

## Research and Management Insights

### Clickstream Data and Inventory Management: Model and Empirical Analysis

Tingliang Huang, Jan A. Van Mieghem

Click tracking is gaining in popularity and the practice of web analytics is growing fast. Can operations managers benefit from click tracking? Tingliang Huang and Jan Van Mieghem consider firms that feature their products on the Internet but take orders offline. Click and order data are disjoint on such non-transactional websites and their matching is error-prone. Yet, their time separation may allow the firm to react and improve its tactical planning. The authors introduce a dynamic decision support model that augments the classic inventory planning model with additional clickstream state variables. This model provides a practical framework to dynamically convert clickstream data into useful advance demand information for inventory management. Using a novel data set of matched online clickstream and offline purchasing data, the authors identify statistically significant clickstream variables and empirically investigate the value of clickstream tracking on non-transactional websites to improve inventory management. The authors show that the clickstream data is statistically significant to predict the propensity, amount, and timing of offline orders. Through a counterfactual analysis, they find that advance demand information extracted from the clickstream data can reduce the inventory holding and backordering cost by 3% to 5% in their setting.

### Management of Energy Technology for Sustainability: How to Fund Energy Technology R&D

Erin Baker, Senay Solak

Governments around the world are faced with decisions about how to invest in an energy technology research and development (R&D) portfolio that will best prepare them to address climate change. This problem is hard because it involves a number of uncertainties and complex interactions between technologies, the economy, and the environment. Baker and Solak develop a framework to help governments make these portfolio decisions using the best available information as well as insights based on complex economic models. They find that using this data-based

approach and explicitly allowing for multi-stage decision making leads to optimal portfolios that are surprisingly robust to the policy environment, to uncertainty about climate change damages, and to assumptions about the true cost of R&D investments. They also note that the availability of R&D is greater in non-optimal environments, and that under-investment in R&D is more costly than over-investment.

### Product Life Cycle Management of Packaged Software

Amit Mehra, Abraham Seidmann, Probal Mojumder

It is well known that a large percentage of industrial software projects are afflicted with cost and time overruns. This problem is particularly severe for a packaged software product as several upgrades are introduced during the product's life cycle and so these cost and time overruns may be encountered multiple times. Since upgrade development costs depend upon the time taken to execute the project, a better understanding of how optimal upgrade time intervals change during the life cycle of a software product can help managers plan better and hence avoid both cost and time overruns. Amit Mehra, Abraham Seidmann, and Probal Mojumder report that optimal upgrade intervals, in general, increase throughout the product's life cycle. Further, increases in rate of market growth and network externalities both increase the value of upgrades for a customer, but their impact on upgrade durations may be different. Thus, upgrade intervals may increase and then decrease during the product's life cycle as network externalities increase, but they always decrease with market growth rate. Finally, an increase in obsolescence rate of the software may also increase and then decrease upgrade durations during the product's life cycle.

### Stable and Coordinating Contracts for a Supply Chain with Multiple Risk-Averse Suppliers

Xin Chen, Stephen Shum, David Simchi-Levi

Contracts that can coordinate the supply chain may not be stable when they provide incentives for a subset of parties to renegotiate. Xin Chen, Stephen Shum, and David Simchi-Levi analyze a supply chain with a

single risk-averse retailer and multiple risk-averse suppliers. They show that supply chain profit is maximized only when the least risk-averse party bears the entire risk and the lowest-cost supplier handles all production. While it is not difficult to design contracts to align the incentives of these active parties with the profit of the supply chain, other suppliers may try to propose deals to the retailer to get some of its business. The authors propose ways to characterize contracts that do not align incentives, but also allocate profits that reflect bargaining powers of different parties and are immune to opportunistic renegotiation.

### **Optimal Per-Use Rentals and Sales of Durable Products and their Distinct Roles in Price Discrimination**

Stephen M. Gilbert, Ramandeep S. Randhawa, Haoying Sun

In practice, many firms simultaneously offer their products for sale (unlimited use) and for rental (single use), and this can be explained in terms of the distinct roles that sales and rentals play in a firm's ability to price discriminate. Sales allow a firm to discriminate among the average rates at which consumers could derive value from the product, while rentals discriminate among the (random) valuations that a consumer obtains from an individual use. Because of these distinct roles, Stephen Gilbert, Ramandeep Randhawa, and Haoying Sun find that selling and renting may co-exist in equilibrium even when transaction costs become arbitrarily small, which contrasts with much of the literature. Intriguingly, although sales and rentals are partial substitutes, when a firm offers both of them simultaneously, the selling price can be either higher or lower than when it offers only sales. This is a consequence of the fact that although the introduction of rentals causes the firm to reduce the number of units available for sale, it also adversely affects the marginal consumers' willingness to pay to purchase the product. On the other hand, rental prices are always higher if offered alongside sales than if offered in isolation.

