Behavioral Operations Management (BOM):

Application of Experimental Economics

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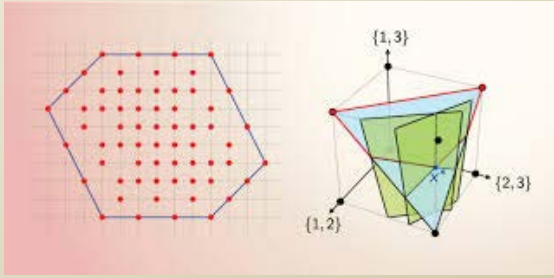
What is Operations Management?

- Operations Management (OM) is an area of business that deals with:
  - Designing and controlling manufacturing and service processes
  - Two broad areas:
    - Strategic: Supply Chain Management
    - Tactical: Logistics
- Related to Operations Research (OR)
  - More about problems and less about methods



OM in the 60's and 70's used to be Logistics, and mostly about central planning

- Supply Chain Design
- Job-shop scheduling
- Lot Sizing
- Queuing Systems
- Inventory Management
- …

The scope of OM

The scope of OM

Operations Management Evolution

- 1980s-1990s: decentralized models (Game Theory)
  - Incentives
  - Contract Negotiation
  - Social Norms
  - Trust
- Requires a model of individual (firm) decision-making.

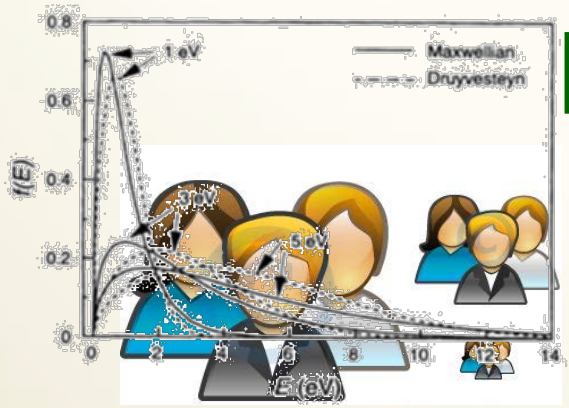
Decentralized Model

Behavioral Operations Management (BOM)

- Understand what decision-makers are doing
- Develops behaviorally-robust models
- **The Goal**: to explain, predict and improve operations.

Decentralized Model

The case of the newsvendor problem



Customers

Retailer

The profit: $\pi(q, D) = p \min(q, D) - cq$

The expected profit to be maximized:

$$\mathbb{E}[\pi(q, D)] = \big(1 - F(q)\big)(p - c)q + \int_0^q f(x)\pi(q, x)dx$$

The optimal order quantity q^* must satisfy:

$$F(q^*) = \frac{p - c}{p}$$

Critical Ratio (CR)

Arrow (1951)

The case of the newsvendor problem

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Decision Bias in the Newsvendor Problem with a Known Demand Distribution: Experimental Evidence

