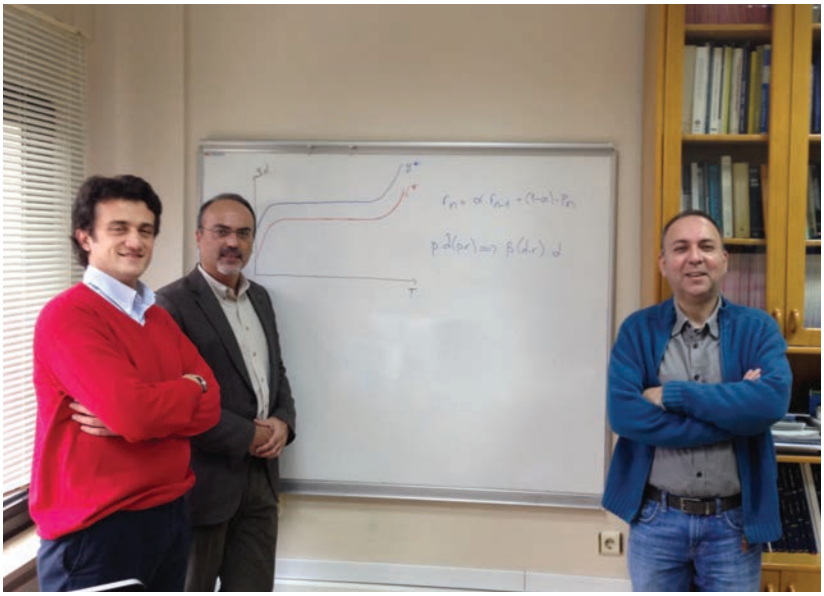
Research

EXECUTIVE SUMMARIES : BY RONALD ASKIN AND THOMAS O. BOUCHER

This month we highlight two articles focusing on understanding consumer demand. The first article examines the impact of historical prices that set expectations for consumers. The second article addresses the use of covariates to improve day-ahead forecasts of electricity spot prices. These articles will appear in the April 2014 issue of IIE Transactions *(Volume 46, No. 4).*

How consumer price expectations affect inventory management

There is now substantial evidence that pricing and inventory management are intimately tied. A further inquiry would be, "What role does consumer behavior have on pricing and inventory decisions?"



Authors M. Güray Güler (from left), Taner Bilgiç and Refik Güllü discuss the evolution of optimal inventory and price levels over time.

As consumers buy a particular product frequently, they develop their own price expectations. This expectation acts as a benchmark price. Consider a 40-ounce jar of peanut butter. If you see that it is priced at $10, you immediately have a perception of it as "underpriced" or "overpriced." If you think that it is expensive, what would be your "loss" if you were to buy it?

Marketing literature provides us with a concept to model this behavior. Consumers develop a reference price against which an announced price is compared. The reference price and the announced price jointly affect the demand. Moreover, the reference price dynamically evolves through time. A company that announces a discounted price may increase its revenue in the short term, but this discount affects its future benefits through the reference price. Therefore the companies face a trade-off between immediate gains and future benefits. Is this another conundrum for the inventory manager?

M. Güray Güler of Karadeniz Technical University and professors Taner Bilgiç and Refik Güllü of Boğaziçi University in Istanbul address this problem in their paper, "Joint Inventory and Pricing Decisions with Reference Effects." The authors assume the demand in each period is random and contingent on the price and the price history as captured by the reference price. The company has to give a pricing decision and determine the inventory level at each period to maximize its discounted expected profit.

The good news is that the replenishment policy is still an order-up-to policy, which is used widely in the practice of inventory management. However, the optimal order-up-to level now depends on the reference price as well. For example, if a company has excessive inventory at the beginning of the period, it is not at liberty to decrease the price too much because doing so will decrease the reference price in the future. Based on a computational study, they show that the company stocks and charges more as long as the consumers believe the product is a good bargain.

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Co-variates help predict electricity's market price

Over the past few decades the electricity sector in most developed countries has undergone a transition from state-controlled monopolies to market settings with many specialized players. Electricity now is traded on exchanges and its price is determined by supply and demand.

While electricity consumption was the main source of uncertainty under the old regime, volatile prices at exchanges add an additional risk dimension to planning processes in the new deregulated market setting. Due to the low price elasticity of consumer demand and the nonstorability of electricity, electricity spot prices are notoriously hard to forecast and exhibit a variety of special features like nested seasonalities, negative prices, jumps and spikes. Hence, understanding the dynamics of electricity prices is instrumental in operational planning and dispatch of power plants, as well as in power trading.

Electricity price modeling is dominated by financial econometrics. Typical models consider electricity prices as isolated from other observable quantities like temperature, prices of other forms of energy or electricity demand. However, practitioners know from their experience that such variables are instrumental in understanding the dynamics of electricity prices.

Forecasting day-ahead electricity spot prices is the aim of "A Semiparametric Model for Electricity Spot Prices" by Raimund M. Kovacevic of the University of Vienna and David Wozabal of Technical University Munich. The article is based on research related to the project "Energy Policies and Risk Management for the 21st Century," funded by the Wiener Wissenschafts-, Forschungs- und Technologiefonds (WWTF).

