Extended Abstract: Integrating Managerial Insight with Optimal Algorithms

What is the economic value of human intelligence and problem-solving when making business decisions? If a survey of laboratory studies in behavioral operations were compiled to address this question, a disturbing picture would appear: Nearly every study would suggest that human involvement in decision-making confers a negative value compared to some alternative decision-making strategy. If this assessment were taken seriously, businesses would be wise to replace a human managers with algorithms that could automatically implement these “optimal” strategies without the costly misguidance (or demand for salaries) of humans. Human decision-making appears to be fundamentally inadequate in laboratory studies because of the way in which they are conceived and designed. The purpose of most experimental research is to test the validity of normative theory. If theoretical findings are to be applicable, experimental settings must adopt all assumptions required by the model. To maintain experimental control, researchers eliminate all complicating features of the real world that are not explicitly under examination. The resultant testing environments ensure the optimality of theoretical results but are impoverished otherwise. The areas in which humans excel – persuasion, creativity, institutional knowledge, etc. – are rendered useless. Most experiments reward precise mathematical calculation above all else. Imagine a math competition between Isaac Newton and a child with a calculator. If points were awarded based on speedy and unerring algebraic computation, the latter would surely win.

Humans have access to a broad range of information that may influence demand but is not typically available to automatable optimization routines. Managers can observe geopolitical and macroeconomic developments, local trends and conditions, and consumer sentiment in real time and then estimate the influence of these factors on demand without any preexisting causal model. Now, there is bound to be substantial noise in this forecasting process, and the well-documented shortcomings of human decision-making may undermine managers’ superior information.
In a normative model and laboratory experiment, we investigate techniques to integrate the superior information possessed by human managers with the superior computational capacity and precision of automated algorithms. Because of its simplicity and pervasiveness in the behavioral OM literature, we adopt a newsvendor setting. However, it should be noted that our general approach can be applied to a wide variety of operational settings.

We assume that human managers can observe a noisy signal of the upcoming demand realization (representing “managerial insight”) and know the distribution from which true demand is drawn. We model managers’ signals as the true demand realization plus a mean-zero normally distributed perceptual error term. Using Bayes’ rule, rational managers can update their beliefs about demand conditional on the value of the signal. This posterior distribution of demand will have a lower variance compared to the unconditioned prior and will be pulled toward the signal. Applying the standard newsvendor critical fractile solution to the conditional demand distribution yields a managerial insight-informed optimal order quantity. In a numerical analysis, we compare expected newsvendor profits with and without the benefit of managerial insight under two different functional forms of demand (uniform and normal). The relative improvement in profitability conferred by managerial insight is decreasing in the critical fractile and (not surprisingly) in the variance of perceptual errors. Insight tends to increase expected profit by 5% to 10%, but the benefit can be substantially larger for some parameterizations.

However, achieving this upper bound on profitability requires substantial calculation – much more than required in the typical newsvendor setting where a vast literature shows persistent (and costly) sub-optimal ordering by human participants. If we were to simply compare human decision-making to fully automated (optimal) algorithms (as is typical in behavioral OM), we would have to choose between utilizing superior information or superior computation. Should it not be the case that the “optimal” solution exploits both superior information and computation?
Interestingly, Schewitzer and Cachon allude to the integration of managerial insight and standard optimization in their seminal 2000 paper that has invited so much subsequent research. “While the forecasting task typically requires managerial judgment, the task of converting a forecast into an order quantity can be automated. A firm may reduce decision bias by asking managers to generate forecasts that are then automatically converted into order quantities.” Our model is designed to capture this feature that forecasting “requires managerial judgement.” To bring managerial insight into the lab, we introduce a novel perceptual task. In a controlled laboratory experiment, subjects (representing inventory managers) receive a “preview” of upcoming demand. An image comprised of many dots is flashed on the screen for a few seconds; each dot represents one unit of demand in the next period (demand is distributed normally with mean 200 and standard deviation 25 or uniformly between 150 and 250). While it is impossible to count hundreds of dots instantly, this signal does give a general sense of upcoming demand. Subjects are asked to give a point estimate of the number of dots shown without any knowledge of the underlying newsvendor ordering decision. Payment is based only on estimation accuracy. We observe the “pull-to-center” effect in estimates which is predicted by theory. Subjects that are aware of their own perceptual error should report an estimate that is different (and pulled toward mean demand) from their true signal (here, “signal” refers to subjects’ initial estimate before this Bayesian hedging). We propose a parsimonious approach with no free parameters to estimate subjects’ perceptual acuity from their past demand estimates (for which true realizations are known) and the value of their observed signal from their current estimate. We can then mechanically compute the optimal insight-informed order quantity. Profits achieved using this approach are higher than those from the standard (non-informed) critical fractile order quantity and from (informed) human-generated order quantities. Our approach effectively extracts managers’ superior information and optimally applies it to the newsvendor ordering task.