The Internet as an Enabler for Dynamic Pricing of Goods

Vaidyanathan Jayaraman and Tim Baker

***Abstract*—The Internet offers the potential for dynamic pricing for a wide range of products across the supply chain. Dynamic pricing can be formally defined as the buying and selling of goods in markets where prices move quickly in response to supply and demand fluctuations. Unlike physical markets where change occurs slowly because of information delays, change occurs very rapidly on the Internet. In the marketplace, the Internet is a powerful tool for almost instantaneous consumer feedback. For example, prices can be changed dynamically to meet demand because the cost of changing a price may be lower on the Internet than in physical markets. The success of dynamic pricing is helping in the growth of new businesses, including broad-based e-commerce portals new interactive networks. This paper has several objectives. The first objective is to look at factors that affected the use of dynamic pricing in the past. The second objective is to summarize the notion of dynamic pricing over the Internet. The third objective is to examine the different methods for collecting dynamic demand data over the Internet. The final objective is to present two models to optimize the revenue obtained for build-to-forecast and build-to-order environments.**

***Index Terms*—Dynamic pricing, e-commerce, Internet, mathematical programming.**

I. Introduction

THE INTERNET offers the potential for dynamic pricing for a wide range of products across the supply chain. One of the important contributions of the Internet to retail and manufacturing industries is the ability to dynamically change pricing. Dynamic pricing strategies have been successfully applied to a variety of industries including airlines, hotels, and rental car agencies. Dynamic pricing is best suited for products that are clearly specified or widely understood, that are either perishable (e.g., consumables) or time-sensitive (e.g., hotel room) or have a depreciating value (e.g., computer components, automotive parts). This paper considers the increased applicability of dynamic pricing in an Internet-enabled environment to different classes of products, the associated pricing strategy, and the collection of dynamic pricing data. This paper has several objectives. The first objective is to look at factors that affected the use of dynamic pricing in the past. The second objective is to summarize the notion of dynamic pricing over the Internet. The third objective is to examine the different methods for collecting dynamic demand data over the Internet. The final objective is to present two models to optimize the revenue obtained for build-to-forecast and build-to-order environments.

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V. Jayaraman is with the Department of Management, School of Business Administration, University of Miami, Coral Gables FL 33124 USA (e-mail: vaidy@miami.edu).

T. Baker is with the Department of Management and Decision Sciences, Washington State University, Richland, WA 99352 USA (e-mail: bakert@tricity.wsu.edu).

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In recent years, a number of industries have used flexible pricing strategies to manage their perishable inventory efficiently. These methods are referred to as revenue management. A number of characteristics are common to all of these applications of dynamic pricing (see [23] and [33]). These characteristics include the following:

1) existence of perishable products;
2) system that has fixed capacity;
3) market that can be segmented, based, for instance, on sensitivity to price or service time.

For example, in the retail industry, seasonal fashion items have seen the application of price differentiation policies and coordination of inventory control under the name "yield management." Gallego and van Ryzin [19] analyzed the dynamic adjustment of price as a function of inventory and length of remaining sales—for the case of products with stochastic demand. Bitran and Mondschein [3] also consider price as a function of inventory and time for hotel applications. In their model, pricing is implicit—from a large set of price points, a subset of price points is opened for sale in a dynamic fashion.

Dynamic pricing systems have been used for a number of years by airlines and other industries to maximize the revenue of perishable goods. However, the use of dynamic pricing to sell nonperishable products is new. These pricing decisions are made by the thousands every day. A decision point occurs anytime there is a customer interaction of any type and is of great interest in dynamic pricing systems. Through the use of this information the three major reasons for imbalances between supply and demand—price inflexibility, demand uncertainty, and production lags—can be minimized or even eliminated [36].

Alternative pricing strategies are being applied to goods and services sold over the Internet. In many cases, what is new is not the pricing strategy but the novel application of the pricing strategy to certain product categories. Internet-based auctions serve as a good example for commodity supplies and other specialized goods, but the Internet increases the ease and efficiency of applying auctions to other goods such as electronics and apparel. Similarly, products that are sold at posted prices in traditional channels, with price changes occurring weekly or longer, can now be sold over the Internet at posted prices that changes rapidly reflecting demand and the competition from other website-based vendors. As a result of these trends, the pricing of products and services sold over the Internet channel is becoming ever more dynamic. The efficiency of forming markets on the Internet, the possibility of quickly adjusting prices, and the effectiveness in measuring demand and tracking competitive prices have all contributed to the emergence of dynamic pricing strategies on the Internet.

