

Research and Management Insights

The Maximum Throughput on a Golf Course

Ward Whitt

Concern has been expressed that the pace of play of golf has become too slow, i.e., that the amount of time spent waiting and the overall time required to play a full round of eighteen holes have become excessively long. It is natural to respond to this challenge by applying the principles of production and operations management, because successive groups of golfers playing on a conventional golf course can be viewed, at least roughly, as a production line. Ward Whitt develops tractable stochastic models of group play on each of the three kinds of holes on a golf course, paying special attention to the inevitable randomness in the times required for each group to complete each stage of play. These models incorporate the realistic feature that more than one group can play at the same time on many of the holes, but under precedence constraints. The models for the individual holes can be combined to obtain a queuing network model for the play of successive groups over the entire course. For each of the basic models, Whitt determines the maximum possible throughput of the hole. That yields the capacity of the golf course, which is important for golf course design and management.

Recent Developments in Dynamic Pricing Research: Multiple Products, Competition, and Limited Demand Information

Ming Chen, Zhi-Long Chen

In the past two decades, there has been a growing research interest in various types of dynamic pricing problems that involve selling a fixed amount of inventory over a finite horizon without inventory replenishment. Unlike early work that is primarily focused on single-firm single-product problems with complete demand information, recent work deals with more complex problems that incorporate more practical issues and richer modeling features. In this survey, Chen and Chen present a comprehensive review on three classes of dynamic pricing problems that have emerged in the last several years, i.e., problems with multiple products, problems with competition, and problems with limited demand information. They also identify a number of practical issues and industrial practices that have received little research attention and are good topics for future research.

Inventory-Based Dynamic Pricing with Costly Price Adjustment

Wen Chen, Qi Feng and Sridhar Seshadri

With rapid advancement in technology, many firms have adopted inventory-based pricing strategy in their daily operations. Such a strategy allows firm to coordinator replenishment and inventory selling to balance the inventory cost and revenue earning. However, price revision is not always free. Particularly in retail industry, price change typically involves labor, printing, shipping, mistake correction and in-store supervision, which can take a significant portion of the revenue. Wen Chen, Qi Feng and Sridhar Seshadri investigate the policy design for inventory-based dynamic pricing by incorporating the cost of changing price. Their findings suggest that, with costly price adjustments, the firm should not always increase the order quantity in response to an increased fixed ordering cost. Instead, the order cycle should be extended, which can be accomplished by increasing the product price to save on price revision frequency. Moreover, the firm may spend more or less on fixed costs than on inventory holding depending on whether the marginal inventory holding cost is increasing or decreasing in the amount of inventory. To implement an inventory-based pricing strategy, it is important to appropriately choose the inventory levels at which the price is revised.

Revenue Management vs. Newsvendor Decisions: Does Behavioral Response Mirror Normative Equivalence?

Ayşe Kocabiyikoglu, Celile Itir Gogus, M. Sinan Gonul

Kocabiyikoglu, Gogus and Gonul compare managerial decisions under the newsvendor and the two-class revenue management models. Their study shows, because newsvendors perceive loss due to left-overs as a direct loss, it weighs more in their decisions, and consequently, behavior under these two equivalent operations management models differ. Decision makers are not able to reap the full benefits of a revenue management system, because they consistently experience more unsold units, which could have been sold to the low-end segment, which exists to compete on surplus capacity, earlier in the sales horizon. Furthermore, in revenue management applications where the price difference between customer

segments is low, decision makers are inclined to reserve fewer units for the low-end customers in times of high demand variability, while the opposite behavior would be more beneficial to earnings.

Coping with Gray Markets: The Impact of Market Conditions and Product Characteristics

Reza Ahmadi, Foad Irvani, Hamed Mamani

Global companies in various industries are increasingly challenged by parallel importers who divert products from authorized channels to gray markets for resale. Reza Ahmadi, Foad Irvani, and Hamed Mamani study the pricing and quantity decisions of a manufacturer who operates in two markets with uncertain demands and faces parallel importation between the low-price market and the high-price market. The authors show that reducing the price gap is more effective than reducing product availability in controlling parallel importation. The authors also explore the impacts of “product characteristics” and “market conditions” on the manufacturer’s optimal (“strategic”) policy towards parallel importation (ignore, block, or allow). Furthermore, the authors compare the strategic policy with uniform pricing, a policy that has been used by some companies to eliminate gray markets entirely. The authors show that although the uniform pricing policy is easier to implement, the strategic policy is significantly more profitable than the uniform pricing policy when market conditions are moderately different and the product has not turned to a commodity. Therefore, companies should adopt a strategic price discrimination policy towards parallel importation under these circumstances.

Service Systems with Experience-based Anecdotal Reasoning Customers

Tingliang Huang, Ying-Ju Chen

The existing queueing literature typically assumes that customers either perfectly know the expected waiting time or are able to form rational expectations about it. In contrast, Tingliang Huang and Ying-Ju Chen study canonical service models where customers do not have such full information or capability. They assume that customers lack full capability or ample opportunities to perfectly infer the service rate or estimate the expected waiting time, and thus can only rely on past experiences and anecdotal reasoning to make their joining decisions. The authors fully characterize the steady-state equilibrium in this service system. Compared with the fully rational benchmark, they find that customers with anecdotal reasoning are less price-sensitive. Consequently, with a higher market potential, a revenue-maximizing firm may increase the price if the service rate is exogenous,

and it may decrease the price if the service rate is at the firm’s discretion. Both results go against the commonly accepted pricing recommendations in the fully rational benchmark. The authors also show that revenue maximization and welfare maximization lead to fundamentally different pricing strategies with anecdotal reasoning, whereas they are equivalent in the fully rational benchmark.