### **Hierarchical Screening for Capacity Allocation in Supply Chains: The Role of Distributors**

Ying-Ju Chen, Mingcheng Deng, Ke-Wei Huang

Distributors play an important role in global supply chains. As a common practice, large international suppliers sell their products worldwide through exclusive distributors and importers located in different countries. While the economic benefits of introducing distributors into a supply chain seem straightforward, Ying-Ju Chen, Mingcheng Deng, and Ke-Wei Huang argue that distributors' superior

information might add further complications to existing incentive problems between suppliers and retailers. The authors construct a game-theoretic two-stage principal-agent screening environment in a decentralized supply chain with retailers, distributors, and a supplier. On the one hand, distributors' superior information about local markets may facilitate efficient allocation among local retailers and thereby increase supply chain efficiency. On the other hand, when the suppliers cannot observe how precise the distributors' superior information is, the inclusion of distributors might add another layer of information asymmetry to the existing supply chain. The supplier may not benefit from contracting with the distributors. In addition, no distributor is excluded based on the heterogeneity of the information precision, even though some distributors do not have better information than the supplier. The authors also document some counter-intuitive quantity allocation rules that arise from the distributors' information advantage.

### **The Value of Category Captainship in the Presence of Manufacturer Competition**

Mumin Kurtulus, Alper Nakkas, Sezer Ulku

Category captainship is a management practice where a retailer relies on a manufacturer, often referred to as a category captain, for recommendations regarding strategic category management decisions. Category captainship practices have been controversial because the captain makes recommendations about not only their own products but competitor's products too. Mumin Kurtulus, Alper Nakkas, and Sezer Ulku investigate the value of category captainship for the involved parties and identify category characteristics where category captainship is more likely to be adopted. The authors find that category captainship is more likely to be adopted in categories where the captain is more capable of driving category traffic compared to the retailer and the competition for captainship is neither intense nor weak. In such categories the collaboration between the retailer and the captain ensures sufficient surplus for both parties. The authors also show that category captainship can benefit not only the retailer and the category captain, but also the non-captain manufacturers.

### **Coordinating Production and Marketing with Dynamic Transfer Prices**

Engelbert J. Dockner, Gila Fruchter

Many companies can be characterized as divisional organizations in which production and marketing departments act as decentralized profit centers. Such

an organizational structure requires a coordination mechanism so that the goods and services that are exchanged between marketing and production induce each division to act so as to maximize the profits of the firm as a whole. Transfer prices are commonly used as such a coordination device. If, however, production and marketing act as two strategic rivals that pursue their own interest only, it is not clear if central management can find a transfer price that eliminates resulting strategic externalities and fully coordinates the actions of the divisions. It turns out that a transfer price can efficiently coordinate in some but not in all strategic settings that might prevail among the decentralized divisions. If production and marketing are able to pre-commit to preannounced strategies there exists a dynamic transfer price that efficiently coordinates both divisions. If, however, both divisions are not able to pre-commit, there does not exist a dynamic transfer price that efficiently coordinates both units. Applying an arbitrary dynamic transfer nevertheless improves overall firm profits without fully eliminating strategic externalities.

#### **A capacitated multi-echelon inventory placement model under lead time constraints**

R. Hammami, Y. Frein

Hammami and Frein develop an optimization model to manage and coordinate inventories in a generic capacitated multi-echelon supply chain under customer lead time constraints. The model can help managers to determine the stock level to be kept for each product in each facility in each period. Managerial insights can be grouped into three main categories: the determination of the amount of capacity to install in a given manufacturing facility, the negotiation of quoted lead time and frequency of orders with customers, and the comparison between different inventory policies. Indeed, the authors examine the impact of considering finite manufacturing capacity and provided analytical insights on the amount of capacity that should be installed in a given facility. Furthermore, the authors show how the model can be used to negotiate the frequency of orders and the quotation of delivery lead time with customers. In particular, they provide analytical insights on how the system cost varies as a function of the frequency of orders. The authors also compare the performance of the proposed model in which they consider time varying stock levels with the case of fixed stock levels. Finally, they evaluate the gain that can be achieved by considering the stocks of input products in the different facilities and not only the stocks of output products.