II. Factors Affecting the Past Use of Dynamic Pricing

For consumer goods, dynamic pricing has occurred in the case of products such as hotel rooms and air travel, because these product classes:

1) *Cannot be stored*—A loss in potential revenue is incurred if any vacancies occur.
2) *Can be classed and priced differently*—The possibility of charging different people different rates either for the same product or different product configurations.
3) *Centralized order processing*—Sales for hotel chains are centralized for some while they are decentralized for others. But all information is available centrally. Consequently, it is possible to track differences in supply and demand for different product configurations at different prices. Hence, a single point of storage and access of information supports a dynamic pricing environment.
4) *High value differential between incremental revenue and incremental cost*—Incremental cost of the product, if it is used, is relatively low compared to the revenue generated. Consequently, profitability can be increased through changes in pricing that optimize the tradeoff between high utilization and high average rate per available asset.
5) *Temporary and sudden increases/decreases in demand*—The potential for periodic increases in revenue due to specific events creates the potential for increased profit through monitoring demand and changing price accordingly.

The advantage of dynamic pricing is that it allows for the management of a firm to vary prices, thereby increasing the difference between price and cost in comparison to firms that use a static pricing model. To demonstrate the benefit of dynamic pricing, we refer to microeconomic models of supply and demand [31]. This model (see Fig. 1) suggests that both demand and supply curves are constant and that the sale price and volume sold will be at the point where the supply and demand curves intersect, all other things being equal. However, in the case of airline seating and hotel rooms all other things are not equal. There is significant lead-time involved for increasing supply over a certain amount and the product cannot be stored. Consequently supply is relatively fixed (see Fig. 2). However, demand may change rapidly due to seasonal variation or specific events. As demand increases, the equilibrium price of the product increases and the price should increase. As demand declines, the equilibrium price of the product and the price charged should decline. In the airline and hotel industry, the ability to collect information over the Sabre system (airlines) and central reservation systems (hotels) identifying changes in demand allows for dynamic pricing. In a situation of perfect dynamic pricing by the seller, each unit of the product will sell at the highest price on offer by any buyer and then a sale will be made at the next highest price that any remaining buyers are willing to offer. This will continue until all products are sold (see Fig. 3). Having offered an overview of the advantages of dynamic pricing, the effect of the Internet on pricing strategy is now considered.

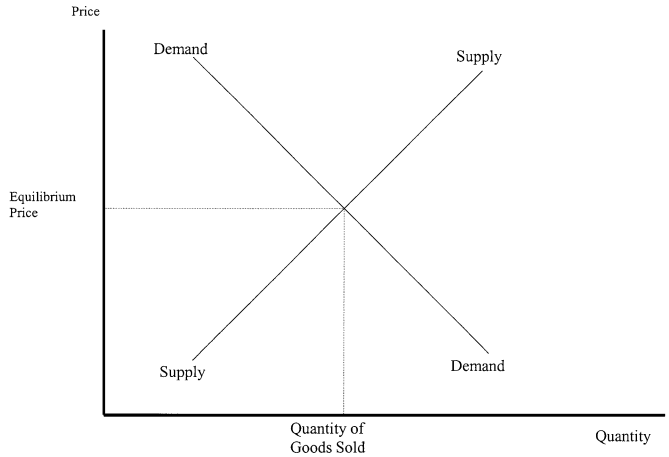

Fig. 1. Static classical microeconomic model of supply and demand.

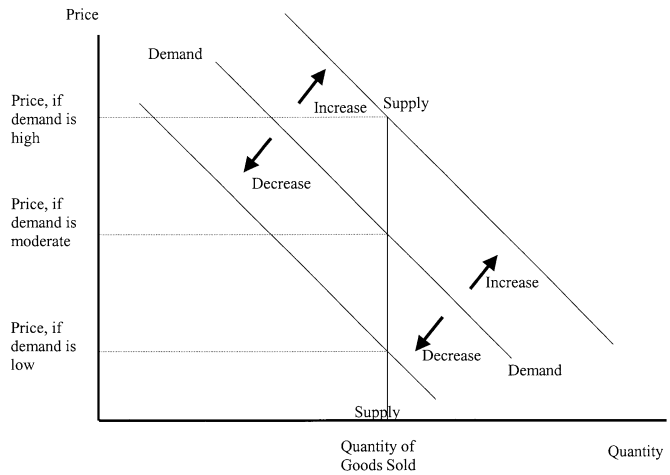

Fig. 2. Model of supply and demand with short-term supply fixed.