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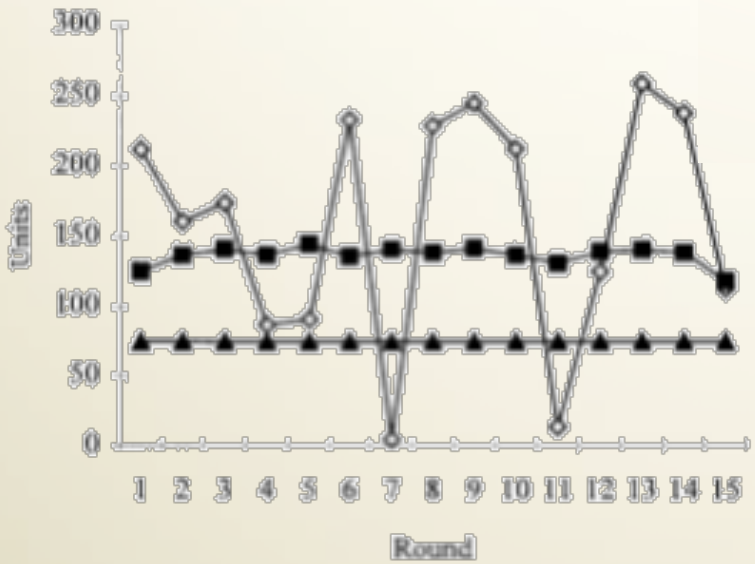
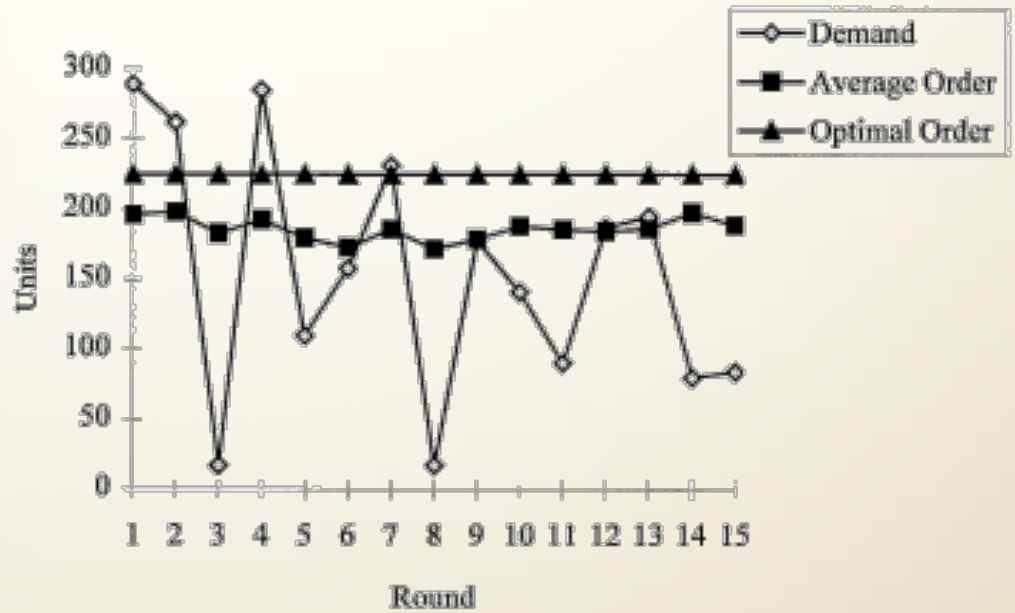
In the newsvendor problem a decision maker orders inventory before a one period selling season with stochastic demand. If too much is ordered, stock is left over at the end of the period, whereas if too little is ordered, sales are lost. The expected profit-maximizing order quantity is well known, but little is known about how managers actually make these decisions. We describe two experiments that investigate newsvendor decisions across different profit conditions. Results from these studies demonstrate that choices systematically deviate from those that maximize expected profit. Subjects order too few of high-profit products and too many of low-profit products. These results are not consistent with risk-aversion, risk-seeking preferences, Prospect Theory preferences, waste aversion, stockout aversion, or the consequences of underestimating opportunity costs. Two explanations are consistent with the data. One, subjects behave as if their utility function incorporates a preference to reduce ex-post inventory error, the absolute difference between the chosen quantity and realized demand. Two, subjects suffer from the anchoring and insufficient adjustment bias. Feedback and training did not mitigate inventory order errors. We suggest techniques to improve decision making.
(*Behavioral Operations*; *Newsvendor Inventory Decisions*; *Decision Bias*; *Anchoring*; *Minimizing Ex-Post Inventory Error*)

Findings



Low profit: CR = 0.25



High profit: CR = 0.75

① The "Pull to Center" Bias
② Asymmetry: low CR is further from optimal (closer to mean demand)
③ Little learning

condition (26 of 33 did). Of the four subjects who ordered exactly 225 units in the first round, two decreased their order quantities in subsequent rounds.

3.1.3. Discussion. Experiment 1 establishes the too low/too high pattern in inventory orders as a robust phenomenon that persisted across multiple periods with feedback. These results cannot be explained exclusively by risk aversion, risk-seeking preferences, loss aversion, waste aversion, stockout aversion, or underestimation of opportunity costs. A combination of these preferences, such as stockout

the decision maker is more likely to increase their orders in the low-profit condition than in the high-profit condition, all else being equal. That effect would lower q_n adjustment scores in the low-profit condition relative to the high-profit condition. There is also a third plausible explanation. Since the absolute stakes were higher in the high-profit condition, subjects may have exerted more effort in that condition, leading to choices that were closer to optimal.

The second noteworthy pattern is that the average choice was remarkably stable across rounds, as is clearly observed in Figures 1 and 2. This result sug-

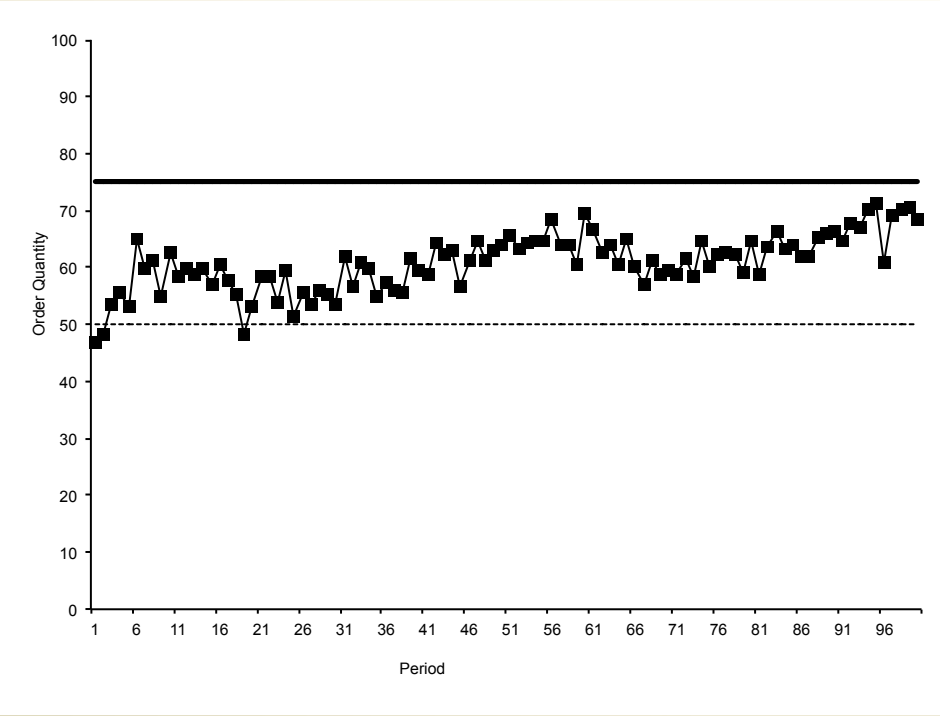
These results cannot be explained exclusively by risk aversion, risk-seeking preferences, loss aversion, waste aversion, stockout aversion, or underestimation of opportunity costs.

