Radically New Product Introduction Using On-line Auctions

Xianjun Geng, Maxwell Stinchcombe, and Andrew B. Whinston

ABSTRACT: Rapid technological innovation and changing market expectations in electronic commerce are pushing companies to develop strategies for radically new products. Fast and unbiased new marketing research methods are needed to reduce the associated risks. A full-revelation mechanism is a crucial element of these new methods. It can be implemented with a two-round, second-price, sealed-bid auction. The process of marketing research is accelerated by conducting the auction on-line.

KEY WORDS AND PHRASES: Full revelation, marketing research, new product introduction, on-line auctions.

Radically New Product Strategy: Opportunities and Challenges

Historically, the pervasive positive network externalities of basic technologies like electricity and the telephone helped to push rapid economic growth. Enabled by global connectivity and broad-spectrum computing, the pace of technological innovation and economic growth is even faster in today's digital age. According to Internet Indicators, the revenue from e-commerce almost doubled from 1998 ($99.81 billion) to 1999 ($171.47 billion) [2]. A large proportion of this growth came from technologies and products that were unheard of a decade ago. The continuing introduction of new products that redefine customer demands and alter old markets compels companies to develop strategies for radically new products [3]. Companies that do this are characterized by a sensitivity to state-of-the-art technologies and the ability to incorporate them into new products to create values for consumers in a prompt time frame, often before any competitor can catch up.

Radically new product strategies bring a very mixed bag of obvious advantages and undeniable risks [4, 11, 15, 20]. On the up side, they enable companies to exploit business opportunities before their competitors. A successful radically new product strategy always helps in gaining the first-mover advantage, a determining factor in competition [6]. For example, SONY's 1979 introduction of the Walkman, an amazingly small, mobile tape-player that was the result of state-of-the-art mechanical engineering technologies, captured consumers' hearts and brand loyalty. SONY continued to enjoy the competitive advantage derived from its reputation as the creator of Walkman even after competitors appeared. It is still one of the world's largest producers of Walkman and its successor, Discman, the two brand names synonymous with

This research was supported in part by IBM Research and Intel.

1086-4415/2001 $9.50 + 0.00.

such products in the minds of many consumers. More recently, the first portal, Yahoo!, has steadily introduced a series of new service products, such as free e-mail, travel service, auctions, and Yahoo! Messenger. This strategy of continuous innovation helps Yahoo! to maintain its leading position in the portal business. Both Yahoo! and SONY face aggressive competition, and staying ahead in their respective markets requires radically new product strategies.

Despite these well-known success stories, there is, potentially, a distinct down side as well, in that radically new product strategies often expose companies to great financial risk. If accurate market information is not available, as is often the case for radically new products, a company that decides to mass produce is betting on a market of uncertain size. The Walkman achieved its phenomenal success because it was small and convenient to carry. Another of SONY's radically new products, the Betamax videotape, failed [5]. SONY did not realize at the time that standard availability was more important to users than videotape size.

Setting up manufacturing facilities for radically new products can pose an enormous financial risk, given the magnitude of the costs involved. For example, in February 1998, Intel announced that it planned to spend more than $1.5 billion between 1998 and 2000 to establish a plant at Hillsboro, Oregon, that would be the first factory to develop and manufacture complex computer chips on 12-inch silicon wafers [8]. This cost would be incurred even before the risk of customer acceptance of the product was considered. Adding up the manufacturing and subsequent marketing costs of any new product introduction only underscores the critical importance of preliminary market research.

As critical as research is, however, time pressure and lack of experience or prototypes makes it difficult to obtain information about potential market demand for a radically new product (and about the prices consumers are willing to pay). First, radically new products often have stringent timelines and shorter life-cycles. This means that it is not feasible to do a thorough long-term market analysis (or equivalently, customer measurement) before initiating production. In the home PC industry, for example, a best-selling high-performance computer will turn into a slow machine that almost no one wants a mere two or three years after its debut. Computer vendors have little time to understand the market after the new components are available and before the new computer appears on retail shelves. In consequence, erroneous decisions about new products due to lack of adequate market research are not rare, even for Dell Computer Corporation, which is famous for understanding consumers. Commenting on the failed "Olympic" plan, Michael Dell once said, "If we had consulted our customers first about what they needed—as we had been accustomed to doing—we could have saved ourselves a lot of time and aggravation" [7].

Second, by definition, consumers have little experience with a radically new product before it is introduced [15, 17]. Thus, any data collected before a prototype of the product is available have a high level of uncertainty, and this means that there is a possibility of major errors in estimating the market demand. In the extreme case, there is no basis whatsoever for an estimate. Before the first Walkman was available, it would have been hard for consumers to describe the pleasure of hiking along a river with music, since they had never had the experience. Examples of new products whose market prospects are difficult to estimate because they are totally new can be found in many industries. In the computer industry, consider the first Palm Pilot, in the toy industry, the recent debut of robot dog AIBO from SONY, in the health industry, the revolutionary LASIK surgery for vision correction.

Traditional customer-measurement theories emphasize the importance of adequately understanding consumer tastes before initiating a new product. However, in recent years traditional customer-measurement theories have largely been abandoned [12]. Akio Morita, the founder of the very successful SONY Corporation, said, “Our plan is to lead the public to new products rather than ask them what they want. The public does not know what is possible, but we do” [24]. Decades of inventions keep proving the wisdom of SONY’s founder. The Walkman was a surprise in size, PlayStation2 was a surprise in graphical performance, and most recently, robot pet AIBO was a surprise in respect to how intelligent a toy can be. All of these products were invented to create a new market rather than to satisfy an existing one, illustrating the difficulty of marketing research for a non-existent market.

The problem of unfamiliarity is largely solved if there is a *prototype* of the product that consumers can try out [18]. Since their experiences with the prototype will resemble what would happen with the final product, marketing research based on their reactions yields more accurate information. As commonly defined in industry, a prototype need not be exactly the same as the product or even a preliminary version of it. Nowadays a prototype of a product need not even be a physical prototype. It may be a piece of simulator software with a similar look and functions that consumers can download from the Internet. You can play with a 3D simulation of robot dog AIBO on the SONY Website at www.us.aibo.com / 3d / index.html to get an idea of whether or not you like it. Or go to phone.com to download UP.SDK at developer .phone.com / dev / ts / to try a simulator on the computer screen that feels and functions exactly the same as a physical digital mobile phone. The power of a software simulator of a physical product is that consumers all over the world can try it as soon as the prototype Web-site is set up, at relatively little cost to the producer. In the case of a digital movie or other digital product, the prototype can be a segment of the movie (or better yet, a short trailer) or a reduced-quality version.