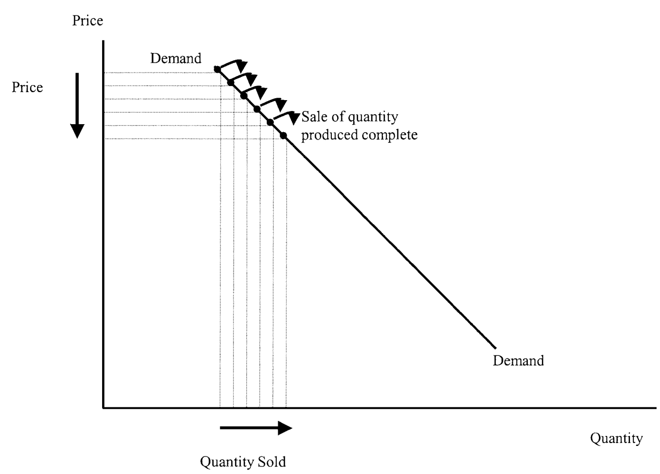

Fig. 3. Model of demand and sales given seller always obtains highest possible seller price.

III. Dynamic Pricing Over the Internet

Dynamic pricing can be formally defined as the buying and selling of products and services in markets where prices change in response to imbalances in supply and demand. In the context of this paper, dynamic pricing could also be defined as a pricing strategy in which prices change either over time, across consumers, or across product bundles.

Since the advent of e-commerce and the Internet, businesses have low-cost global access to highly focused and greatly expanded network of customers in the supply-value network. One of the most promising opportunities to improve this network is the application of dynamic pricing models to an organization's sourcing and selling activities. Dynamic pricing is now a critical component of e-commerce offering the potential of increased revenues, lower costs, and improved processes. The promise of dynamic pricing is currently helping fuel the growth of entirely new businesses, including e-commerce portals and marketplace focused exchanges [8], [14], [21], [27]–[30]. The emergence of new interactive networks and the rapid adoption of e-commerce capabilities increases the use of electronic marketplaces where goods and services are exchanged in real-time pricing environments analogous to the trading of securities on the NASDAQ market today. The ability to quickly and perhaps easily analyze retail traffic at websites, consumer preferences, and demographic data facilitate and support real-time setting of dynamic pricing policies. Sites like CarPoint.com, AutoByTel.com, and AutoVantage.com, for example, shift much of the consumer search, comparison, pricing, and other decision-making connected with auto purchases from the physical platform of the traditional car dealer to the virtual world of the Web.

A. Effect of the Internet on Pricing

The Internet is changing pricing practices in many industries. The Internet has resulted in an increase in the presence and use of auctions. Furthermore, Internet exchanges allow for the disintermediation of middlemen. (Disintermediation is the term commonly used to describe the elimination of middle layers by the Internet.) The low cost and ease of access to the Internet has encouraged the use of auctions as a method of selling products [4], [5], [7], [9], [11], [18], [24], [25], [32]. In fact, the Internet has resulted in renewed research and interest in auctions [10], [15], [16]. A number of exchanges have appeared for the buying and selling of various commodities [14]. The presence of exchanges often allows for the disintermediation of brokers, wholesalers, and other middlemen. Brokers and others were able to charge a fee for acting as a conduit between sellers and buyers. The ability to charge a fee for service is based on the value of the broker's information on the needs of various buyers and sellers. The high cost of information collection results in the buyers and sellers paying a small fee to the broker in the belief that the benefits outweigh the broker fee. The Internet, often through exchanges, reduces the cost of information allowing buyer and seller to find and interact with each other whether or not they are in close proximity to each other—eliminating the need for brokers.

The Internet changes the way many products are priced and sold. In the case of unusual objects, the search costs between buyers and sellers are often high, the use of auctions has reduced the barrier of imperfect information. The result is that pricing is closer to the clearing price of the product. In the case of commodity goods, the use of exchanges allows low-cost access for both buyers and sellers on a real-time basis, thereby reducing barriers to and the cost of obtaining information resulting in a price that is closer to the theoretical clearing price of the products.

In Section IV, we present a typology for collecting data to be used as part of dynamic pricing strategies on the Internet. In the pre-Internet era, the physical chain (the so-called traditional market) was the dominant model where information about product and information flow was gathered through various channels. The Internet has now decoupled the virtual chain from the physical chain such that the virtual chain transcends time and space and, thus, is distinct from its physical counterpart [22].

IV. Alternative Methods for Collecting Dynamic Demand Data Over the Internet

There are a number of different ways to collect demand data to identify and respond to changes in the price-demand relationship of potential customers. In this section, the different possibilities for collecting dynamic demand data—auctions, exchanges, offers to purchase, online surveys and focus groups—are briefly considered here. After these methods of demand data collection are considered, the challenges associated with all of these alternatives are discussed, followed by a summary of under what circumstances each method appears to offer the greatest potential.