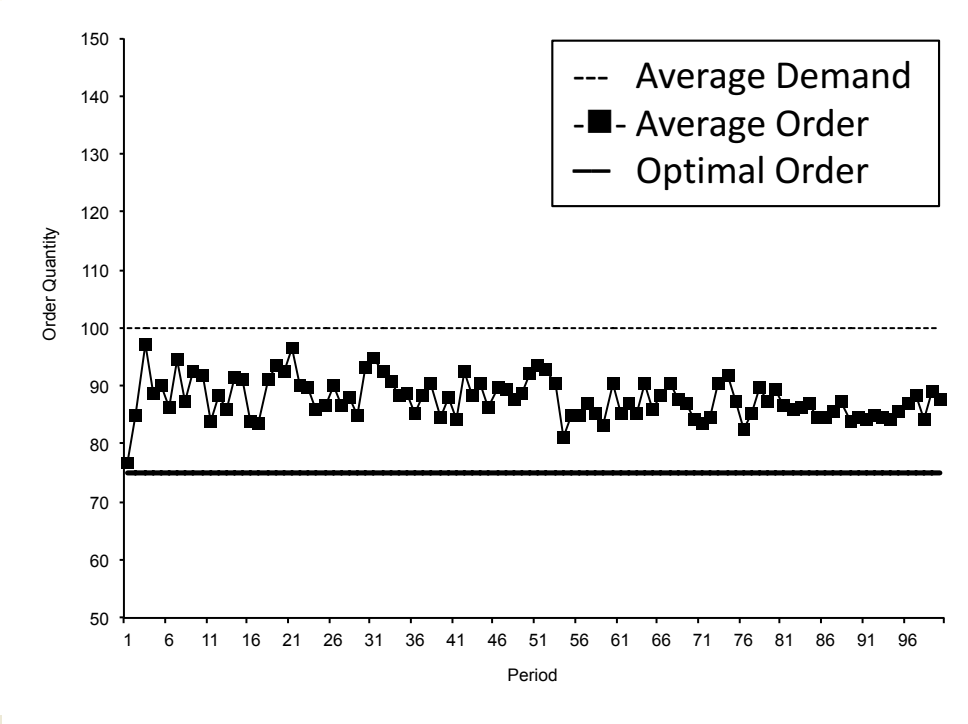
risk-seeking in losses than risk averse in gains. Alternatively, the asymmetry could be explained with a combination of preferences. For example, suppose a decision maker wishes to minimize ex-post inventory error and avoid stockouts. Recall that the latter preference causes the decision maker to increase their order quantities. Since stockouts are more likely in the low-profit condition than in the high-profit condition,

averse and therefore always order less than q_n. Hence, in this setting the too low/too high pattern is not consistent with Prospect Theory.

As before, subjects in this experiment received feedback after each round of decisions. In addition, all of the subjects in this experiment had formal training in the newsvendor problem. Consequently, this experiment investigates whether the too low/too high pat-