Once a prototype strategy is adopted, the next challenge, in the case of radically new products, is the comparatively stringent timeline for customer measurement. The time available for customer measurement is the interval between the debut of the prototype and the beginning of mass production, which must be as short as possible in light of the pressure from a continually changing market. Traditional marketing-research methods often take too long, and consequently are avoided [12]. As an alternative, marketing research is shifting attention to the Internet as a rapid way of doing customer measurement [18, 21]. The Internet and related data-analysis technologies enable nearly instantaneous multimedia contact with a geographically more diverse range of consumers.

Even if abundant market information can be collected promptly for a radically new product, there is a more fundamental question: *Do the market data reflect market demand?* This problem is pervasive in marketing research. For example, the Coca-Cola Company introduced New Coke in 1985 after years of intensive market analysis. New Coke was never as popular as the market data had suggested. The mismatch between collected market data and true market demand is potentially more severe in the digital economy than in the traditional economy because the digital economy faces a greater trust problem. According to the Internet Fraud Watch operated by the National Consumers League, "online auction sales remained the number one Internet fraud for 1999, increasing from 68 percent of frauds reported to the Internet Fraud Watch in 1998 to an overwhelming 87 percent in 1999" [9]. This indicates that people tend to feel more comfortable cheating a producer (or retailer) if they can hide behind a computer screen. Research in customer measurement has largely ignored this problem, taking the accuracy of the collected market data as a given.

The discussion in this paper will treat the mismatch between collected market data and true market demand in the specific context of new product introduction. It suggests that use of a full-revelation mechanism is a crucial requirement for effective marketing research [13, chap. 14]. In a producer-consumer relationship, any mechanism that induces consumers to believe that telling the truth is beneficial for them is called a full-revelation mechanism. Two facts are relevant here. First, if consumers are putting their money where their mouth is, as they do in an auction, then their stated values can be trusted. Second, if consumers know a company's reaction to collected market data, they may try to provide data that will induce behavior from the company that is beneficial to themselves. This phenomenon is explored below, and a solution based on a two-round auction design is outlined.

The Full-Revelation Problem in Marketing Research

The crux of the marketing research problem associated with new-product introduction is the question of whether the collected market data reflect actual market demand. To simplify the discussion, it is assumed here that a prototype of the product is accessible before the market data are collected, so that potential consumers are able to form a reasonable valuation of it. Even when this is the case, the answer to the question is often no. Data collected from potential customers may be biased and erroneous even if they understand the new product, quite simply because what customers say may be very different from what they intend.

One behavioral explanation is that people react differently when asked to *evaluate* something and when asked to *pick* something. Consider the choice between using interactive television for education and for watching movies [12]. When asked, people regularly said that they would choose education. However, once they began using the interactive TV, they regularly switched to watching movies. Thus, producing educational programming with an audience-size estimate based on the number of interactive TVs sold and the percentage of buyers who claimed that they would use them for learning might result in a disaster.

One explanation for this phenomenon is the observation that people want to present themselves as conscientious and serious.[1] More generally, they may answer one way if asked a question that has no consequences, but another way when faced with actual choices. Although marketing researchers have to assess the answers consumers give when faced with a decision, they cannot assume that there is a direct link between answers to survey questions and subsequent purchases or actions.

In economics, this is called a *full-revelation problem* [13, chap. 14]. In the context of producer-consumer relationships, it states that if a producer asks for information, consumers will provide whatever information yields the most benefit for them. The full-revelation problem here is how to get consumers to believe that telling the truth is the most beneficial option. In the interactive television example, with no financial value to be considered, consumers often feel more comfortable representing the perspective of a conscientious citizen rather than an average consumer.

A marketing research mechanism is said to be a *full-revelation mechanism* if consumers believe that revealing the truth (i.e., their true valuation of the product if they are making a buy-or-not decision) is the most beneficial choice. In the context of radically new product introduction, this can be actuated in a two-round auction setting where real money is paid for real consumption. Since production levels in a second-round auction are determined by the intensity of the first-round bidding, it is necessary to take account of the fact that people may try to influence the outcome. For example, reporting extreme willingness to pay may result in a glutted market and low prices.

Asking consumers for their valuations and then producing according to this estimated demand is not a full-revelation mechanism. Furthermore, as mentioned earlier, the mismatch between stated intentions and reality tends to be more severe if customer measurement is done on-line rather than in person, as there is less trust in on-line businesses than in physical businesses. That is why designing the customer-measurement process as a full-revelation mechanism is a crucial step in preventing mismatches. The full-revelation mechanism is not only theoretically useful but practically workable, as will be shown in the discussion that follows.

Framework Design

The first premise of this new framework is that consumers tend to overstate their valuations if there is no risk in doing so. Since a survey entails no obligation, they can always decide to buy at a price different from the one they report. In an auction, however, a bid is a commitment. A second-price, sealed-bid (SPSB) auction offers the further advantage that the producer knows the entire distribution of bids and not just the winner's bid. Therefore, once consumers are familiar with the prototype, the first-round SPSB auction is designed to be an information-collection round. The purpose of this round is not to maximize profit but to collect market information. This process is based upon three assumptions:

1. The valuation of the prototype is consistent with the later valuation of the product.
2. Although the consumers experiencing the prototype and attending the auction are only a sample of the potential consumer population, they reflect the whole population in an unbiased way, so that market-demand information attained from them can be extended to the whole population.[2]
3. Each consumer wants at most one product.

For the sake of simplicity, it is assumed here that only one product is auctioned off in the first round, although the two-round auction process is still a full-revelation mechanism if more than one prototype is auctioned off in the first round. Since at this point a consumer can only see the prototype, which is often not the final product, the producer is actually auctioning off a commitment to a future product. The producer will ship the product to the first-round winner only after the second round is finished and will collect a payment from the winner when mass production begins. If the mass production is canceled, there is a separate compensation plan for the first-round winner that incurs a cost for the producer.