The Internet has proven itself as a viable channel for marketing and selling to customers. It is no longer a necessity to buy from only local suppliers since customers can now easily access a global marketplace at a very low cost. This offers better buying power due to improved market information and increased competition between sellers. The combination of Internet communication infrastructure and personal computer computational power allows for the exchange large amounts of information in real time. These two advances are changing the traditional model of static pricing. Buyers and sellers can now interact using the power of dynamic pricing. This is illustrated through interaction models that use dynamic pricing.

The Internet fundamentally alters the customer–supplier relationship, empowering both the customer and supplier, by removing the transaction costs associated with imperfect information and vendor search. The Internet is also a viable channel for marketing and selling to customers. Customers no longer need to purchase based only on lower cost best-brand association or vendor location [20]. Having considered the Internet as an enabler of dynamic pricing and the advantages of dynamic pricing, the specific methods for collecting dynamic pricing data over the Internet are considered [37]. The methods are: auctions, reverse auctions, exchanges, negotiations and bundle pricing. See Fig.4 for a depiction of these methods.

A. Auctions

Interest in auctions has increased as a result of the Internet's ability to simultaneously reduce the cost of running an auction

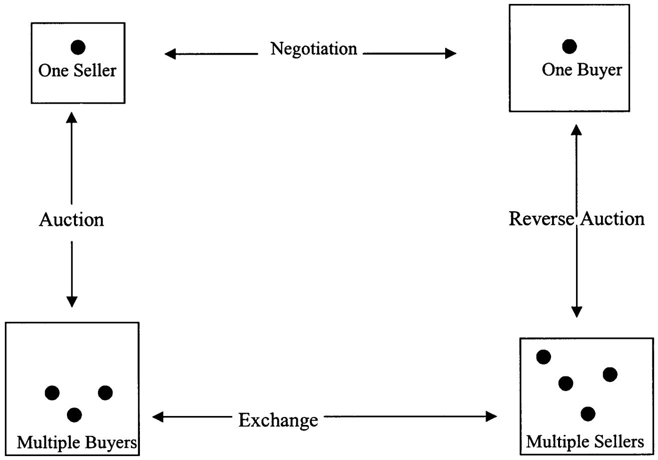

Fig. 4. Model of related interactions used in dynamic pricing.

and increase, by orders of magnitude, the number of potential participants. The use of auctions on the Internet has resulted in many questions about the effect of different auction types, duration, and bidder tactics. Until these questions are answered, uncertainty will remain on whether auctions are offering a true reflection of the demand characteristics of individuals. Theoretically, the auction offers a forum in which individuals will continue to increase their offering price until they have reached the maximum price they are willing to offer, at which point they drop out of an auction. By collecting data on at what price people cease to bid, one identifies the individual's demand for a product. This process allows for the identification of the demand for every individual in the auction, except the highest bidder. Auctions such as eBay, allow for bidders to place a confidential maximum bid into the auction, this allows for automatic bidding. The collection of this data also identifies the maximum price that the individual is willing to pay. Auctions hold great potential if it is possible to have a large number of people to bid on products. Transaction cost theory [26], [34], [35] suggests that inexpensive and common-place products, such as food products, are unlikely to be bid for since the cost of participating in an auction exceeds the expected value of the savings obtained through participation. Auctions have excellent potential for collecting demand data on expensive and/or unusual products. Questions regarding auction type, duration, and effect of different bidder tactics must still be considered.

B. *Reverse-Auctions (Offer to Purchase)*

The concept of offers to purchase has also been extended by the use of the Internet. Prior to the Internet, offers to purchase has been limited to real estate. In real estate, but few other products, an intent to sell and a suggested price is stated and potential buyers are invited to offer to purchase the property at a price and with terms that they decide. In the offer-to-purchase approach to pricing, an individual agrees to purchase a product at a price that they offer. Potential sellers are given the opportunity to accept the offer. Once the offer to purchase is accepted by the seller, the purchaser is legally committed to complete the purchase.

Reverse auction is a transaction format that allows the buyer to procure goods and services at the lowest possible price. In a reverse auction, prospective buyers can list any items they wish to buy, and then sellers bid to provide the best price. The buyer decides the exact specifications of each item, instead of the specifications being dictated by the seller. Reverse auction, or "name-your-own-price" model, used by Priceline.com is an interesting type of auction model for consumer goods [1]. The company allows the prices of products to be specified and uses the virtual world to make prices dynamic across consumers. Priceline's profit depends on the difference between the price bid by the consumer and the price at which the company can obtain the item from the producer or retail provider (see [12]).