#### **Lean Control for Make-to-Order Companies: Integrating Customer Enquiry Management and Order Release**

Matthias Thürer, Mark Stevenson, Cristovao Silva, Martin Land, Lawrence Fredendall, Steve Melnyk

Matthias Thürer, Mark Stevenson, Cristovao Silva, Martin Land, Lawrence Fredendall, and Steve Melnyk present a simple yet effective production planning and control concept called *Workload Control (WLC)* for use in low-volume high-variety manufacturers, which typically produce on a make-to-order basis. WLC can achieve the same leveling of workload to capacity achieved by lean tools in repetitive manufacturing but does so when work cannot be standardized and it is not possible to synchronize the flow on the shop floor. Within the structure of the WLC concept, order release control and customer enquiry management act as workload filters and are considered complementary tools for protecting throughput from variance. Customer enquiry management defines the lead time buffer and controls the incoming workload in line with available capacity, ensuring due dates are short yet feasible. This then allows order release to balance the shop floor workload, reducing the required inventory buffer and ensuring capacity is used effectively. WLC is particularly suitable for embedding in small organizations as its core principles are simple to use and do not require significant investment in technology.

#### **Updating Inventories of Substitutable Resources in Response to Forecast-updates**

Saurabh Bansal, James S. Dyer

Substitution is useful in managing demands of closely related resources. However, substitution also complicates the inventory acquisition decision for the resources under a demand uncertainty. Saurabh Bansal, James Dyer consider an environment where the demand forecasts are normally distributed, as would be the case if they were obtained using regression or exponential smoothing models. The products are such that it is always optimal to use the inventory of a resource to meet its own demand before using it for substitution which is common in many practical situations. The authors show that when the mean demand forecast of a substitutable resource changes, an optimally acting manager should change only the inventory of this resource by an equal amount. She should not change any other inventory level, irrespective of the substitution structure. Further, at the new optimal inventory levels, the expected profit, fill rates and service levels of the resources change predictably. The simplicity of the results lends to an easy automation in enterprise planning systems where forecasts

feed into inventory/capacity planning decisions for substitutable resources.

### **Hierarchical multi-skill resource assignment in the telecommunications industry**

Christiane Barz, Rainer Kolisch

A common feature when assigning incoming jobs to resources in the telecommunication industry is that, at the time of assignment, there is only probabilistic knowledge about the service time, but the service time becomes known immediately after assignment. This occurs e.g. when a call center assigns jobs to technicians but the individual technicians can follow up to complete the assessment. The objective of the assignment is to minimize the long run average sum of waiting and rejection cost of customers. The resources are multi-skilled and hierarchical. Multi-skill implies that a resource has multiple skills which are all or partly required to process a job. Hierarchical means that a lower level resource has always a subset of the skills possessed by a resource on a higher level. While simple greedy assignment performs poorly in general, price directed approximate dynamic programming heuristics can significantly improve the system performance. The parameters needed for the heuristics can easily be obtained by the solution of a relatively small linear problem. The solution gaps of

such approximate dynamic programming heuristics are small in realistic settings.

### **Peakedness Based Staffing for Call Center Outsourcing**

Jean-Christophe, Van den Schrieck, Zeynep Akşin, Philippe Chevalier

Jean-Christophe Van den Schrieck, Zeynep Akşin and Philippe Chevalier show that the short-term variability (or burstiness) of arrivals to a call center can have a major influence on the staffing required to reach any given performance target. It is shown how the peakedness can be used to estimate this variability from easily available data. Several staffing methods are presented to take the variability into account; a simulation experiment is carried out to compare the advantages of each method. The main conclusion is that the peakedness based method appears to be more robust than the method based on the coefficient of variation of arrivals. The authors also show that a call center outsourcing part of its load will in general generate a load for the service supplier that exhibits such short term variability. An explanation for the origin of this variability is presented and it is shown that this variability will not diminish asymptotically when the size of the call center grows.