The second-round SPSB auction is the profit-maximization round.[3] The central decision for the producer is now x, that is, how many units to produce and sell in the auction.[4] In essence, the market information collected in the first round will be used to optimize the production decision. Intuitively, the optimal decision will be a quantity that yields a monopoly profit for the producer. There should be more bidders in the second round than in the first, for whereas the first round only represents a sample of the potential consumer population, in the second the producer tries to attract all potential consumers. However, it is assumed that the market information in both rounds is consistent, as stated in Assumption 2. After both rounds of the auction are finished, the winner of both rounds will get a product and pay a price equal to the highest losing bid in the second round. Out of fairness, the winner of the first round pays the same amount after the second- round auction, since he or she only gets the product after the second round.

Generally, consumers are smart enough to understand the purpose of the first-round auction. They also know that the producer will try to capture a monopoly profit in the second auction based on the collected market information. To make this point even more clear, the producer describes the entire process at the beginning, so that all the consumers are well aware of the second-round auction and the possible benefit to themselves if they attend.

An analysis of three questions will show why the two-round SPSB auction process is a full-revelation mechanism: (1) When the auction enters the second round, will bidders bid values other than their true valuations? (2) Will they bid less than their valuations in the first round? (3) Will they bid more than their valuations in the first round?

1. No. Since the second round is the final round, it turns into a standard SPSB auction, in which the famous result is that bidders will bid their

true valuations [25]. Intuitively, bidding less than one's valuation does not affect the price to be paid if one wins, but it will lower the chance of winning. Bidding more than one's valuation cannot result in a lower price on winning, and furthermore there is a risk of winning with a price higher than the valuation, resulting in a net loss to oneself.

2. No. By bidding less than your valuation, your chance of winning in the first round is lowered. In the event of biased bidding information, the auctioneer may produce less for the second round and the bidder's chance of winning in the second round is also lowered. However, the final price will not be lower, since everyone is telling the truth in the second round. So bidding less is not a rational choice for the bidder.
3. No. By bidding higher than one's valuation, one may win it in the first round while paying a price higher than the valuation. Intuitively, the only reason for bidding higher is to induce the producer to produce more, so that in the second round one has a better chance of getting a product. However this intuition is wrong: If the bidder can win the product in the second round by telling the truth in both rounds, bidding high in the first round affects nothing but puts the bidder at risk of winning a product in the first round at a price higher than the valuation, whereas if the bidder cannot win a product in the second round by telling the truth in both rounds, bidding high in the first round may induce the producer to produce more for the second round. However the benefit of extra production will always be enjoyed by other bidders, since one still cannot win a product in the second round.

Since no is the answer to all three questions, the optimal choice for all bidders is to bid their true valuations in both rounds. As a result, and as will be proved in the next section, the two-round SPSB auction process is a full-revelation mechanism from which the producer can collect unbiased market information through the bids in the first-round auction.

An On-line Auction-Based Radically New Product Introductory Framework

This section formally specifies an on-line auction-based radically new product introductory framework for collecting market information and optimizing production. The framework incorporates all the concepts developed in the preceding sections: the idea of a prototype, the use of the Internet for prompt market research, a two-round auction process that provides full revelation, and criteria for when this framework is beneficial for the ultimate purpose of marketing research: the pursuit of profit maximization.

The Framework

Figure 1 is an overview of the process. The framework consists of four stages: prototype production and test drive, the first-round SPSB auction (the infor-

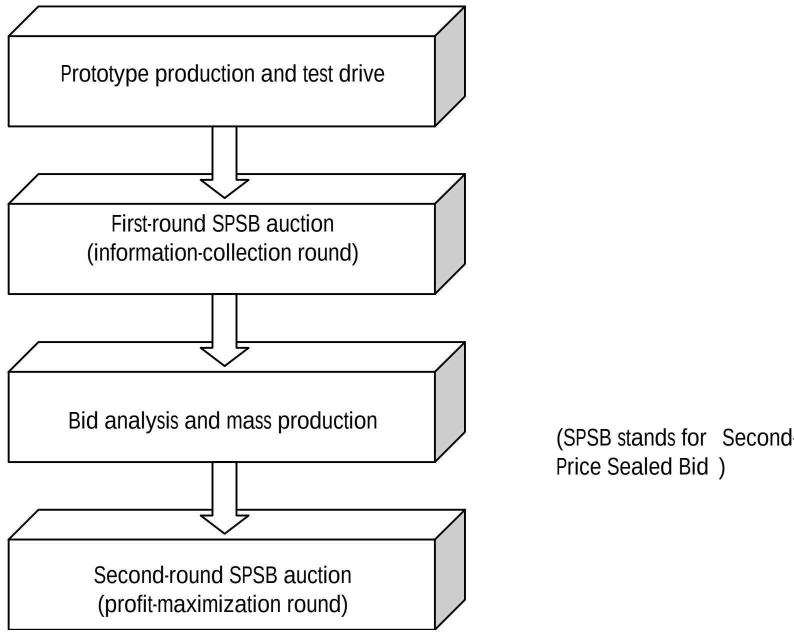

Figure 1. An Online Auction Based Radically New Product Introductory Framework

mation-collection round), bid analysis and mass production, and the second-round SPSB auction (the profit-maximization round). Stage 2 is the first-round SPSB auction, and Stage 4 is the second-round SPSB auction. Before the first stage, the auctioneer must describe the entire process so that both the auctioneer and the bidders know the sequence of events.

Stage 1: Prototype Production and Test Drive

The purpose of the prototype is to give consumers information about a radically new product. As discussed earlier, a prototype should provide a reasonable experience of the final product before the first-round SPSB auction. A digital prototype is preferred because it can be delivered directly to consumers' networked computers, reducing the time needed for customer measurement.

After they feel or try the prototype, consumers will have their own valuations of the new product. In this way, the demand curve of the sample consumers (and thus the whole market) will be determined, even though it is still unknown to the producer. To capture such an experience of a test drive, assume that all the consumers know their own valuations of the new product but know nothing about the other consumers' valuations.[5] On the other hand, the producer (i.e., the "auctioneer") still knows nothing about the bidders' valuations and the demand curve. All consumer valuations are independent of one other.