The “Pull to Center“ Bias Appears to be Generally Persistent…



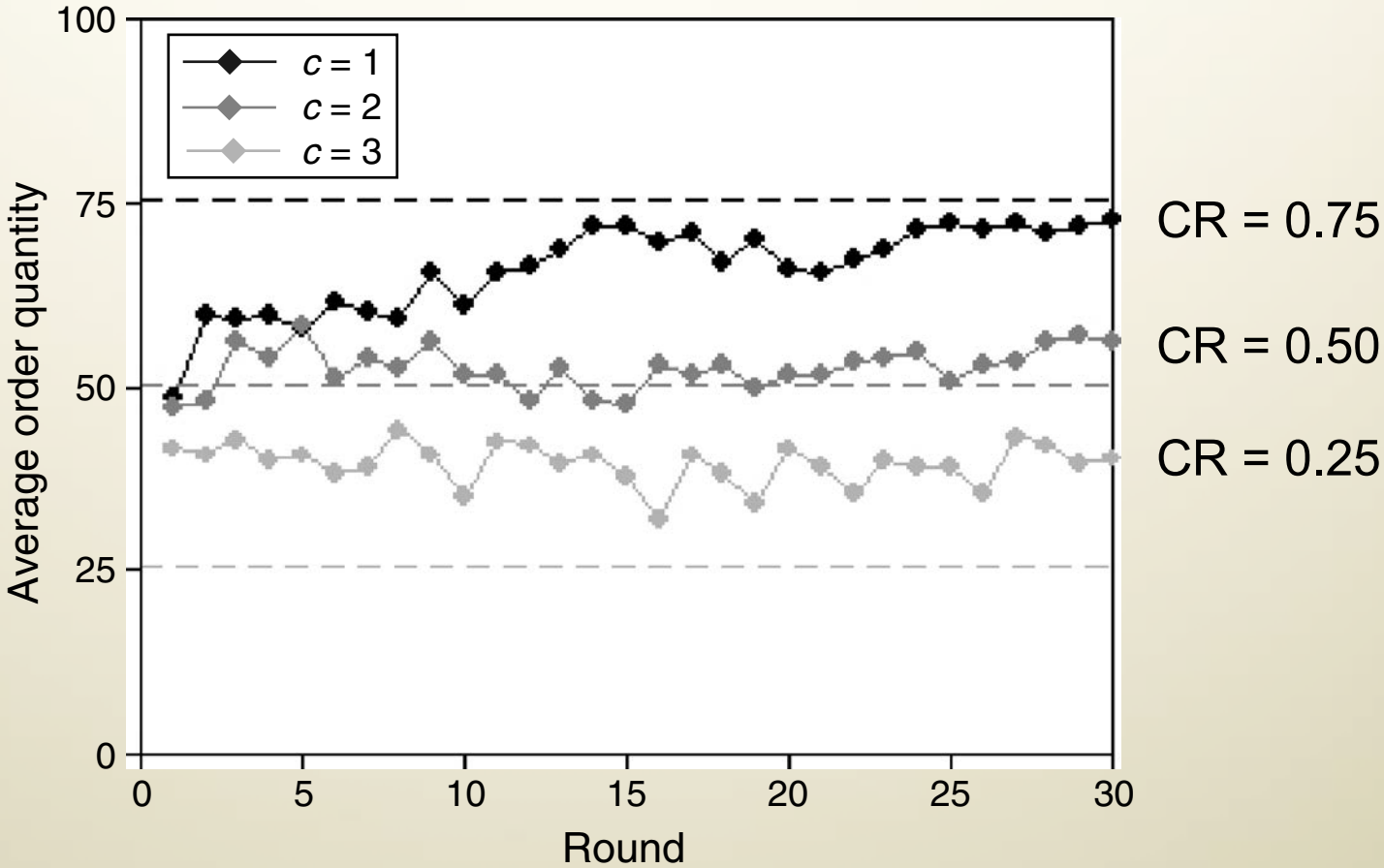


High profit: CR = 0.75

Low profit: CR = 0.25

Source: Bolton and Katok (2008)

The "Pull to Center" Bias Appears to be Generally Persistent…



Source: Bostian, Holt and Smith (2008)

The asymmetry result is less robust: this dataset does not show much of an asymmetry

