysis of new product announcement behavior in the software industry leads to the following three main observations: First, the many small, entrepreneurial firms in the software industry frequently base their new product development efforts around the new product announcements of their larger, more dominant competitors. Second, new software development is an inherently uncertain process in which there are often legitimate reasons for delays. Third, in addition to the usual uncertainties in the new product development process, some software firms may intentionally use vaporware in a strategic manner.

A MODEL AND ANALYSIS

In this section, we formulate and analyze a stylized model of the timing of new product introduction with the possibility of product preannouncements. We define new products as new software titles as well as upgrades of existing titles. We study the incentives for intentional vaporware by emphasizing the interfirm signaling aspects and assume that false announcements have associated penalty costs.[9] We consider the possibility that intentional vaporware can be a way to discourage other firms from developing their own products. To make these points as clearly and as simply as possible, we consider a duopoly with one firm the dominant firm. Dominance is incorporated in our model formulation through the assumption that followers cannot expect to succeed if they enter later than the dominant firm. We further assume that firms can choose their product introduction time with certainty. In reality, a firm cannot determine its product introduction time without error, and consequently some vaporware is unintentional. Our assumption, however, enables us to focus on the more interesting case of intentional vaporware.

The sequence of decisions in our model is as follows: At time 0, Firm 1 (the dominant firm) preannounces an introduction time T_a that is observed by Firm 2. (We argue subsequently that total expected duopoly profits are higher with preannouncements than without.) After the preannouncement, both firms simultaneously decide on a time of entry by maximizing their discounted expected profits over time. If Firm i is a monopolist in the market, its expected revenues per period are denoted by π_i^m.[10] In line with software industry experiences, we assume that the marginal costs of production are negligible for each firm (e.g., Shapiro and Varian 1998). When Firm i is in the market with the other firm, its expected duopoly revenue flow is denoted by π_i^d. We make the usual assumption that $\pi_i^m > \pi_i^d \geq 0$. If Firm i decides to enter at time t, we define the net present value of its product development costs to be $c_i(t)$. Consistent with empirical findings (e.g., see the review in Graves [1989]), we also write Firm 1's product development cost function as $c_1(t) = \alpha\psi(t)$. The parameter $\alpha \geq 0$ will be used subsequently to model Firm 2's uncertainty about Firm 1's product development costs.[11] Finally, we assume that false preannouncements are costly; that is, if Firm 1 preannounces an introduction time T_a and enters at $t > T_a$, then it incurs a penalty cost (e.g., see Landis and Rolfe 1985; Prentice and Langmore 1994; Shughart 1990). We model this cost as a function $p(t - T_a) = \beta\xi(t - T_a)$, where $\xi(t - T_a) > 0$ for $t > T_a$ and 0 otherwise and $\beta \geq 0$ is a constant.

The following mathematical assumptions ensure the preceding environment:

Assumption 1: $c_i'(0) < 0$, $c_i''(t) > 0$, and $\lim_{t\to\infty} c_i'(t) > 0$ for i = 1, 2.

We note that this assumption is consistent with prior empirical findings that show that the relationship between a firm's development costs and its entry time is a U-shaped function (e.g., Boehm 1981; Brooks 1975; Graves 1989; Mansfield 1971; Putnam and Fitzsimmons 1979). The assumption that $\lim_{t\to\infty} c_i'(t) > 0$ guarantees that each firm has a positive, finite product introduction time in the absence of strategic considerations.

Assumption 2: $c_i''(t) > re^{-rt}\pi_i^m$ for i = 1, 2.

This assumption ensures that the profit functions are concave (e.g., see also Reinganum 1981).

Assumption 3: $\pi_2^d \leq c_2(t_2)re^{rt_2} \forall t_2$.

This assumption ensures that Firm 2 will not find it profitable to be a follower (because Firm 1 is dominant). We note that this assumption is always satisfied if π_2^d is close to zero. Note that

[9]For example, the justice department's 13-year antitrust investigation of IBM cost the company and government an estimated $200 million for legal and photocopying costs alone (*Wall Street Journal* 1982). By the end of the case, IBM was paying $5 million a year just to store the 46,000 tons of documents associated with the investigation (Chase 1982). One study estimates that the cost of private antitrust lawsuits to U.S. companies is $250 million per year (Shughart 1990). In the 1990–91 period, 300 class action securities fraud suits were filed at an average litigation cost of $692,000 per suit (Bowers and Gupta 1994). In total, for 1992, class action defendants paid settlements of approximately $1.55 billion, and the average settlement was approximately $10.8 million (Bowers and Gupta 1994). It has also been argued that the reputations of IBM and Wang Laboratories were damaged by the firms not living up to their own product announcements (Prentice and Langmore 1994). See also Landis and Rolfe (1985).