Formally, there are *J* potential consumers for the new product. *I* bidders are randomly drawn from the whole potential consumer population to participate in the first-round auction. A consumer participating in the first-round auction is called a first-round bidder, and a consumer participating in the second-round auction is called a second-round bidder. The number of first-round bidders, *I*, is large enough so that the sample reflects the demand curve of the whole potential consumer population. The ratio of the whole population to the sample population is k (= J / I). k is also large in that the sample population is only a small proportion of the whole potential consumer population. There is one auctioneer and one product to be introduced to the market. Each bidder wants, at most, one unit of the product. After experiencing the prototype, each first-round bidder forms a private valuation of the product, v_i, that is known to no one else and is independent of all other first-round-bidder valuations. Collectively the inverse market demand curve for this first-round auction is $p = p(x)$, where x is the quantity to be produced and sold, and p is the price at which x units will sell. By assumption, the whole market demand is consistent with this sample. Therefore, the inverse market demand curve for the second-round auction is $p = p_1(x) = p(x / k)$. Estimating $p_1(x)$ is the essence of marketing research for a new product.

> *Let V_1, V_2, …, V_I be the order statistics for v_1, v_2, …, v_I. That is, for each realization of v_1, v_2, …, v_I, the rearranged V_1, V_2, …, V_I are a reordering of these I realized values such that V_1 ³ V_2 ³ … ³ V_I. If the I consumers bid their true valuations, $p(x) = V_{x+1}$ is the inverse demand function. Since I is large, the inverse demand curve generated by $p(x) = V_{x+1}$ at points $x = 1, 2, …, I-1$ can be treated as a continuous function.*

Stage 2: First-Round SPSB Auction

In the first, or information-collection, round, the auctioneer announces that one product will be put on auction.[6] An on-line auction market is chosen to that will efficiently reach consumers in a large geographical range. Strictly speaking, it is only one prototype that is auctioned, with a commitment that the winner of the first-round auction will get a real product later. Suppose there is a fixed cost S_1 for the prototype. Although the winner is determined in the first round, the production and shipping of the single product is postponed until after the second round. Thus, the winner of the first round and the winners of the second round will get products and will make complete payments at the same time.

Stage 3: Bid Analysis and Mass Production

After the first-round auction, the producer gets the data of all the submitted bids, since this is a sealed-bid auction. If the bids reflect consumer valuations, as will soon be proved, the producer finds out $p = p(x) = V_{x+1}$ for the first-round bidders. Then from $p_1(x) = p(x / k)$ the producer can find out the inverse demand curve for the second round. Again these are based on the assumptions that I is large and the sample consistent with the entire potential buyer population.

Once the inverse demand curve $p(x)$ is available, the number of products to be produced in the mass production stage, kx, is determined by

$$\max_x \pi(x) = \max\{kx(p(x)\text{-}c) - S_2, \text{-}d\} \tag{1}$$

in which S_2 is the fixed cost of the mass production, and c is the constant marginal cost of the mass production. Option $-d$ means that the producer can cancel the mass production if it results in a negative profit, and a compensation of d is made to the winner of the first round. In the special case where the winner of the first round wishes to accept the prototype as a product (i.e. if the prototype is also a product), d can be a negative number, which means that the winner of the first round pays a price equal to the second-highest bid in the first-round auction.

Stage 4: Second-Round SPSB Auction

The second, or profit-maximization, round takes place only if the producer decides to go to mass production. In that case, the producer puts all the kx products into the auction and captures the monopoly profit.

Two Important Results of This Framework

Equation (1) can be rewritten as:

$$\max_x \pi(x) = k^*\max\{x(p(x)\text{-}c) - S_2/k, \text{-}d/k\} \tag{1b}$$

This indicates that the producer's profit-maximization problem in the second-round auction can be simplified by considering only I bidders with valuations as shown in the first-round auction, while multiplying the resulting profit by k to get the expected profit including all consumers in the second round. Such a simplification is viable on the assumption that I is large. Moreover, $-d/k \longrightarrow 0$ if k is large. Therefore, the compensation to the first-round auction winner can be ignored if the mass production is canceled. Thus (1b) is simplified to:

$$\max_x \pi(x) = k^*\max\{x(p(x)\text{-}c) - S_2/k, 0\} \tag{1c}$$

> *Proposition 1. The proposed on-line auction-based radically new product introductory framework is a full-revelation mechanism.*

Proposition 1 indicates that marketing researchers can expect the market information collected in the first- round auction to be unbiased.

The detailed proof for this proposition is shown in the appendix.

The unbiased, two-stage procedure of Proposition 1 will now be contrasted with the faster but riskier alternative of going directly to mass production. Assume that the producer faces a discount factor δ, $0 < \delta \leq 1$. Typically $\delta = 1/(1+R)$ where R is the per period interest rate. The special case $\delta = 1$ means that the values are not discounted between stages. Suppose the producer knows, from past experience and knowledge, that there are two possible linear demand situations: high demand, characterized by the demand curve $q = a - b_1 p$, and low demand, characterized by $q = a - b_2 p$. Here p is the price, q is market demand, and $b_2 > b_1 > 0$. Let $t = b_2 / b_1 > 1$. Suppose that the producer's experience indicates that the probability that demand is high is r, $0 < r < 1$. Since k is large, the first-round auction winner's impact on the producer's profit can be ignored. To avoid boundary solutions and simplify the analysis, it is assumed that marginal cost, c, satisfies $c < a/b_2$. For notational convenience, let $d = r\frac{1}{b_1} + (1-r)\frac{1}{b_2}$ so that $\frac{1}{b_1} > d > \frac{1}{b_2}$.

The assumption of two possible linear-demand situations captures the risk problem in radically new production introduction. The assumption that I is large allows the producer to use the bids collected in the first-round auction to distinguish which of the two possible situations is the true situation. Therefore using this model simplifies econometric issues.

It is also necessary to address the question of whether the two-stage auction approach improves profits in situations where going directly to market is profitable on average. First, note that if the true situation is known to be low, then the producer's maximum expected profit is $E\pi_L^* = \frac{1}{b_2}\left(\frac{a-cb_2}{2}\right)^2 - S_2$; if it is known to be high, it is $E\pi_H^* = \frac{1}{b_1}\left(\frac{a-cb_1}{2}\right)^2 - S_2$. Let $E\pi_M^*$ denote the producer's maximum expected profit by going directly to mass production, then $E\pi_M^* = >0$. Let $E\pi_N^*$ denote the producer's maximum expected profit by employing the proposed framework.