This method attracted substantial customer interest, but has had difficulty in attracting supplier interest. Plane tickets were initially obtained by Priceline.com in exchange for shares of Priceline.com stock. Food manufacturers have not accepted the offer to purchase scheme, which has been withdrawn by Priceline.com. The offer to purchase approach is noteworthy in that it requires buyers to state what they are willing to pay for products. The products tend to be a commodity product such as air travel (with user specified departure and destination points and dates), gasoline, and food products. Such a system allows for an understanding of the increases in demand that are likely if the price is reduced from its current price. Upon first observation, the system appears attractive for commodity products including low-value items.

However, transaction cost theory suggests that auction participation would be low for low-cost commodity items such as certain grocery items and gasoline is difficult since the cost of participation is likely to outweigh the expected savings for most people [34], [35]. The "offer to purchase" approach has great potential if the time to participate does not outweigh the value of the potential savings. Consequently, to collect data using this method it may be necessary to offer incentives to obtain participation. For example, free collection and delivery of goods would make such an approach attractive to many people in income brackets that would not normally participate in such a scheme. The offer to purchase and reverse auction approaches offer great potential for a variety of commodity or clearly definable products, but it is unclear for which product it is possible to operationalize the collection of demand and pricing data on a sustained basis.

C. *Exchanges*

Exchanges existed long before the Internet. However, the Internet has increased the number of exchanges serving existing sectors. An exchange involves transaction of goods or services between multiple buyers and suppliers. Exchanges offer value by inexpensively linking buyer and seller of products in real-time. This is being accomplished on the Internet at the expense of brokers and other middlemen that historically have charged a commission or fee to link buyers and sellers—profiting from their superior market knowledge. Exchanges exist for a variety of different markets including: chemicals, steel, and energy [14]. The current belief is that the low entry cost and potential profitability of exchanges has resulted in an oversupply and the number of exchanges will decline over time. This is likely since an exchanges' value is dependent on the number of buyers and sellers that utilize it. Every new buyer is a potential customer to all sellers and every new seller is a potential supplier to every buyer. Products sold on exchanges are typically commodities that are sold or purchased in either large quantities or smaller quantities on a regular basis with great time specificity. Data from these exchanges could provide useful information on the shifts in demand for a commodity product, assuming that increases in demand by large purchasers is indicative of demand for the purchase of smaller quantities.

D. Negotiations

Negotiation involves the agreement on terms of a purchase of good and/or service between buyer and seller. Unlike an auction, negotiations typically involve a single buyer and a single supplier. For a supplier, the negotiation begins with his or her first contact with a buyer. Buyers might, however, view a negotiation as an end to a process. For example, in software negotiations, a software supplier helps a buyer to be aware of a number of factors that drive the supplier as well the motivation of the sales person. Suppliers often study their customers (annual reports, competition, websites) before they engage in a transaction. The terms and conditions are explicitly provided for this auction. These would provide important clues for determining if there is congruency between the buyer and the supplier. Some "driving" factors that might be part of the terms and conditions may include issues such as functionality, initial price, and general business practices.

E. Bundle Pricing

There are two variations of bundle pricing. In the first case, the consumer purchases a large amount of a single item to take advantage of a quantity discount. Alternatively, a set of items is included in a bundle and the price the seller asks for is dependent on the entire bundle being purchased. In volume purchases of the same product consumer demand is aggregated to lower the cost of an item [13]. Prices at such websites are posted as a function of quantity sold. Typically, multiple price discount levels are offered depending on the quantity sold. This approach is now applied on a much larger scale because of the aggregation capabilities of the Internet.

In the second variation of bundle pricing, an item price is a factor of the bundle in which it is included. For example, the *Wall Street Journal* and Elsevier publications are two examples of publications that offer a discount on electronic publications to those who also subscribe to their printed products.

Having considered the different approaches that can be used to collect demand data dynamically, we consider the use of an auction model to collect demand data and how this data is linked to the supply side of the supply-demand equation. In doing so, we are led to two separate models that provide information on optimal pricing and production levels. These models are required for considering a build-to-order and a build-to-forecast product provider.

V. E-Business Supply Models

A. Strategic or Build-to-Forecast Model

We define a product as a unique combination of physical characteristics-extras-price range-purchase restrictions. This definition is general enough to encompass computers and other physical goods, as well as perishable assets. For instance, for computers, one particular model would be the physical characteristic, extras would be items like warranty terms and service agreements for the computer, and purchase restrictions could be physical characteristic-extras-price range sale restrictions to only certain market segments (e.g., government employees).

We propose that the firm conducts limited Internet auctions for a wide range of products; each auction would be for a single product within a set of substitutable products (e.g., for a computer manufacturer, one auction might be for high-end servers for intranets and another might be for low-end home use). The prices for all but the single product should be set for a single auction. These prices can then be varied akin to a full or fractional factorial experiment across further auctions of that single product. The firm should generate as many products for the auction as possible—this generation refers principally to thinking of many extras, price ranges, and purchase restrictions.