The approach captures the dependency of electricity prices on co-variates, such as demand for electricity, amount of energy produced by intermittent sources and weather-dependent variables. Forecasted production by wind turbines plays a special role in explaining negative prices. The estimation procedure combines the use of principal component analysis with semiparametric single-index models, where the link function of a generalized linear model is estimated by locally linear Kernel regression.

Raimund M. Kovacevic (left) and David Wozabal, shown here at the WWTF kickoff meeting, discuss new ways to forecast electricity prices.

The proposed approach is applied to data from two markets: the European Energy Exchange and the Pennsylvania-New Jersey-Maryland Interconnection. The models show good in-sample and out-of-sample performance as compared to several models from the literature and some approaches widely used by practitioners.

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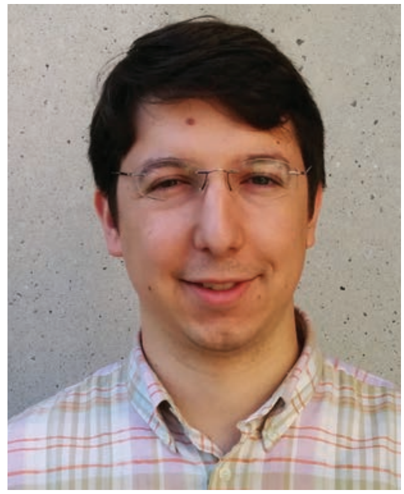
The most recent issue of The Engineering Economist *(Volume 58, Number 4) contains three articles, one of which is highlighted here. In it, the authors introduce a novel approach to thinking about and modeling the economics of scale in engineering design.*

Thinking small

Infrastructure investments, for example in energy or materials processing, tend to have one thing in common – a very large unit size. However, the advent of low-cost automation technologies has made it possible to provide the same aggregate capacity at similar (or lower) cost by scaling up in numbers of units rather than in unit size.

Like the shift from single-processor to massively parallel computing, this change may jolt industries now considered mature and significantly alter our approach to new technology development.

Empirically, we know capital cost tends to decline with the size of a unit or process equipment. This has resulted in notions like the "two-thirds law," which describes the underlying power law relating cost and unit size. Yet looking at cost reductions due to learning curves in mass production, the same power law emerges, albeit through very different mechanisms. Hence, once labor cost is automated away, the total cost of "building larger" and "building more" scales similarly with increasing capacity. Moreover, the increased flexibility (locational, financial and operational) that accompanies a smaller unit scale suggests that economies of numbers can in fact dominate traditional economies of (unit) scale.



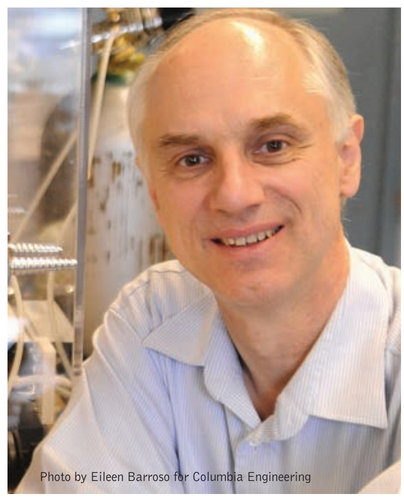


Photo by Eileen Barroso for Columbia Engineering

Eric Dahlgren (clockwise from top left), Caner Göçmen, Klaus Lackner and Garrett van Ryzin present the case that low-cost automation technologies could lead to scaling down industrial infrastructure.

In "Small Modular Infrastructure," Eric Dahlgren, Caner Göçmen, Klaus Lackner and Garrett van Ryzin of Columbia University present a novel approach to understanding the economics of scale in engineering design. Citing current examples, such as the design of small modular nuclear reactors, they present empirical evidence and begin to construct a framework for a theory of "unit scale" as opposed to the conventional view that design has to "scale up."

Even in circumstances where the underlying physics would suggest that a larger scale is more efficient, the authors show that this can prove insignificant in terms of the ultimate bottom line. For instance, a statistical analysis of the operational cost of generating electricity in thermal power plants in the United States shows no correlation between larger generators and lower cost once labor is excluded. This result is interesting considering the observed evolution toward larger units across all thermal generating technologies.

Case studies as well as theoretical arguments beckon the engineering and business communities to abandon the entrenched question, "Does this technology scale up?" as a litmus test for further development. Instead, the history of the computer industry reveals the tremendous potential of scaling down, conforming to standards and using mass production. This shift will put emphasis on design for manufacturability and automation technologies that enable unattended and nearly fault-free operation. The result could be a radically altered landscape for the industrial infrastructure that supports our global economy.

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About the journals

IIE Transactions is IIE's flagship research journal and is published monthly. It aims to foster exchange among researchers and practitioners in the industrial engineering community by publishing papers that are grounded in science and mathematics and motivated by engineering applications.

The Engineering Economist is a quarterly refereed journal devoted to issues of capital investment. Topics include economic decision analysis, capital investment analysis, research and development decisions, cost estimating and accounting, and public policy analysis.

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