Proposition 2. If $E\pi_L^* > 0$, then the proposed on-line auction-based radically new product introductory framework increases the producer's expected profit if and only if $\delta(rE\pi_H^* + (1-r)E\pi_L^*) - S_1 > E\pi_M^*$, or equivalently, if and only if

$$\delta - \frac{c^2}{4d}(1-b_1 d)(b_2 d - 1) - (1-\delta)\frac{(ad-c)^2}{4d} - S_1 + (1-\delta)S_2 > 0 \qquad (2)$$

If $E\pi_L^* < 0 < E\pi_M^*$, under the proposed framework the producer will cancel the mass production if demand is low, and the proposed on-line auction-based radically new product introductory framework increases the producer's expected profit if and only if $\delta r E\pi_H^* - S_1 > E\pi_M^*$, or equivalently, if and only if

$$\delta r\frac{1}{b_1}\left(\frac{a-cb_1}{2}\right)^2 - \frac{(ad-c)^2}{4d} - S_1 + (1-\delta r)S_2 > 0 \qquad (3)$$

The detailed proof of this proposition is shown in the appendix.

Proposition 2 distinguishes two cases. The first case, in which $E\pi_L^* > 0$, implies that mass production deserves to be carried out in both low- and high-demand situations, and the advantage of the proposed framework is only the optimization of the amount of production. The second case, in which $E\pi_L^* < 0 < E\pi_H^*$, implies that if the demand is low, then under the proposed framework the producer will cancel the mass production, since the fixed cost of the mass production is too high. Therefore, the expected profit is increased in the proposed framework not only because of optimal production, but also because of the decision to cancel the mass production under low demand.

Taking partial derivatives in (2) or (3) gives the following direct implications of Proposition 2.

> *Corollary 3. The proposed on-line auction-based radically new product introductory framework is more attractive, i.e.,* $E\pi_N^* - E\pi_M^*$ *increases, as*

1. The discount factor, δ, increases
2. The fixed cost of the mass production, S_2, increases
3. The marginal cost of the mass production, c, increases
4. The difference between high- and low-demand situations, captured by the ratio b_2 / b_1, increases
5. The fixed cost for the prototype and the first-round SPSB auction, S_1, decreases

Below are some examples that illustrate the intuition of Corollary 3.

First of all, the discount factor δ captures the time value. The faster the marketing research is done, the less loss of time value in the proposed framework. For markets where technology is undergoing fast development, which is often the case for radically new products, speeding up marketing research to capture time value is crucial. Digital cameras are good examples. At the start of 2000, 1 mega pixel models were popular choices, with prices usually more than $500. By the end of 2000, they had been pushed off the popular list by 2–3 mega pixel models. Furthermore, their prices had dropped to less than $300, which is a 40 percent–plus drop in less than one year [10, 22].

Second, the fixed-cost component is especially high in high-tech industries where vast investments are needed to build facilities. As an example, recall that that Intel spent more than $1.5 billion to establish a factory for complex computer chips on 12-inch silicon wafers. The proposed framework, as stated in Proposition 2, helps to avoid the mass production investment in low-demand situations.

The third part of Corollary 3 implies that the proposed framework is more favorable if the product is expensive to produce. Intuitively, companies producing digital products do not concern themselves with over producing if the marginal cost is very low. However, for physical products, overproducing is a major financial burden.

The next part of Corollary 3 states that when the ratio b_2 / b_1 is large, betting on the high-demand situation can result in a big loss if the truth is a low-demand situation. AT&T's videophone is an example. Sheldon Hochheiser, AT&T's corporate historian, concluded that the videophone is "the most famous failure in the history of the Bell system" [16]. AT&T tried to promote the videophone twice, in 1970 and 1990, but failed both times. Bell Labs understandably thought that the market demand for the videophone would be similar to that for the telephone; but the market treated videophone and telephone totally differently.

Finally, the fixed cost for the prototype and the first-round SPSB auction in the proposed framework is the overhead for marketing research. The auction cost is lowered by using existing electronic markets. The cost of the prototype can be reduced by digitizing it, that is, providing consumers with a digital simulator. For example, to promote a digital mobile phone, it is cheaper to let consumers try phone-simulation software (e.g., the one available at www.phone.com) than to build a real device.

Conclusion

The framework presented in this article addresses the issues of accuracy and timeliness in marketing research for radically new products.

In the case of new product introduction, marketers challenge the effectiveness of traditional customer-measurement theories by asking whether consumers know what they want. Mahajan and Wind use an analogy to a doctor's office [12]. Doctors do not normally expect patients to know what medicine they need. By diagnosing the patient's symptoms, the doctor gradually identifies the illness. New product introduction is exactly the same: Consumers cannot be expected to have a stable feeling and thus a firm opinion of a radically new product when they are not sure what the final product will be and what the experience will be.

However, earlier theories ignored the important question of accuracy. Even if consumers have access to a prototype, the customer measurement may still be ineffective, even erroneous, because the consumers may provide biased data. The term "biased data" here means that from the producer's perspective, the data are not consistent with consumers' later shopping behaviors. The phenomenon of biased market information can occur even if consumers know about the new product, and this fact should dispel the common misunderstanding that ill-informed or inconsistent consumers are the source of biased data.

The discussion in the preceding sections explains that the void in marketing research is a full-revelation problem. It describes how the problem arises in radically new product introduction, and proposes a two-round auction-based process as a solution.

Another critical issue in marketing research is timeliness. New products are riskier than established products. One approach to reducing the risk is to sample the reaction of a small group of consumers to a prototype before going to mass production. However, the nature of radically new products requires that the test period be as short as possible. Thus, as a second contribution, this article proposes a complete framework for radically new product introduction that is designed to do effective and speedy marketing research. The framework is enabled by the Internet, electronic markets, and advanced data-processing technology.

First, using a prototype allows for the collection of richer market information. In the case of digital products (e.g., software, music, e-books), customer measurement can be done rapidly once an interested on-line shopper clicks on the product image. Second, the use of an electronic auction market enables the collection of unbiased price information. Such price information is significant because consumers are making real decisions. Third, Internet data collection is fast. If the product is a digital one, then the test drive can also be done quickly. For physical products, the data-collection period is speeded up by the Internet. Moreover, the test drive of a physical product may be done digitally if the prototype is a digital simulation of the physical product. Any one interested in a digital mobile phone can log onto developer.phone. com/ dev/ts/ and download UP.SDK to try a simulator on the computer screen that feels and functions exactly the same as a physical digital mobile phone.