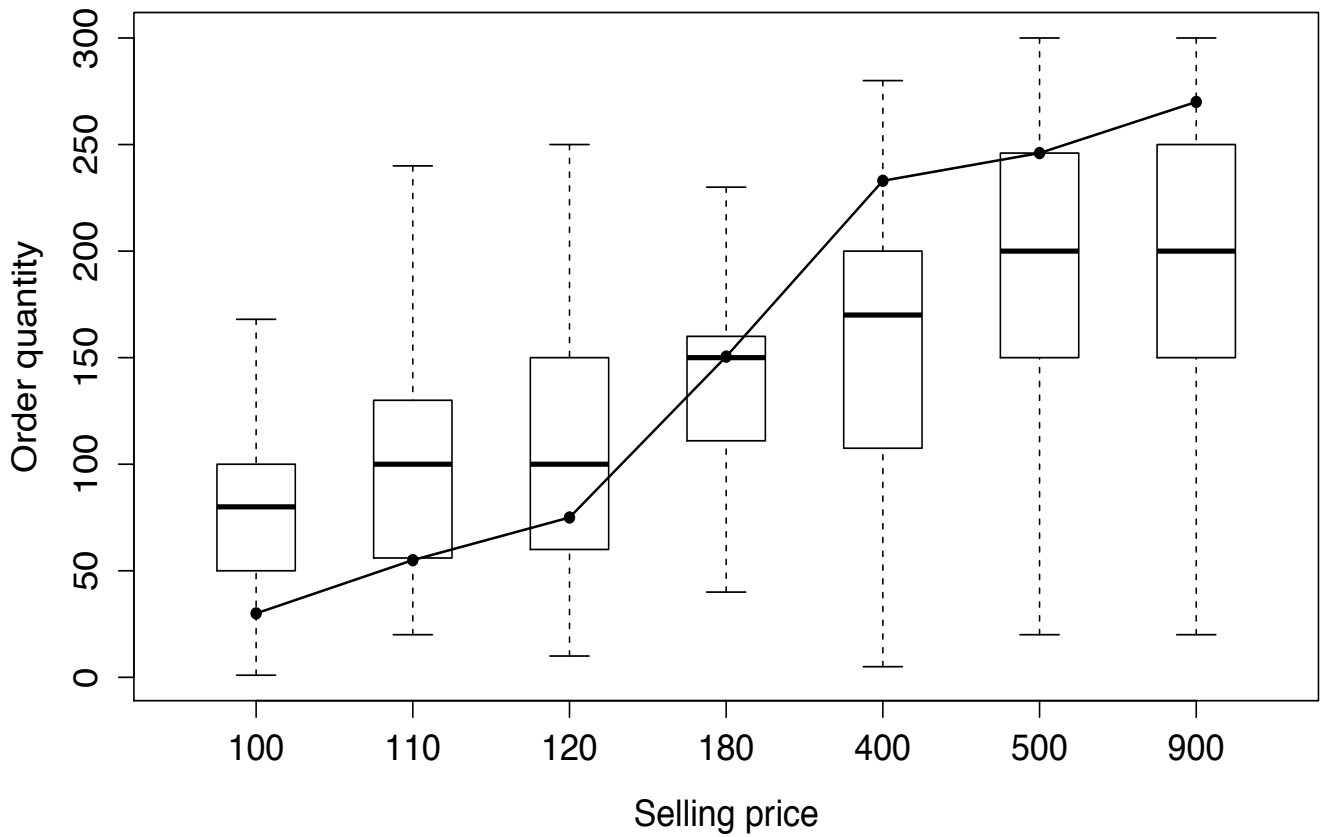
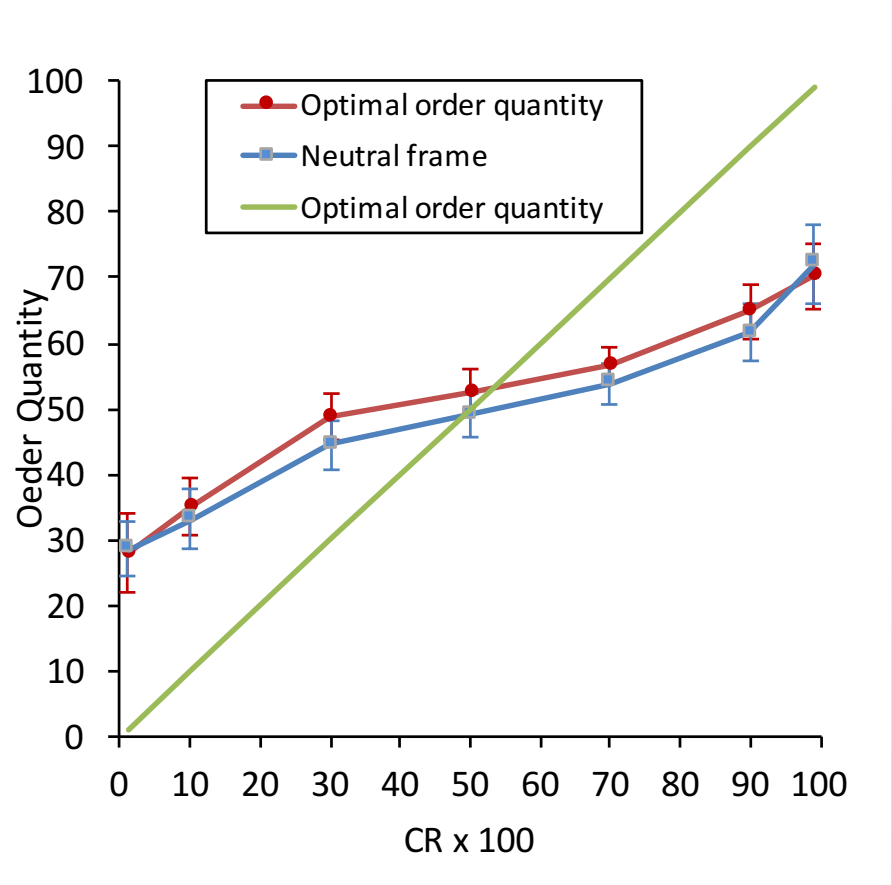


