2. ARTÍCULOS DE INVESTIGACIÓN OPERATIVA

PRICING AND REVENUE MANAGEMENT: PRESENT AND TRENDS

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Revenue management is considered one of the most successful application areas of operations research in the business practice. It has been defined as "selling the right product to the right customer at the right time for the right price"(Kimes [12]).

The canonical examples for the practice of revenue management are the airline and hospitality industries, where highly perishable units of capacity (an airline seat or a hotel room), generally subject to high fixed costs and targeting heterogeneous customers, are sold with the objective of maximizing revenues. During the last 20 years, the scope has broadened to other sectors like car rental, cruises, retailing, broadcast advertising, and health care.

Revenue management is mainly concerned with demand-management decisions. It involves managing the firm's interface with the market, and in this sense can be thought of as the complement of supply-chain management, which addresses the supply decisions and processes of a firm, with the objective of minimizing the costs of production and logistics. Demand management decisions can be addressed by adjusting the price or quantity offered. Pricing decisions involve setting fixed prices or individual-offer prices, pricing products across different categories, and adjusting prices dynamically over time. The selling practice of low-fare airlines and markdowns in retailing are examples of price-based revenue management. Quantity decisions are related to the control of the capacity or inventory in terms of whether to accept or reject a request for a unit, and to the allocation of capacity to different segments, products or selling channels. This is typically the practice of full-fare airlines and big hotel chains. We next explore these two streams of research (price-based and quantity-based demand management) in some more detail.

The integration of pricing and production or inventory decisions has the potential of significantly improving the performance of manufacturing and service supply chains. Research addressing demand management decisions through the adjustment of retail prices includes single-period settings, multi-period settings (both with fixed and dynamically adjusted prices), settings with a single monopolistic firm, or with multiple firms competing for customer demand. In addition, these models differ in their assumptions regarding the type of demand (deterministic or stochastic), demand functional form (additive or multiplicative), and the costs incurred (e.g., presence or absence of fixed ordering costs). We refer to the detailed classification of work in this area provided in the survey chapter of Chan et al. [5].

Petruzzi and Dada [15] provide a unifying framework for analyzing pricing decisions in a single-period, single-firm, newsvendor model. Federgruen and Heching [7] characterize the structure of an optimal combined pricing and inventory strategy in a dynamic, multi-period model with periodic review. In this setting, it is optimal to adopt a base-stock list-price policy, i.e., in each period the ordering policy is characterized by an order-up-to level and a price that depends on the initial inventory level at the beginning of the period. If the initial inventory level is below the base-stock level, the firm charges a list price, and if it is above the base-stock level, no order is placed and the firm offers a price discount which is a function of the initial inventory level. Chen and Simchi-Levi [6] extend the analysis to a setting in which the firm incurs fixed cost for each order placed. In a setting with stochastic demand and a single ordering opportunity, Gallego and van

Ryzin [10] characterize the optimal dynamic pricing policy as a function of the inventory level and the time left in the horizon.

A number of papers have studied the integration of traditional inventory/production models with demand management decisions in oligopoly settings with multiple firms compete for customer demand by adjusting their retail prices. Kirman and Sobel [13] develop a multi-period model in which a number of competing firms decide in each period the price and the amount to produce to satisfy random demand. Bernstein and Federgruen [2] consider a newsvendor setting with multiple firms that face stochastic demand and compete in terms of their prices, while Bernstein and Federgruen [1] consider a model with competing firms making pricing and replenishment decisions in a multi-period setting with deterministic demand and fixed ordering costs.

There remain many challenging research problems in the area of joint pricing and production/inventory decisions. These include, for example, retail pricing decisions in serial supply chains, dynamic adjustment of prices in settings with multiple competing firms, or the incorporation of lead times in multi-period models. The increased ability to jointly manage inventory and demand through the adjustment of retail prices is allowing firms to increase profits and better match demand with supply.

Production or capacity inflexibility due to high fixed costs, economies of scale, or production delays, are conductive to quantity-based revenue management. This practice emphasizes the demand side in the management of the supply-demand matching equation. In settings with capacity inflexibility, a firm can exploit customer heterogeneity, in terms of their preferences for different products and their willingness to pay for them, by creating multiple product types from the same homogeneous capacity. The use of capacity controls by airlines is the typical example of quantity-based demand management. Here, different "ticket types" are sold at various times and prices, and under different terms and conditions, but offering essentially the same service.

Traditional, quantity-based revenue management models, and the practice derived from them, have been built upon fairly strong assumptions. Specifically, revenue management models generally assume that the firm is a monopolist and that demands for different products are mutually independent. Those are the building blocks of the so-called "single-leg problem,"that is, the problem of selling the capacity of a single flight under the assumption that leisure, price-sensitive customers arrive first, while business travelers arrive later. In this problem, the airline establishes the number of seats to reserve for business travelers, who will typically purchase their tickets close to the flight departure at a higher price. This single-airline, independent-demand model has subsequently been extended to networks of multi-leg flights, for which heuristics must be used due to the complexity of the problem. Developing good approximations for network revenue management problems continues to be a thriving topic of research (e.g. see Topaloglu [18]).

Even though the practical implementation of these models provide good enough improvements on the revenues obtained, the validity and usefulness of the underlying assumptions in global and more sophisticated markets are dubious. For instance, customers behave in complex ways, and make their purchases as a function of the various products available in the market and of their individual preferences. Indeed, incorporating customer choice behavior in revenue management has been one of the most recent trends in the field (e.g., see Talluri and van Ryzin [17], Gallego et al. [9], van Ryzin and Liu [19]).