Theoretical and empirical research in this area will continue in the future. This paper only deals with radically new product introduction, but the full-revelation problem is pervasive in many areas of marketing research whenever the incentive of consumers is at odds with the incentive of the marketing researcher. Future research can explore other domains in marketing research where constructing a full-revelation mechanism may require more effort and different approaches than in the case of new product introduction.

The framework presented here will yield more profits for companies pursuing radically new product strategies under the conditions of Proposition 2. Empirical research is expected once comparisons based on industry data are available.

Other questions remain open to further research as well. As shown above, auctioning off one or more units of a product will not affect either the full-revelation mechanism or the producer's profit if k and I are known. However, it is intuitively known that by auctioning off more products in the first round, the producer may attract more potential bidders to participate in the first round, and thus k and I could be influenced by the decision for the first-round auction. The relation between the number of products auctioned off in the first round and the proportion of the potential consumer population that will be attracted by the first-round auction remains an open question.

There may also be other alternatives to the format of Stage 4, designed here as an SPSB auction. The reason an SPSB auction was chosen for Stage 4 is that it stimulates bidders to bid their true valuations. Using backward induction, it can be proved in Proposition 1 that bidders will also bid their true valuations. For other market mechanism, the proof, if any, will not be that straightforward. However, two facts are important here: First, the Revenue Equivalence Theorem in auction theory [13, p. 889; 25] implies that there are alternative auction mechanisms first-price, sealed-bid, English, Dutch) that yield the same profit for the producer as an SPSB auction. Second, if the producer knows the demand curve, and the consumer population is large enough to be treated as a continuous variable, putting a monopoly-level quantity of products for sale in an SPSB auction is equivalent to producing a monopoly-level quantity of products and selling them in a retail market at the monopoly price, in the sense that both yield the monopoly profit for the producer. Therefore, a retail mechanism, as a non-auction mechanism, is a possible alternative in the second round. Further research is necessary to see whether these alternatives also represent full-revelation mechanisms.

In addition, determining *k* (the ratio between the size of the whole potential consumer population and the number of consumers who have come to the first-round auction) can also be done empirically. More research is needed to understand how to estimate *k* more accurately.

And finally, the new product introductory framework presented here is not used to reduce the financial risk in research and development, which is endogenous for a radically new product strategy. However, the same philosophy applies if the R&D process has multiple stages. Market data collected upon the interim outcome of R&D can be used during the R&D process.

Appendix

Proof of Proposition 1:

The proof is presented in two parts.

(1) In the Second Round

There are kI-1 bidders in the second round, with valuations $v_1, v_2, \ldots, v_{kI-1}$. Let $V_1, V_2, \ldots, V_{KI-1}$ denote the ordered statistics of $v_1, v_2, \ldots, v_{kI-1}$ such that $V_1 \geq V_2 \geq \ldots \geq V_{KI-1}$. Suppose that the auctioneer puts x units of the product on auction, $1 \leq x \leq kI-2$. Then the first x highest bidders will each win a product. Consider bidder i with valuation v_i and bid b_i. Suppose all the other bidders are bidding their true valuations in the second round, that is, $b_{j = vj}$ for all $j \neq i$. The trivial case where $V_x = V_{x+1}$ is ignored. Assuming that the density function for the distribution of V_{x+1} is $_{gx+1}(v)$, the density function for the distribution of V_x given V_{x+1} is $g_{x\,|\,x+1}(v)$.

If $b_i \geq v_i$, then bidder i's expected net payoff is

$$u_i(b_i) = \int_0^{v_i} (v_i - v) g_{x+1}(v) dv + \int_{v_i}^{b_i} [\int_v^{b_i} (v_i - w) g_{x|x+1}(w) dw] g_{x+1}(v) dv$$

$$\text{Thus } \frac{du_i(b_i)}{db_i} = (v_i - b_i) g_{x|x+1}(b_i) \int_{v_i}^{b_i} g_{x+1}(v) dv < 0$$

If $b_i \leq v_i$, then bidder i's expected net payoff is

$$u_i(b_i) = \int_0^{b_i} (v_i - v) g_{x+1}(v) dv$$

$$\text{Thus } = > 0 \quad \frac{du_i(b_i)}{db_i} \quad (v_i - b_i) g_{x+1}(b_i) > 0$$

Therefore, the optimal bid for bidder *i* is $b_i = v_i$. Thus, in the second round all the bidders will bid their true valuations.

(2) In the First Round

Consider bidder *i* with valuation v_i and bid b_i. Suppose all the other bidders are bidding their true valuations in the first round, that is, $b_j = v_j$ for all $j \neq i$. Further suppose that if all the bidders are bidding their true valuations, the producer's production will be kx^* following (1c).

Since the first round is also an SPSB auction (but now with only one product), bidder *i* cannot get any benefit in the first round by deviating from the true valuation. Concerning the second round, bidder *i* may benefit from overbidding if the producer is induced to produce more than kx^* units for the second-round auction.

Suppose bidder *i* overbids, and suppose the producer is induced to produce $kx > kx^*$ units of product. There are two situations in which bidder *i* may get more benefit compared with telling the truth.

Situation 1. Bidder *i* is able to win a product by telling the truth, thus $I \leq x^*$. By overbidding, bidder *i* wishes to induce more products in the second round and thus lower the price. However, since V_{x^*+1} through V_I is not affected by bidder *i*'s overbidding, $kx > kx^*$ is impossible.

Situation 2. Bidder i is not able to win a product by telling the truth, thus $i > x^*$. By overbidding, bidder i wishes to induce more products in the second round and thus win a product at a lowered price, that is, $x > i$. However, the only chance that the producer may increase the production is if setting the price at b_i is more profitable, since other than b_i's increase nothing else is changed. In this scenario bidder i still cannot win the product, thus $x > i$ is impossible.

Therefore, both of the above situations are impossible.

The best strategy for bidder *i* is to tell the true valuations in both rounds. Since *I* is an arbitrary choice, the proposed on-line auction-based radically new product introductory framework is a full-revelation mechanism.

Q.E.D.

Proof of Proposition 2:

For convenience we first derive the following results. Suppose the producer knows the true demand curve.

If the true situation is a high demand, and the producer chooses to produce q_{21} *products, the profit is:*

$$E\pi_H = q_H \frac{1}{b_1} (a - q_H) - c) - S_2$$

Thus $q_H^* = \dfrac{a - cb_1}{2}$, and $E\pi_H^* \ \dfrac{1}{b_1} \left(\dfrac{a - cb_1}{2}\right)^2 - S2$, where asterisks

denote optimal solutions.