Figure 3: Box-and-whisker plot and standard optimal order quantities

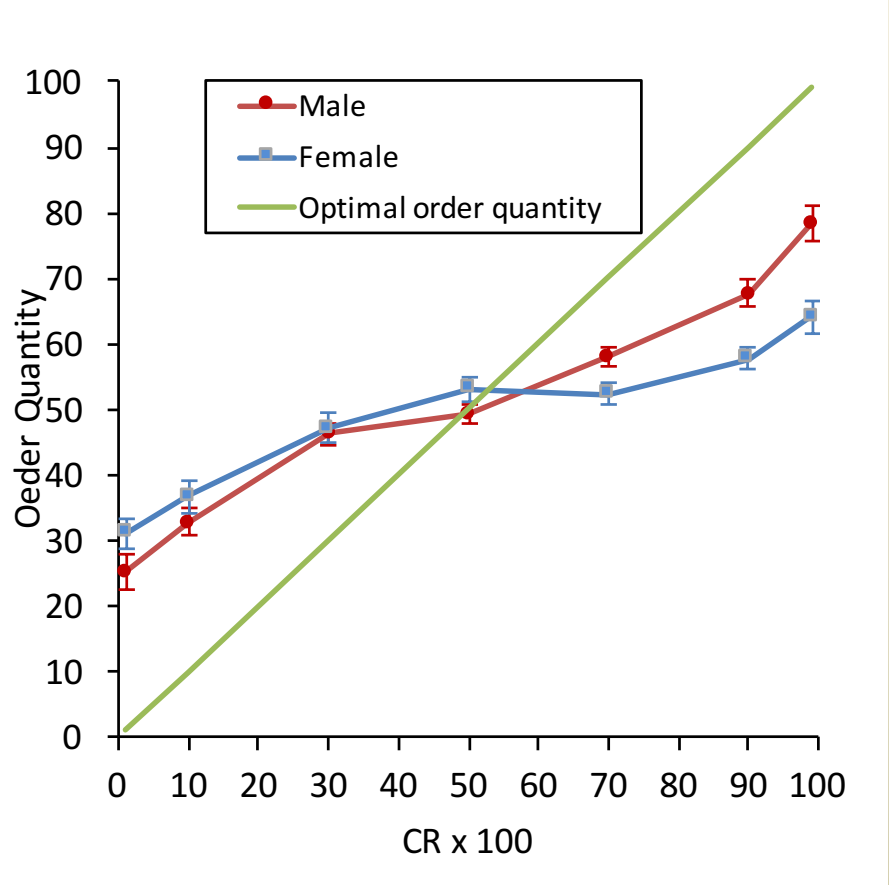
Source: Zhao, Geng, Chao and Zhang (2011)