[10]We can also admit exogenous market growth effects in the model by including an appropriate term. For example, exponential growth can be incorporated by multiplying π_i with $e^{\rho t}$. As long as ρ is less than the discount rate, the analytical results in this section remain unchanged.

[11]The parameter α can also be interpreted as representing how far along Firm 1 is in its development process at the time of its preannouncement. Thus, firms with a low α incur lower costs to introduce a product at any given time than firms with high α, because firms with low α have already made substantial progress in developing the product.

this assumption does not rule out entry by Firm 2 before the dominant firm.

Assumption 4: $\pi_2^m < -c_2'(0)$.

This assumption rules out the possibility of immediate entry by Firm 2.

Assumption 5: $-(\pi_2^m - \pi_1^d)e^{-rt} - [c_2'(t) - c_1'(t)] \leq 0$.

This assumption ensures that Firm 2's optimal entry time t_L^* is less than Firm 1's entry time t_F^*.

Assumption 6: $\xi'(x) > 0$ for $x > 0$, $\xi''(x) > 0$, and $0 < \lim_{t \downarrow T_a} \xi'(t - T_a) < \infty$.

This assumption ensures that penalty function is an increasing convex function of the difference between the actual entry time and the announced time and that penalty costs are not so large that a firm will never find false preannouncements profitable.

Finally, we note that all our analytical results in this section extend to the situation in which either firm (or both) already has a product in the market; that is, either firm (or both) may be considering an upgrade to one of its existing products. Although the details are not provided here (but are available on request), we only need a model structure with two firms, one of which is dominant, and assumptions similar to Reinganum's (1981).[12]

Now we can write the firms' profit functions for various entry decisions. If Firm i (i = 1, 2) is a monopolist and enters at time t, its profits are

$$\Pi_i^m(t) = \int_t^\infty e^{-r\tau}\, \pi_i^m \, d\tau - c_i(t). \tag{1}$$

If Firm 2 enters at time t_L followed by Firm 1 at time t_F, then the expected profits for Firms 2 and 1 are given by

$$\Pi_2^L(t_L) = \int_{t_L}^{t_F} e^{-r\tau}\, \pi_2^m \, d\tau + \int_{t_F}^{\infty} e^{-r\tau}\, \pi_2^d \, d\tau - c_2(t_L) \tag{2}$$

$$= \frac{\pi_2^m}{r}(e^{-rt_L} - e^{-rt_F}) + \frac{\pi_2^d}{r} e^{-rt_F} - c_2(t_L)$$

and

$$\Pi_1^F(t_F) = \int_{t_F}^{\infty} e^{-r\tau}\, \pi_1^d \, d\tau - c_1(t_F) \tag{3}$$

$$= \frac{\pi_1^d}{r} e^{-rt_F} - c_1(t_F).$$

Proofs of strict concavity of the profit functions and uniqueness of the optimal solutions, along with proofs of the lemma and propositions in this article, are available from the authors or on the Web (http://itr.bschool.unc.edu/faculty/marketing/bayusb/).

Lemma 1: Firm 1's entry time is increasing in α.

This lemma shows that as the development costs of Firm 1 increase, it would enter later. Consequently, as the development costs of Firm 1 increase, Firm 2 earns monopoly profits for a longer period of time. This implies that Firm 2's profits must be increasing in α. Using this observation, we have the following result:

P_1: Under perfect information about Firm 1's development costs, there exists an α^* such that Firm 2 enters the market if and only if $\alpha > \alpha^*$.