If the true situation is a low demand, and the producer chooses to produce q_{22} products, the profit is:

$$E\pi_L = q_L(\frac{1}{b_2}(a-q_L)-c)-S_2$$

Thus $q_L^* = \frac{a-cb_2}{2}$, and $E\pi_L^* = \frac{1}{b_2}(\frac{a-cb_2}{2})^2 - S_2$.

$a/c > b_2 > b_1 \Rightarrow q_H^* > q_L^*$, and $E\pi_H^* > E\pi_L^*$. Thus, if the producer knows the true situation, the high-demand situation will result in more production and more profit.

Now we go back to the question in Proposition 2. Since $E\pi_M^* > 0$, then $E\pi_H^* > 0$. If the producer chooses option 1 (i.e., goes directly to mass production) and chooses to produce q_M products, the expected profit is:

$$E\pi_M = r[q_M\frac{1}{b_1}(a-q_M)-c)-S_2] + (1-r)[q_M\frac{1}{b_2}(a-q_M)-c)-S_2]$$

Thus the optimal quantity is $q_M^* = \frac{a}{2}-\frac{c}{2d}$, in which $d = \frac{r}{b_1}+\frac{1-r}{b_2} = \frac{1}{b_1}[r+(1-r)/t]$.

$$E\pi_M^* = -S_2 + adq_M^* - cq_M^* - dq_M^{*2}$$

$$= -S_2 + \frac{(ad-c)^2}{4d}$$, in which $ad-c>0$.

Consider the following three situations:

(1) If $(\frac{a}{2}-\frac{c}{2d})(\frac{1}{b}(\frac{a}{2}+\frac{c}{2d})-c) \geq S_2$

Then, whether the true market demand is low or high, the producer can always get non-negative profit by mass production under choice 1.

A producer who chooses option 2, that is, employs the proposed framework, will incur a cost of S_1 for the prototype and the arrangement for the first-round auction. From Proposition 1 it is known that the bids in the first round are not biased and reflect the true market demand. Since I is large, the producer will find out the true situation from the data,[7] and can produce accordingly. Note that $0 \leq (\frac{a}{2}-\frac{c}{2d})(\frac{1}{b}(\frac{a}{2}+\frac{c}{2d})-c) - S_2 < \frac{1}{b_2}(\frac{a-cb_2}{2})^2 - S_2 = E\pi_L^*$, thus by following choice 2, the producer will go to mass production under both low demand and high demand.

Then the producer's expected profit is:

$$E\pi_N^* = \delta[rE\pi_H^* + (1-r)E\pi_L^*] - S_1$$

$$= -S_1 - \delta S_2 + \delta[\frac{(ad-c)^2}{4d} + \frac{c^2}{4d}(1-b_1d)(b_2d-1)]$$

Note that $1-b_1d=(1-r)(1-\frac{b_1}{b_2})>0,\ b_2d-1=r\frac{b_2}{b_1}-\ 1)>0.$

$E\pi_N^* > E\pi_M^*$

$$\Leftrightarrow \delta\frac{c^2}{4d}(1-b_1d)(b_2d-1) - (1-\delta)\frac{(ad-c)^2}{4d} - S_1 + (1-\delta)S_2 > 0 \qquad \text{(a.1)}$$

(2) $(\frac{a}{2}-\frac{c}{2d})(\frac{1}{b}(\frac{a}{2}+\frac{c}{2d})-c) - S_2 < 0 \leq E\pi_L^*$

Then if the true market demand is low, the producer will get negative profits from mass production under choice 1.

However, if the producer follows choice 2, and then observes a low demand, the producer can change the supply from q_M^* to q_L^*, and still get a non-negative profit from mass production. Therefore, the producer will still go to mass production under both low and high demand. The criterion is not changed:

$E\pi_N^* > E\pi_M^*$

$$\Leftrightarrow \delta\frac{c^2}{4d}(1-b_1d)(b_2d-1) - (1-\delta)\frac{(ad-c)^2}{4d} - S_1 + (1-\delta)S_2 > 0 \qquad \text{(a.1)}$$

(3) If $E\pi_L^* < S_2 < E\pi_M^*$

If the true market demand is low, not only the producer will get a negative profit from mass production under choice 1, but it also cannot get a positive profit by shifting the supply from q_M^* to the optimal supply q_L^* under choice 2 (i.e., $E\pi_L^* < 0$). Thus the producer will cancel the mass production if it observes a low market demand. The expected profit is then:

$$E\pi_N^* = \delta rE\pi_H^* - S_1$$

$$= -S_1 - \delta rS_2 + \delta r\frac{1}{b_1}(\frac{a-cb_1}{2})^2$$

$E\pi_N^* > E\pi_M^*$

$$<=> -S_1 + (1-\delta r)S_2 + \delta r \frac{1}{b_1}\left(\frac{a-cb_1}{2}\right)^2 - \frac{(ad-c)^2}{4d} > 0 \quad \text{(a.2)}$$

Note that $E\pi_N^* = \delta r E\pi_H^* - S_1 > \delta[rE\pi_H^* + (1-r)E\pi_L^*] - S_1 > E\pi_M^*$ if (a.1) is true, thus (a.1) => (a.2). This implies that (a.2) is a stronger condition than (a.1).

Q.E.D.

NOTES

1. There are other behavioral explanations as well. For example, Shiv and Fedorikhin speculate on the confliction of a human being's heart and mind in making decisions [19]. This paper focuses on situations where monetary consequences dominate the decision-making process.

2. The problem of extending information about a sample to a whole population is heavily studied in econometrics. This paper uses the econometric fact that if an unbiased sample is large enough, it can represent the whole population with little error. For simplicity it is assumed that the demand curve obtained from the sample is the same as the demand curve of the whole population.

3. Strictly speaking it is an $x + 1$ price sealed-bid auction, since if x products are being sold, the final price will be the $x + 1$'th highest bid. This is still an SPSB auction because it is simply a generalization of the one-product case. Also, if the consumers in the first round are only a sample of the consumers in the second round, x should be replaced by kx, where k is the ratio of the numbers of consumers in the two rounds.