Robustness to framing and somewhat robust to gender

Framing



Gender

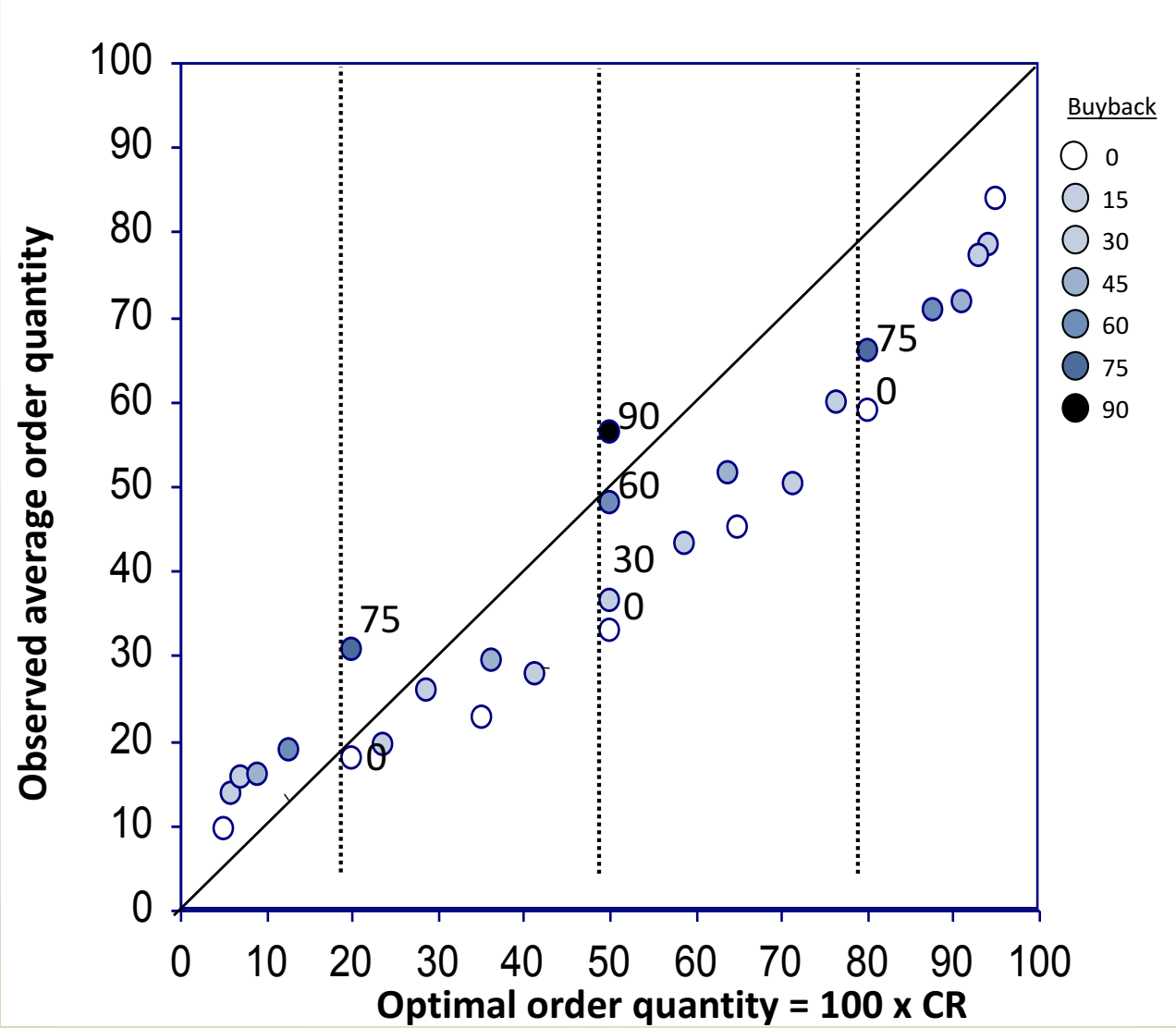


Source: Stangl and Katok and Thonemann (2017)

…while this one shows low CR is better (closer to optimal than high CR)

Source: Ockenfels and Selten (2013)

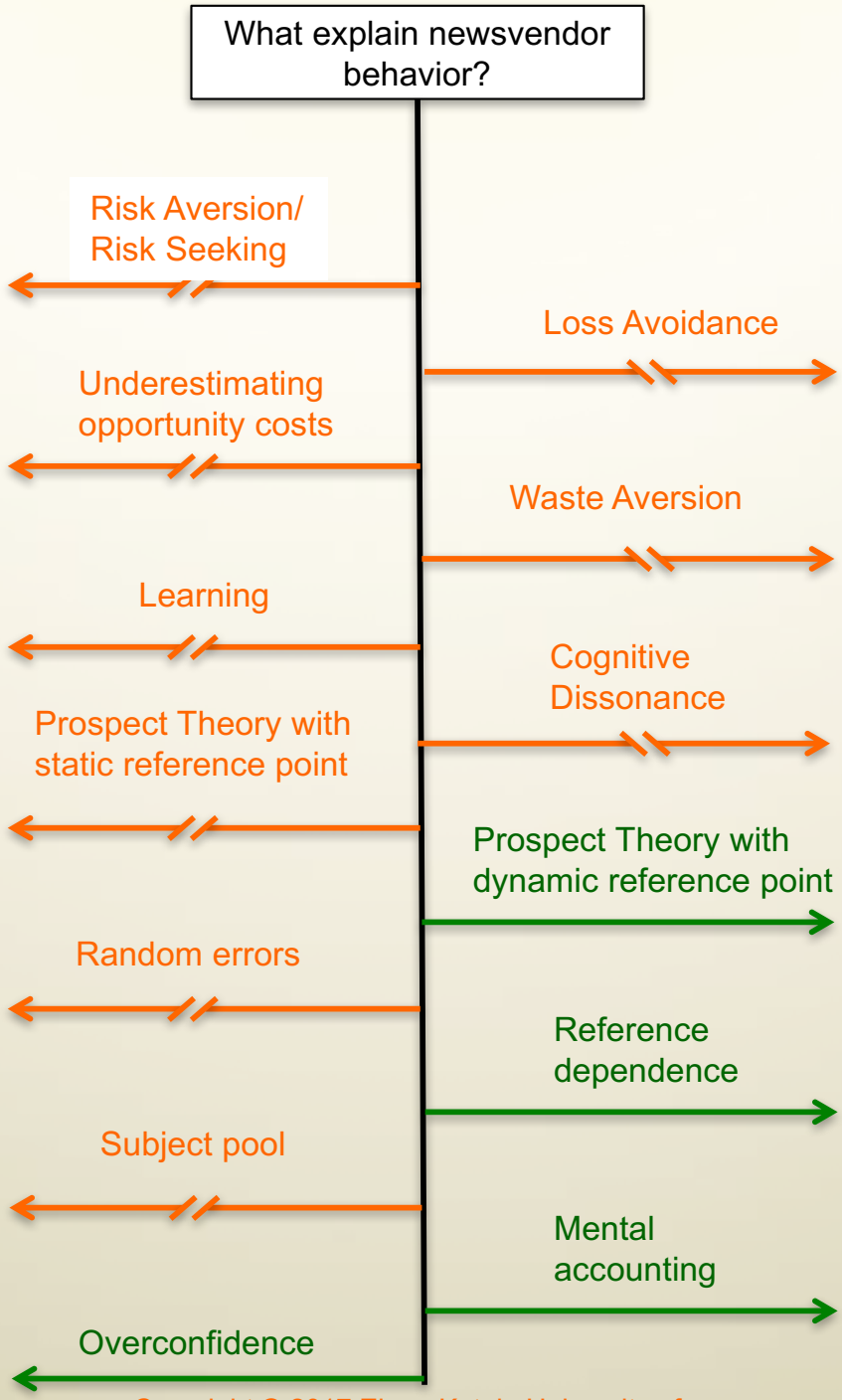
Asymmetry persists with the Buy-back contract



Source: Becker-Peth, Katok and Thonemann (2013)

Hypothesis Tree

Branches are hypotheses addressing questions at the base.
Cut branches indicate hypotheses found "unsatisfactory."