Supply Contract Design for Competing Heterogeneous Suppliers under Asymmetric Information

Zhaolin Li, Jennifer K. Ryan, Lusheng Shao, Daewon Sun

In practice, procurement often involves multiple competing heterogeneous suppliers. However, the effect of competition between heterogeneous suppliers on the optimal contract menu under asymmetric information has not been thoroughly studied. Zhaolin Li, Jennifer K. Ryan, Lusheng Shao, and Daewon Sun analyze contracting under asymmetric information with two heterogeneous competing suppliers. Each supplier offers a retailer a menu of contracts. The retailer chooses the contract that maximizes its expected profit. For this setting, the authors characterize the equilibrium contract menus offered by the suppliers to the retailer. They find that the equilibrium contract menus depend on which supplier-retailer match can generate the highest supply chain profit and on how much information rent the supplier may need to pay. An important feature of the equilibrium contract menus is that the contract assigned to the more profitable retailer will coordinate the supply chain, while the contract assigned to the less profitable retailer may not. In addition, in some circumstances, the flexible supplier may choose not to serve the high-volume retailer, in order to avoid excessive information rent.

Managing Supply Disruptions When Sourcing from Reliable and Unreliable Suppliers

Bin Hu, Dimitris Kostamis

Bin Hu and Dimitris Kostamis use an analytical model to study a manufacturer’s optimal multiple-sourcing strategies when some but not all suppliers face risks of complete supply disruptions, and show several interesting properties of the optimal sourcing strategies that involve both reliable and unreliable suppliers. First, the optimal unreliable orders are ranked by the cost-advantage-to-risk ratio. This criterion is intuitive and simple to use by sourcing managers. Second, the optimal unreliable orders are invariant of minor market size changes. This means that even if a manufacturer has to place orders with

unreliable suppliers earlier on, it could later account for the latest market size updates in its reliable order without needing to modify the unreliable orders, which allows the manufacturer to achieve both cost savings and responsiveness. Finally, when ordering from one reliable and one unreliable supplier, the total order quantity and its allocation between the two suppliers are independent decisions, which means that jointly deciding the total order quantity and the sourcing plan—which is theoretically beneficial but practically difficult—is not necessary in this case.

Efficiency or Competition? A Structural Econometric Analysis of Canada's AWS Auction and the Set-Aside Provision

Kyle Hyndman, Christopher F. Parmeter

With the continued growth in the use of auctions to procure goods and services, appropriate auction design is imperative. In many settings, the auction designer has several goals that may be in conflict. For example, a manufacturer wants to procure parts from its supplier at a low price, but it may also want to employ multiple suppliers to ensure robustness to shocks in its supply chain or to ensure sufficient long run competition by suppliers. While many theoretical exploits on these conflicting goals exist, gaps exist in empirical work to determine where these tradeoffs arise, and their overall scope. Kyle Hyndman and Christopher Parmeter analyze the AWS spectrum auction held by Industry Canada in which the goals of auction efficiency and promoting competition in the wireless market were in conflict. Industry Canada chose to implement a set-aside, which guaranteed that 40MHz of spectrum would be won by new entrants, with the hopes that their entry would spur competition in the wireless market at lead to lower consumer prices.

Hyndman and Parmeter use structural econometric techniques based on a matching estimator in order to estimate the profit function of telecommunications firms who won licenses. Using these estimates, they then compare profits across alternative allocation scenarios in the absence of the set-aside. Their results

show that the set-aside lowered overall firm profits by approximately \$450 million. Hyndman and Parmeter then seek to understand whether the social welfare benefits from enhanced competition out-weighed the loss in firm profits. After documenting the myriad financial difficulties of the new entrants and other factors in the post-auction landscape, they question the long-term sustainability of the new competitive landscape, raising doubts about whether the gains to consumers outweighed the efficiency loss in the auction. Thus, the paper highlights some of the real-world difficulties in using auction design to promote other desirable outcomes in a given market or industry.

A New Two-bin Policy for Inventory Systems with Differentiated Demand Classes

Sugoutam Ghosh, Rajesh Piplani, S. Viswanathan

Differentiated service as a strategy is well recognized among practitioners in marketing, logistics and operations. In after-market logistics operations, service differentiation for parts availability is typically achieved through a critical level rationing (CLR) policy, in which demand from the lower priority class is backordered (or not fulfilled) once inventory falls below the critical level, as this inventory is reserved for the higher demand class. CLR policy works well when the difference in service level required for the two demand classes is high. Ghosh, Piplani and Viswanathan propose a new class of two bin (2B) policy for service differentiation where separate bins of inventory are assigned for the two demand classes. The demand for each class is fulfilled from its assigned bin. However, when the bin intended for the higher demand class is empty, the demand from the higher class can still be fulfilled with the inventory from the other bin. Cost expressions for the proposed policy are developed by authors. The proposed 2B policy is able to achieve a finer granularity of service differentiation than the traditional CLR policy and has the potential to outperform the CLR policy under a service level constrained optimization problem.