This proposition shows that Firm 2's optimal entry decision depends on its knowledge of Firm 1's product development costs. However, such development cost information is often unavailable to Firm 2 at the time of entry (particularly if Firm 1 has already sunk some resources into product development). Instead, Firm 2 is likely to have only a prior probability distribution of Firm 1's development costs. Consistent with empirical literature on the time–cost relationship (e.g., Putnam and Fitzsimmons 1979), we assume Firm 2 knows $\psi(\tau)$ but is uncertain of the value of α. For simplicity, we assume that α can take two values, α_{low} and α_{high}, where $\alpha_{low} < \alpha^* < \alpha_{high}$. Firm 2 assigns a probability η that Firm 1 has $\alpha = \alpha_{low}$ (i.e., Firm 1 has relatively low development costs) and probability $1 - \eta$ that Firm 1 has $\alpha = \alpha_{high}$ (i.e., Firm 1 has relatively high development costs). Given the assumption $\alpha_{low} < \alpha^* < \alpha_{high}$, it follows from P_1 that if Firm 2 has perfect information, it will not enter the market if $\alpha = \alpha_{low}$ and will enter the market if $\alpha = \alpha_{high}$. Because Firm 2 is not aware of the actual development costs of Firm 1, to make an entry decision Firm 2 must use its prior distribution and possibly Firm 1's preannouncement. If Firm 2's priors do not favor entry, it does not enter the market. We consider instead the more interesting case in which Firm 2's priors favor entry. For ease of exposition, we assume that Firm 1 is aware of Firm 2's development costs.[13]

The next proposition shows that in such situations, preannouncements can serve a useful purpose. To achieve uniqueness, we restrict beliefs based on the intuitive criterion (Cho

[12]We need the following conditions: (1) There is a benefit to introducing the upgrade, (2) there is a benefit to introducing the upgrade when the other firm has done so, and (3) the incremental revenues from being first exceed the incremental revenue when Firm 1 is the follower.

[13]The assumption that the dominant firm knows the development costs of Firm 2 is not critical to our results discussed here. To see this, consider the case when the costs of Firm 2 are modeled as $c_2(t) = \theta\varphi(t)$, where θ is not known by Firm 1 with certainty. Then, $\alpha^*(\theta)$ is the critical value of α in P_1 that depends on Firm 2's development costs. There are three possibilities: (1) If $\alpha^*(\theta) < \alpha_{low}$, then Firm 2 will enter regardless of Firm 1's costs; (2) if $\alpha^*(\theta) > \alpha_{high}$, then Firm 2 will not enter regardless of Firm 1's costs; and (3) if $\alpha_{low} < \alpha^*(\theta) < \alpha_{high}$, then the analysis and results discussed here remain unchanged. In the general case in which there is some probability that Firm 1 is facing a Firm 2 of each of these three types, the benefit function considered will need to be replaced by an expected benefit function, and the appropriate probabilities and outcomes will be considered. For example, letting σ_1, σ_2, and σ_3 be the respective probabilities that Firm 1 is facing a Firm 2 of these three types, the probability that a preannouncement has no effect on Firm 2's entry decision is $\sigma_1 + \sigma_2$. If $\sigma_3 = 1$, then our analysis is as before. However, as long as $\sigma_3 > 0$, the benefit function is still increasing in α, and the main results of the article continue to hold. Thus, adding uncertainty about Firm 2's costs would only complicate the presentation of the analysis and would not change our basic results.

and Kreps 1987).[14] We also make the reasonable assumption that firms weakly prefer to preannounce truthfully. In other words, if a firm is indifferent between preannouncing truthfully and lying, it prefers to preannounce truthfully.

P_2: Assume that preannouncing an entry time $T_a = 0$ is not profitable (this holds for sufficiently large α_{low}, α_{high}, and β). Then, there exists a unique perfect Bayesian separating equilibrium in which the following is true: (a) Firm 2's beliefs are

$$\Pr(\alpha = \alpha_{low}) = \begin{cases} 1 & \text{if } T_a \le T_a^* \\ 0 & \text{otherwise} \end{cases};$$

that is, if Firm 1 preannounces a time less than or equal to T_a^*, then Firm 2 believes with certainty that the preannouncement came from a low-cost firm. (b) The low-cost Firm 1 preannounces a time $T_a^{**} \le T_a^*$, and the high-cost Firm 1 preannounces a time $t^*(\alpha_{high}) > T_a^* \ge T_a^{**}$. (c) Firm 2 does not enter if Firm 1 preannounces a time $T_a \le T_a^*$ (i.e., Firm 2 believes that Firm 1 has low development costs) and enters otherwise (i.e., Firm 2 believes Firm 1 has high development costs). Thus, in equilibrium, the low-cost Firm 1 preannounces a time T_a^{**}, and Firm 2 does not enter the market. In contrast, the high-cost Firm 1 preannounces a time $t^*(\alpha_{high}) > T_a^* \ge T_a^{**}$, and Firm 2 correctly infers that the preannouncement came from a high-cost firm and enters the market.