Another recent stream of research in revenue management has extended these models to settings with multiple competing firms (e.g., see Netessine and Shumsky [14], Gallego and Hu [8]). Certainly, in most cases, firms are not monopolists and must make pricing and capacity decisions in view of the offers made by other firms in the market. But it is not all about competition–the airline industry has witnessed a significant growth of alliance activity, with an increasing number of code-sharing agreements between companies, emphasizing cooperation between different players in complementary routes. The problem here is how to coordinate the different capacity control decisions, including the split of revenues (e.g., see Wright et al. [21]).

There has also been increased interest, both in academia and in practice, in alternative mechanisms for pricing. Fixed, posted prices have been around in

the quantity-based revenue management field since its origins. However, since the rise of the Internet, many firms have begun experimenting with alternative pricing mechanisms such as auctions (e.g. see Vulcano et al. [20]), guaranteed purchase contracts (Priceline.com's patented selling mechanism), and negotiations (e.g., see Bhandari and Secomandi [3]). The simultaneous use of different selling channels by the same firm has also received attention. Here, the firm designs a selling scheme that does not cannibalize itself and that, at the same time, takes advantage of a natural market segmentation (e.g., Caldentey and Vulcano [4], Gallien and Gupta [11]).

In summary, pricing and revenue management constitutes a prominent area of research within the field of operations management, with significant potential and many problems to explore. There is a growing community in the field, reflected in the Revenue Management and Pricing Section within INFORMS (http://revenue-mgt.section.informs.org/) that holds an annual conference (the last one took place in Barcelona in June 2007), and in specific Areas/Departments in important journals like Operations Research, and Production and Operations Management. The excellent book by Talluri and van Ryzin [16] provides a comprehensive learning source on the field. New ideas and research contributions are always welcome.

References

[1] F. Bernstein and A. Federgruen. Pricing and replenishment strategies in a distribution system with competing retailers. *Operations Research*, 51:409–426, 2003.

[2] F. Bernstein and A. Federgruen. Decentralized supply chains with competing retailers under demand uncertainty. *Management Science*, 51:18–29, 2005.

[3] A. Bhandari and N. Secomandi. Dynamic revenue management with negotiated prices. Technical Report PA, Tepper School of Business, Carnegie Mellon University, 2007.

[4] R. Caldentey and G. Vulcano. Online auction and list price revenue management. *Management Science*, 53:795–813, 2007.

[5] L. Chan, Z. Max Shen, D. Simchi-Levi, and J. Swann. *Coordination of Pricing and Inventory Decisions*. Kluwer Academic Publishers, New York, NY, 2004.

[6] X. Chen and D. Simchi-Levi. Coordinating inventory control and pricing strategies with random demand and fixed ordering cost: The finite horizon case. *Operations Research*, 52:887–896, 2004.

[7] A. Federgruen and A. Heching. Combined pricing and inventory control under uncertainty. *Operations Research*, 47:454–475, 1999.

[8] G. Gallego and M. Hu. Dynamic pricing of perishable assets under competition. Technical report, Department of Industrial Engineering and Operations Research, Columbia University, 2007.

[9] G. Gallego, G. Iyengar, R. Phillips, and A. Dubey. Managing flexible products on a network. Technical Report CORC TR-2004-01, Department of Industrial Engineering and Operations Research, Columbia University, 2004.

[10] G. Gallego and G. Van Ryzin. Optimal dynamic pricing of inventories with stochastic demand over finite horizons. *Management Science*, 40:999–1020, 1994.

[11] J. Gallien and S. Gupta. Temporary and permanent buyout prices in online auctions. *Management Science*, 53:814–833, 2007.

[12] S. Kimes. Yield management: A tool for capacity constrained service firms. *Journal of Operations Management*, 8:348–363, 1989.

[13] A. Kirman and M. Sobel. Dynamic oligopoly with inventories. *Econometrica*, 42:279–287, 1974.

[14] S.Ñetessine and R. Shumsky. Revenue management games: Horizontal and vertical competition. *Management Science*, 51:813–831, 2005.

[15] N. Petruzzi and M. Dada. Pricing and the newsvendor problem: A review with extensions. *Operations Research*, 47:183–194, 1999.

[16] K. Talluri and G.J. van Ryzin. *The Theory and Practice of Revenue Management*. Kluwer Academic Publishers, New York, NY, 2004.

[17] K. T. Talluri and G. J. van Ryzin. Revenue management under a general discrete choice model of consumer behavior. *Management Science*, 50:15–33, 2004.

[18] H. Topaloglu. Using lagrangian relaxation to compute capacity-dependent bid-prices in network revenue management. Working paper, ORIE Cornell University, New York, 2006.

[19] G.J. van Ryzin and Q. Liu. On the choice-based linear programming model for network revenue management. Working paper, Graduate School of Business, Columbia University, New York, 2004.

[20] G. Vulcano, G.J. van Ryzin, and C. Maglaras. Optimal dynamic auctions for revenue management. *Management Science*, 48(11):1388–1407, 2002.

[21] C. Wright, H. Groenevelt, and R. Shumsky. Dynamic revenue management in airline alliances. Working paper, Simon Graduate School of Business, University of Rochester, New York, 2006.

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