These should be open auctions. Accordingly, all participants are able to view all bids that have been made to-date. Participants can make multiple bids, and they can withdraw from the auction at any time. The host-firm should attempt to allocate products to the auctions in insufficient quantities. This way, the maximum willingness-to-pay for the product can be ascertained. This information can be used to set prices for nonauction sales. In addition, this information can be used to set the minimum sale price on auctions that are more than just willingness-to-pay assessors.

Data for demand curve generation can be obtained from the limited auctions. First, rate classes—unique combination of nonphysical product attributes—can be defined from the auction results if each participant is required to fill out an information form prior to participating. This form would capture the participant profile—whether the participant was planning to purchase for a company or just for themselves, and likes and dislikes about physical characteristics-extras. Thus, the maximum bid from each participant is stored with the profile of the participant. A review of these data should reveal the rate classes—participants with similar profiles. Thus, a price-demand relationship can be plotted for each rate class, and a curve can be fit through this.

If multiple auctions are played, then regression analysis, rather than curve-fitting, can be employed to estimate the error of estimating demand for a given price. Rate class demand for a product can be estimated as a function of not only the product's price, but the prices of other products in the auction as well. This is achievable because the auction for that single product is repeated for different price levels of substitute products. The demands in the database can be inflated by a factor that estimates the proportion of the total market that is participating in the auction.

These demand curves can be used to refine the product definitions. For instance, let us say that a demand curve has been generated for a small company buyer rate class for a Micron PC with 1.5 GHz, 128-Mb RAM, 2 Gb of disk space, no software preinstalled, and no warranty. Maximum willingness-to-pay could range from $2000 down to $700. Another product might be a Micron PC with 500 MHz, 64-Mb RAM, 2 Gb of disk

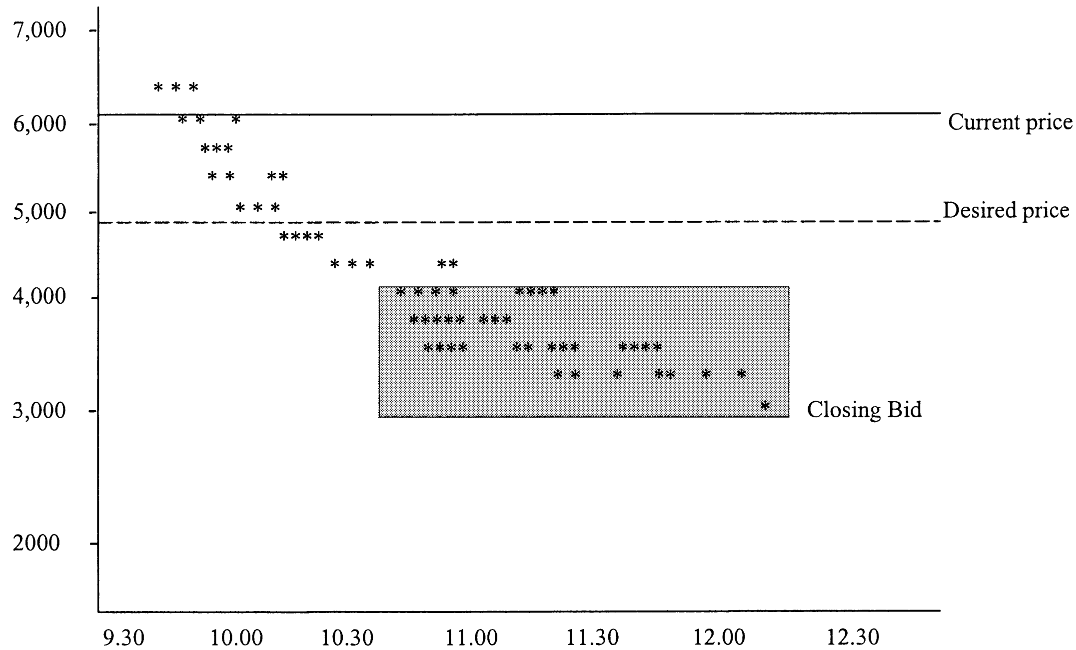

Fig. 5. Interpreting auction results.

space, Office 2000 installed, and no warranty. A K-12 school system buyer might have a maximum willingness-to-pay on this ranging from $700 to $400. Our small company buyer might also have a willingness-to-pay for this product that ranges from $1000 to $600. For example, analysis may reveal that the 500 MHz PC should be sold only to school district employees, since overall company revenue declines if this type of PC is made available to the small company buyers (who, if denied access to this PC, would purchase the higher priced PC). To determine the optimal price, an unconstrained optimization model that can be used to simultaneously set all nonauction prices to maximize revenue is offered.