P_3: If entry at time 0 is not profitable for Firm 1, then for a given α_{low} and α_{high} there exists a range $(\underline{\beta}, \overline{\beta})$ such that if $\beta \in (\underline{\beta}, \overline{\beta})$, then the low-cost Firm 1 enters later than its preannounced time (i.e., it intentionally engages in vaporware), and the high-cost Firm 1 enters at its preannounced time $[t^*(\alpha_{high})]$. If $\beta > \overline{\beta}$, then both the low-cost and the high-cost Firm 1 enter at their preannounced time. If $\beta < \underline{\beta}$, then a separating equilibrium does not exist.

P_4: For a given β, there exists an $\underline{\alpha}$ such that if $\alpha_{low} < \underline{\alpha}$, then Firm 1 of both types (i.e., low- and high-cost) enters at its preannounced time. If $\alpha_{low} \in (\underline{\alpha}, \alpha^*)$, where α^* is defined in P_1, then the low-cost Firm 1 enters at a later date than it preannounced (i.e., it intentionally engages in vaporware), whereas the high-cost Firm 1 enters at the preannounced time.

The general intuition for these propositions is straightforward. Note that in our framework, the only benefit that accrues to a firm through preannouncements is that it can deter entry by preannouncing at an early enough time. If a firm successfully deters entry by a preannouncement, it can enter as a monopolist. The time of entry will depend on the preannounced time and the firm's product development costs. We know that low-cost firms find it less costly to enter at an earlier date than high-cost firms. Because the benefit of deterring entry is negatively affected by the penalty a firm incurs if it does not enter at its preannounced time, it follows intuitively that the benefit from intentional vaporware is larger for the low-cost firm. Thus, a low-cost firm can credibly signal its costs by announcing a time of entry such that the high-cost firm would rather enter as a follower than mimic the low-cost firm. This is because the high-cost firm incurs costs that exceed the benefit of entering as a monopolist. Thus, the dominant firm with high development costs preannounces truthfully, and the dominant firm with low development costs intentionally engages in vaporware.

P_3 shows how, for a given α_{low} and α_{high}, the penalty function affects Firm 1's entry timing relative to its preannouncement. Note that if the penalty for lying is too small, then preannouncements are not credible and there is no separating equilibrium. However, as the penalty function reaches a critical value, the low-cost firm can credibly signal its development costs by preannouncing. However, for moderate penalty levels, the low-cost firm finds it profitable to enter at a later date than the date it preannounced. This is because, after successfully deterring entry, the low-cost firm would prefer to enter at a time that maximizes its monopoly profits. Thus, for moderate values of β, the low-cost firm finds it profitable to incur the penalties associated with missing its preannounced time. As the penalty associated with lying increases, however, the firm finds it preferable to enter at its preannounced time. P_4 shows that a firm with very low costs (i.e., a sufficiently small development cost parameter α) will enter at its preannounced time. This result is intuitive: If the firm has sufficiently low costs such that it can deter entry by preannouncing its monopoly entry time, then it has no reason to lie. Thus, this proposition implies that the firms that practice intentional vaporware are those with low, but not very low, product development costs.

Finally, our analysis indicates that total expected duopoly profits are higher with preannouncements than without. Given that the dominant firm preannounces its introduction time, the rival firm can save its development expenses by not entering if its competitor has low costs. However, if the dominant firm does not make a preannouncement, then the rival firm will enter and lose its investment (with prior probability η) if its competitor has low development costs. With a preannouncement by a dominant firm that has high development costs, the rival firm will earn profits as given by Equation 2. However, if there is no preannouncement, the rival firm has only a $(1 - \eta)$ prior probability of earning these same profits.