4. Actually $x + 1$ products need to be produced, because one will be shipped to the winner of the first round.

5. From now on "consumer" and "bidder" will be used interchangeably, as the consumer will participate in auctions.

6. The truthful-revelation mechanism still holds if the auctioneer sells more than one product in the first round. Moreover, selling more products in the first round may attract greater participation by consumers.

7. There is always a possibility that the producer cannot recognize the true demand by the I sample points. However if I is large, this possibility is very small. Without loss of generality, it is assumed to be 0.

REFERENCES

1. Barabba, V.P., and Zaltman G. *Hearing the Voice of the Market: Competitive Advantage Through Creative Use of Market Information*. Boston: Harvard Business School Press, 1991.

2. Cisco Systems and University of Texas. Measuring the Internet Economy. www.internetindicators.com / june_full_report.PDF.

3. Cooper, L.G. Strategic marketing planning for radically new products. *Journal of Marketing, 64*, 1 (January 2000), 1–16.

4. Courtney, H.; Kirkland, J.; and Viguerie, P. Strategy under uncertainty. *Harvard Business Review*, *75* (November / December 1997), 67–79.

5. Cusumano, M.A.; Mylonadis, Y.; and Rosenbloom, R.S. Strategic maneuvering and mass-market dynamics: The triumph of VHS over Beta. *Business History Review*, 66 (spring 1992), 51–94.

6. Datar, S.; Jordan, C.C.; Kekre, S.; Rajiv, S.; and Srinivasan, K. Advantages

of time-based new product development in a fast-cycle industry. *Journal of Marketing Research*, *34* (February 1997), 36–49.
7. Dell M., and Fredman, C. *Direct from Dell*. New York: Harper Business, 1999.
8. Intel. Intel Breaks Ground on Its First 300mm Chip Development Plant. www.intel.com / pressroom / archive / releases / CN21898B.HTM.
9. Internet Fraud Watch. National Consumers League Warns Consumers Millions Are Lost to Internet Fraud. www.fraud.org / internet / 99final.htm.
10. Jones, M. New Year's resolutions. *PC World* (January 2000), www.pcworld.com / reviews / article.asp?aid=13916.
11. Lambert, D., and Slater, S.F. Perspective: First, fast, and on time: The path to success. Or is it? *Journal of Product Innovation Management*, *16*, 5 (September 1999), 427–438.
12. Mahajan, V., and Wind, J. Rx for marketing research. *Marketing Research*, *11* (fall 1999), 6–13.
13. Mas-Colell, A.; Whinston, M.D.; and Green, J.R. *Microeconomic Theory*. New York: Oxford University Press, 1995.
14. McAfee, R.P., and McMillan, J. Auctions and bidding. *Journal of Economic Literature*, *25* (June 1987), 699–738.
15. Mullins, J.W., and Sutherland, D.J. New product development in rapidly changing markets: An exploratory study. *Journal of Product Innovation Management*, *15*, 3 (May 1998), 224–236.
16. Videophone: Always in the wings. *New York Times*, April 24, 2000. www.sptimes.com / News / 042400 / Technology / Videophone__Always_in.shtml.
17. O'Connor, G.C. Market learning and radical innovation: A cross case comparison of eight radical innovation projects. *Journal of Product Innovation Management*, *15*, 2 (March 1998), 151–166.
18. Ozer, M. A survey of new product evaluation models. *Journal of Product Innovation Management*, *16*, 1 (January 1999), 77–94.
19. Shiv, B., and Fedorikhin, A. Heart and mind in conflict: The interplay of affect and cognition in consumer decision making. *Journal of Consumer Research*, *26* (December 1999), 278–292.
20. Smith, P.G. From experience: Reaping benefit from speed to market. *Journal of Product Innovation Management*, *16*, 3 (May 1999), 222–230.
21. Stewart, B. Multimedia marketing research. *Marketing Research*, *11* (fall 1999), 15–18.
22. Thornton, C. Sharp shooters. *PC World* (December 2000), www.pcworld.com / reviews / article.asp?aid=32521.
23. Urban, G.L., and Hauser, J.R. *Design and Marketing of New Products*. Englewood Cliffs, NJ: Prentice Hall, 1980.
24. Urban, G.L., and Hauser, J.R. *Design and Marketing of New Products*, 2d ed. Englewood Cliffs, NJ: Prentice Hall, 1993.
25. Vickrey, W. Counterspeculation, auctions, and competitive sealed tenders. *Journal of Finance*, *16*, 1 (March 1961), 8–37.

XIANJUN GENG (gengxj@mail.utexas.edu) is a doctoral student in the department of management science and information systems at the Graduate School of Business, University of Texas at Austin, and a research associate at the Center for Research in Electronic Commerce. His research focuses on the impact of emerging technologies on the digital economy. He is also interested in the use of economic principles to analyze competition and marketing issues in electronic commerce.

MAXWELL STINCHCOMBE (maxwell@eco.utexas.edu) received his Ph.D. in economics in 1986 and his M.A. in statistics in 1984, both from the University of California at Berkeley. He has published numerous articles in mathematical economics, game theory, econometrics, mathematics, and the theory of artificial neural networks, and was recently honored as an ISI Thomson Scientific Highly Cited researcher for his work on neural networks. His present research is concentrated on the use of a branch of mathematics known as nonstandard analysis in game theory, and infinite dimensional genericity analyses of statistical estimators and testing procedures. He has held positions as assistant and associate professor of economics at the University of California at San Diego, and associate and full professor of economics at the University of Texas at Austin, where he currently holds a joint appointment with the finance department and is the McCarty Centennial Professor.

ANDREW WHINSTON (abw@uts.cc.utexas.edu; crec.bus.utexas.edu) holds the Hugh Cullen chair of information systems, computer science, and economics at the University of Texas at Austin. He obtained his Ph.D. from Carnegie-Mellon University in 1962 and subsequently held academic posts at the University of Texas at Austin, Purdue University, the University of Virginia, Yale University, and the University of California, Los Angeles. He was awarded the Ford Foundation Faculty Research Fellowship in 1966. Dr. Whinston's research has explored artificial intelligence, e-commerce, information systems, and the New Economy. He is editor-in-chief of *Decision Support Systems*, a member of the editorial board of *Annals of Mathematics* and *Artificial Intelligence*, and editor-in-chief of the *Journal of Organizational Computing and Electronic Commerce*. He is also the director of the Center for Research in Electronic Commerce.