Let

p_i price (decision variable) for product i;

d_i^r $f(p_1, p_2, \ldots)$ demand for product i from rate class r (this is a function of potentially every product's price in the firm's inventory of products);

c_i per unit production cost of product i.

Then, the objective is

$$\max \sum_i \sum_r (p_i d_i^r - c_i d_i^r). \tag{1}$$

The objective is to select prices for all rate classes to maximize revenues across a time-horizon. Theoretically, this horizon lasts until a change in a demand curve or unit cost. The challenge is to monitor changes in demand curves-costs and update prices as soon as possible. The output from this model can be used to estimate production capacities. If costs are also a function of capacity, this can be incorporated into c_i as a step-function.

A key advantage of this strategic model is that it provides a detailed understanding of willingness-to-pay and customer characteristic information from the Internet. This should provide more accurate price-demand projections than are attainable via traditional survey methods.

1) Interpreting Auction Results: The model that we have proposed could be used to generate a record of bids for a selected group of products by a selling firm in a reverse auction. The current price also known as the historic price is the most recent price paid by the buyer for the products contained within a group. The desired price also known as the reserve price is the price below which the group of items must fall in order for the buyer to consider it worthwhile to outsource the products to another supplier. The difference between the current and the desired price can thus represent switching costs.

This auction is conducted in real-time, and each supplier witnesses anonymous bids as they are placed by their competitors. The dynamic bidding and price transparency usually results in dramatically lower pricing than the buyer is able to achieve by traditional request for quote (RFQ). In the accompanying figure, suppliers who are judged to be competitive are shown in the shaded box. Various factors including supplier delivery and quality performance may preclude the lowest bidder from winning the lot.

It is important to note that post-auction analysis is an important ingredient of the total process. Further, suppliers in general see different information than the buyer does during the online auction. Specifically, the suppliers do not know the current price, but are aware of the desired price and also recognize that in order to be competitive, their bids must be at or below this price. The suppliers in most cases do not know the names of the other bidders.

Fig. 5 is a good example of a successful online auction in which the price of the lot fell below the buyer's desired price. Bid records may have a trend that fail to meet the desired price or trend upward. Typically there are rules that could be built into the software so that it will not accept bids greater than 5%–10% of the buyer's current price. The lowest bid represents the maximum gross savings that could be achieved.

B. Tactical or Build-to-Order Model

If a firm is operating in a just-in-time (JIT) mode, then the strategic model is sufficient; inventory might be so low that a more detailed model is superfluous. However, if their environment is not conducive to a JIT system, then this model could be useful in determining time-phased production and inventory levels, given that prices have already been set from the strategic model.

Let

- I_{it} ending inventory of product i in period t;
- P_{it} production of product i in period t;
- c_{it} per unit production cost of product i in period t;
- h_{it} cost of holding one unit of product i in inventory for the duration of period t;
- d_{it} demand for product i in period t (this can be obtained by a time series projection of demands that have been adjusted to a constant price level);
- K_{it} production capacity of product i in period t.

Then, the integer-linear program to solve is

$$\min \sum_{i} \sum_{t} (h_{\mathrm{it}} I_{\mathrm{it}} + c_{\mathrm{it}} P_{\mathrm{it}}) \tag{2}$$

subject to

$$P_{\mathrm{it}} + \sum_{j=1}^{i-1} I_{\mathrm{ij}} \geq d_{\mathrm{it}} \forall i, t \tag{3}$$

$$P_{\mathrm{it}} \leq K_{\mathrm{it}} \forall i, t \tag{4}$$

$$P_{\mathrm{it}} + I_{\mathrm{it}-1} - d_{\mathrm{it}} = I_{\mathrm{it}} \forall i, t \tag{5}$$

$$P_{\mathrm{it}}, I_{\mathrm{it}} \geq 0 \tag{6}$$

and integer.

The objective is to select product and time-phased production and inventory amounts to minimize time horizon unit production and inventory costs. Constraint (3) ensures that demand for each product in each period is met. Constraint (4) limits production by product and time period. Constraint (5) is the inventory balance equation.

VI. Managerial Implications in Using Dynamic Pricing Strategies

Price discrimination is the strategy of charging different prices to different customers for the same product or service offering. One type of price discrimination is based on setting different prices for different groups of customers. Dynamically changing prices is now being viewed as a profit maximizing strategy for companies who garner the power of the Internet to conduct business. One reason why a retailer finds price discrimination a very attractive strategy is because they can obtain higher profits without increasing their costs. The maximum price that a customer is willing to pay is their reservation price. From the customer's perspective, the difference in the price that they are willing to pay and the actual price that they end up paying is called as a consumer surplus. The retailer surplus is the difference between their actual selling price and what they are willing to sell at. Price discrimination moves some of the customer surplus to retailer surplus.