DISCUSSION

In this section, we revisit the software industry data to see if there is any empirical evidence that is consistent with our analytical findings in P_2–P_4. Unfortunately, detailed cost information at the product development project level is not publicly available. Appropriate information on new product sales and research and development expenses at the firm level is also not generally available for the firms in our sample. Thus, we follow industry practice and use a productivity measure, that is, a ratio of sales revenues to the number of employees. We recognize that productivity is a crude measure of product development costs, but it is consistent with the metrics used by firms to assess product development performance (see, e.g., McGrath and Romeri 1994; Reinertsen 1997). Moreover, these data are available for several firms in our sample. Finally, to alleviate any concerns over the direction of causality, we use a measure that is lagged relative to the announcement date.

Using historical data published by *Soft-Letter* and *Hoover's Guide to Computer Companies* (The Reference Press 1995),

[14]The intuitive criterion restricts out-of-equilibrium beliefs a firm may have in the following way: Consider a deviation by Firm 1 from the equilibrium strategy. If the deviation cannot increase the profits of one type of firm (say, the low-cost firm) from the equilibrium profits regardless of the beliefs of Firm 2, then the intuitive criterion requires that Firm 2 must believe with certainty that the deviation did not come from this type of Firm 1. A more formal definition is that of Cho and Kreps (1987), who also show how the intuitive criterion can be used to select a unique separating equilibrium in Spence's (1974) job market signaling model.

this ratio was available for 82 observations in our sample. To allow comparisons at different points in time, we use a measure of relative productivity. This measure was constructed by dividing the firm's productivity by an industry average based on the sales per employee of the top 100 software companies as reported in *Soft-Letter*'s annual rankings.[15] Using this approach, we note that more than 60% of the observations in our subsample are product announcements by firms with productivity greater than the industry mean.[16] The distribution of this measure is shown in Figure 2.

Because our analytical results in P_2 and P_4 suggest an inverse U–shaped relationship between V and development costs, we regressed V on linear and quadratic terms of lagged relative sales per employee, C. The regression model is statistically significant overall:

$$V = \underset{(-.67)}{-1.07} + \underset{(2.76)}{8.06C} - \underset{(-2.33)}{2.96C^2}$$

($F(3,82) = 4.24$, $p = .02$; $R^2 = .10$). The linear and quadratic terms are significant at better than the .05 level (t-ratios are in parentheses).[17] The positive coefficient for C and the negative coefficient for C^2 suggest that an inverted U–shaped relationship exists between productivity and vaporware. We also find that V is significantly and negatively related to firm size (e.g., relative sales: $r = -.23$, $p = .05$, or relative number of employees: $r = -.24$, $p = .05$). Given that larger firms such as IBM and Microsoft are more likely than smaller firms to attract the attention of antitrust investigators (e.g., Dratler 1996), this result is not surprising, because it indicates that larger firms (with greater chance of scrutiny and possible penalty costs) tend to be more accurate in their preannouncements (which is consistent with P_3). These results suggest that as product development costs increase, V initially increases, but eventually, as product development costs increase sufficiently, V decreases. Recognizing the limited data that are available to study vaporware, these empirical findings are in agreement with our analytical results in P_2–P_4.

IMPLICATIONS AND CONCLUSIONS

Many industries, including computer hardware and software, have a long history of making announcements in advance of a new product introduction. Certainly, there are valid marketing reasons for this practice, yet preannouncements also afford firms the opportunity to intentionally mislead the market to obtain a competitive advantage. For example, our data suggest that some software firms have practiced intentional vaporware. Not surprisingly, the possible predatory and anticompetitive implications of false prod-

[15]The *Soft-Letter* 100, published annually since 1984, is a ranking based on annual revenues of the top 100 personal computer software companies in the United States. This list, which includes public and private firms, is based on data directly provided by firms. To ensure accountability, estimates from analysts or other outside sources are not used. We thank Jeffrey Tarter, the editor and publisher of *Soft-Letter*, for making all the historical *Soft-Letter* 100 rankings between 1984 and 1995 available to us.

[16]Not surprisingly, Microsoft is generally considered to have low product development costs, and in some years very low development costs, using this measure. This is consistent with published information about Microsoft's software development process (Cusumano and Selby 1995).

[17]We note that these results are unchanged when we also control for firm sales, amount of time in advance of the release date the announcement was made, public or private ownership of the firm, and year the product announcement was made.

Figure 2
RELATIVE SALES PER EMPLOYEE (n = 82)

uct announcements have caught the attention of the U.S. Department of Justice.