Auctions have proven to be a useful mechanism where retailers can gather large amounts of information about their customers in order for them to make a better estimate about the customer's reservation price and also dynamically set prices. Having discussed how the Internet is an enabler for dynamic pricing, the methods for collecting dynamic pricing data have been outlined. An experiment has been proposed to collect dynamic pricing data. Finally, optimization models for determining the optimal supply in both build-to-order and build-to-forecast environments are offered. Having offered a framework for both the supply and demand side of dynamic pricing on the Internet, conclusions are offered.

VII. Conclusion

E-commerce already offers a proliferation of digital marketplaces. These new markets offer the potential for dynamic pricing. Electronic agents may compete in dynamic pricing markets on behalf of companies in the future. The expected result is for prices to approach their "true" market value with trade partners competing on factors such as quality, reliability, and value added services.

Dynamic pricing is expected to grow to support more complex transaction formats such as multiattribute auction formats (e.g., condition of goods, supplier performance history), complex bid schedules, formats that allow a higher level of negotiation between sellers and buyers (e.g., online negotiations, online chat), and continuous matching formats where electronic agents perform the matching in real-time.

Future research should consider whether demand and pricing data collected over the Internet is generalizable to buyers that are not Internet-based. Reverse auctions have been noted as the data collection method that appears to be most promising for the collection of dynamic pricing and demand data, this being the case, it is of great value to determine for what product categories can the data collection process be operationalized. That is, at what point do transaction costs prevent sufficient potential buyers from participating so that the results are biased and of reduced or little value. Once these two concerns are addressed, testing and validation of the proposed build-to-order and build-to-forecast models is recommended. The efficacy of our proposed approach should be quantified by comparing profits for the products under consideration before and after model implementation. An econometric model that estimates profits for those products as a function of factors not under control in our models should be generated. This would ensure that our before-after implementation comparisons are adjusted for different before-after economic conditions.

Another area for future research involves the issue of having different prices for different segments that might lead to the problem of fairness [17]. The notion that consumer preference for firms is affected not just by prices the consumers themselves are offered but also by prices available to others needs further investigation. Another key factor that managers need to know is how to identify people who can be targeted with differential prices. The optimization models that have been proposed in this paper need to be extended to parametrize such demographic information. Issues such as number of bidders, the effect if any the number of bidders have on the final price and the effect of bid increment all need to be addressed via building more complicated and robust models. The Internet is an important enabler of dynamic pricing. However, much further investigation is still required.

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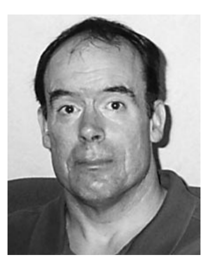
Vaidyanathan Jayaraman received the B.S. degree in applied mathematics from the University of Madras, Madras, India, the M.S. degree in mathematical sciences, the M.B.A. degree from the University of Akron, Akron, OH, and the Ph.D. degree from the Fisher College of Business, The Ohio State University, Columbus.

He currently teaches operations and supply chain management at the University of Miami, Miami, FL, where he is a Faculty Member in the Department of Management, School of Business Administration. Prior to joining the University of Miami, he was a Faculty Member at Washington State University, Pullman, as well as a Faculty Member with the College of Business Administration, the University of Southern Mississippi, Hattiesburg. His papers have appeared in journals such as *Transportation Science*, *European Journal of Operational Research*, *Journal of Operations Management*, *Decision Sciences*, *Journal of Operational Research Society*, *International Journal of Production Research*, and *INTERFACES*. His research interests include supply chain management, transportation and logistics problems, hierarchical network design, and production planning and control in recoverable manufacturing environment.

Dr. Jayaraman won the Louis Brandt Faculty Research Award from the University of Southern Mississippi in 1997, the College of Business Faculty Teaching Excellence Award from University of Southern Mississippi in 1998, and the School of Business Faculty Teaching Excellence Award at the University of Miami in 2002.



Tim Baker received the B.A. degree in mathematics and economics from Claremont McKenna College, Claremont, CA, in 1980, the M.S. degree in operations research and systems analysis from the University of North Carolina at Chapel Hill, in 1982, and the Ph.D. degree in operations management from The Ohio State University, Columbus, in 1994.

He is currently an Assistant Professor of decision sciences at Washington State University at Tri-Cities. His research has appeared in *Decision Sciences*. He has 12 years of operations research analyst experience in the industry. His research interests include airline and hotel revenue management, petroleum products distribution system design, weapons system effectiveness analysis, and manpower planning modeling.