Consistent with the observed software industry environment, in this article we consider several important aspects associated with the possible effects of vaporware that have not been previously addressed. First, we study the situation in which intentional vaporware by a dominant firm may be used to deter entry by discouraging the development of a competing new product. Second, we explicitly model the product development time–cost trade-offs for competing firms and consider asymmetries in development costs between rivals. Finally, we explicitly consider the role of penalty costs in a firm's decision to engage in vaporware intentionally.

We identify one possible incentive for dominant firms to engage in vaporware intentionally. Analyzing a stylized game-theoretic model of the product announcement and introduction timing decisions of two competing firms, we find that preannouncing a product can be a way for a dominant firm to signal its product development costs. A dominant firm with low development costs thus deters entry; it can then enter at a later time than it originally preannounced, earning monopoly profits that exceed any penalty costs. In addition, dominant firms with very low development costs, having also deterred competitive entry, enter at the preannounced time. These theoretical results are consistent with our empirical observations from the software industry.

It is clear that intentional vaporware can also lead to adverse consumer implications (e.g., higher prices, lack of continuous product innovation). The cost-effective dominant firm not only exercises its existing market power by making a (possibly) false product announcement and thus deters entry but also enhances its power by monopolizing the new market. Our analysis suggests that the government's approach to antitrust law enforcement can influence a firm's incentive to engage in vaporware intentionally (see P_3): To eliminate the incentives for false product announcements, the justice department should (1) completely ignore such behavior (hopefully destroying the credibility of any false preannouncements) or (2) crack down on this behavior (thus raising the penalty costs for any false preannouncement).[18] However, both true and false product announcements provide useful information that can be used strategically by smaller competitors to determine their optimal product development and entry strategies. For example, when the dominant firm's preannouncement signals that it has low development costs, the smaller firm does not enter and thus saves its development expenses. These potential benefits of intentional vaporware, however, need to be carefully balanced with its possibly harmful consequences. This seems to be one rationale for the justice department's interpretation of Section 2 of the Sherman Act 15 (U.S.C. 2), which states that a violation of antitrust laws requires proof that a preannouncement is both knowingly false and has actual or likely market impact. As our analysis shows, false preannouncements by themselves should not automatically be deemed anticompetitive. This is the same position taken by Ordover and Willig (1981), Prentice and Langmore (1994), Prentice (1996), and Dratler (1996). In our model and results, it is this intermediate position on possible penalties that ensures that intentional vaporware will be practiced by some firms.

Although our analytical and empirical results suggest that firms with low costs (but not extremely low costs) tend to engage in vaporware, some of these firms truthfully preannounce their products. Why? One possible reason lies in our proxy measure for product development costs. Recall that the available data are only at the firm level, not for each product. However, there could be considerable variation in product development costs across products within a firm. Another possible reason lies in our modeling approach. Consistent with prior models, we have considered only a single play of the competitive market entry game. However, in a repeated game framework, the dominant firm's penalty costs would accumulate if it always made false product announcements (e.g., its reputation would decay). Thus, we conjecture that under some conditions, the dominant firm's optimal strategy is mixing true and false announcements (see, e.g., Prentice 1996). This is an area for further research.

Given our findings, the general sentiment in the software industry that preannouncing products is not too damaging is understandable, because useful product development cost information may be obtained. However, careful scrutiny of this practice on a product-by-product (not company-by-company) basis is also necessary to prevent the abuse of market power by cost-effective dominant firms. This seems to be the current approach of legal teams filing class action lawsuits, as well as the justice department.[19]

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[18]We note that the possible actions by the justice department do not consider the possible harm to consumers from false announcements. As discussed previously, lawsuits involving vaporware have cost firms millions of dollars in damages (e.g., Carelton, Weisbach, and Weiss 1996; Prentice and Langmore 1994).

[19]For example, four recent investigations of Microsoft launched by the justice department involved the firm's proposed merger with Intuit (Hill 1995), bundling application software with *Windows95* (Brandt 1995), the practice of requiring computer makers that license *Windows95* to promise not to bring patent infringement suits (Novak 1995), and *Windows95*'s tendency to disrupt competitor products' Internet links and programs (Sandberg and Hill 1995). For a recent summary of the various antitrust inquiries involving Microsoft, see Black and Wylie (1997).

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