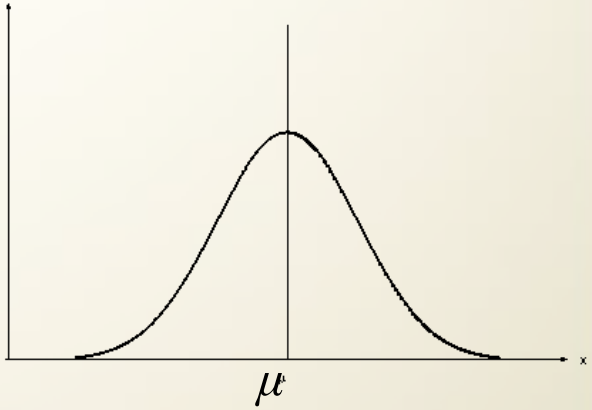


Decentralized Model

Supply Chain Contracting

Supplier
(Seller)

Manufacturer
(Buyer)



Demand $\boldsymbol{D} \sim \boldsymbol{F}()$
Market price $\boldsymbol{P}$

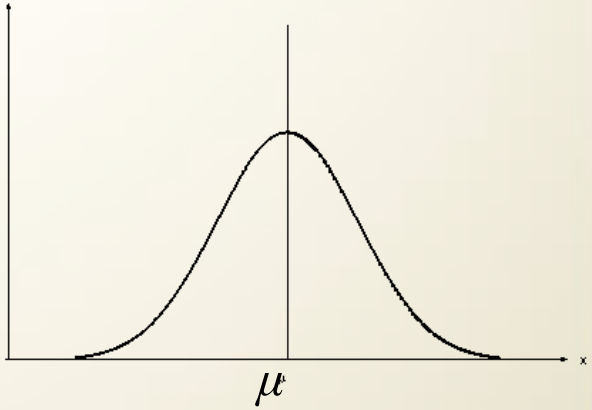
This has the structure of the the much-studies **Stackelberg Game**:

- Seller is the first mover: proposes a contract terms (eg. w)
- Buyer id the "Newsvendor" chooses order quantity (q)

Wholesale Price Contract

Supplier
(Seller)

Manufacturer
(Buyer)



Demand $\boldsymbol{D} \sim \boldsymbol{F}()$
Market price $\boldsymbol{P}$

The Buyer pays the Seller $\boldsymbol{w}$ for each unit ordered:

$$\pi_{Supplier} = (w - c)q$$

$$\pi_{Retailer} = p \min(D, q) - wq$$

$$\pi_{Channel} = p \min(D, q) - cq$$

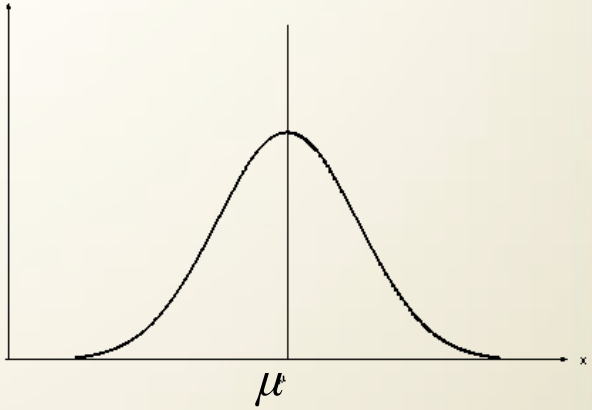
Double Marginalization

- The Buyer orders less than the efficient amount under the wholesale price contract.
- Contracts can be designed to “coordinate” the channel.

Buyback Contract

Supplier
(Seller)

Manufacturer
(Buyer)



Demand $\boldsymbol{D} \sim \boldsymbol{F}()$
Market price $\boldsymbol{P}$

The Buyer pays the Seller $\boldsymbol{w}$ for each unit ordered and the Seller return to the buyer $\boldsymbol{b}$ for each un-sold unit:

$$\pi_{Supplier} = (w - c)q - b\max(0, q - \min(D, q))$$

$$\pi_{Retailer} = p\min(D, q) - wq + b\max(0, q - \min(D, q))$$

$$\pi_{Channel} = p\min(D, q) - cq$$

Automated Buyer

- Coordinating Contracts don't work well
  - Buyback: Katok and Wu 2009,
  - Service Level Agreements: Davis 2014,
  - Advance Purchase discount: Davis et al. (2014)

Sellers do not take sufficient risk to coordinate the channel.

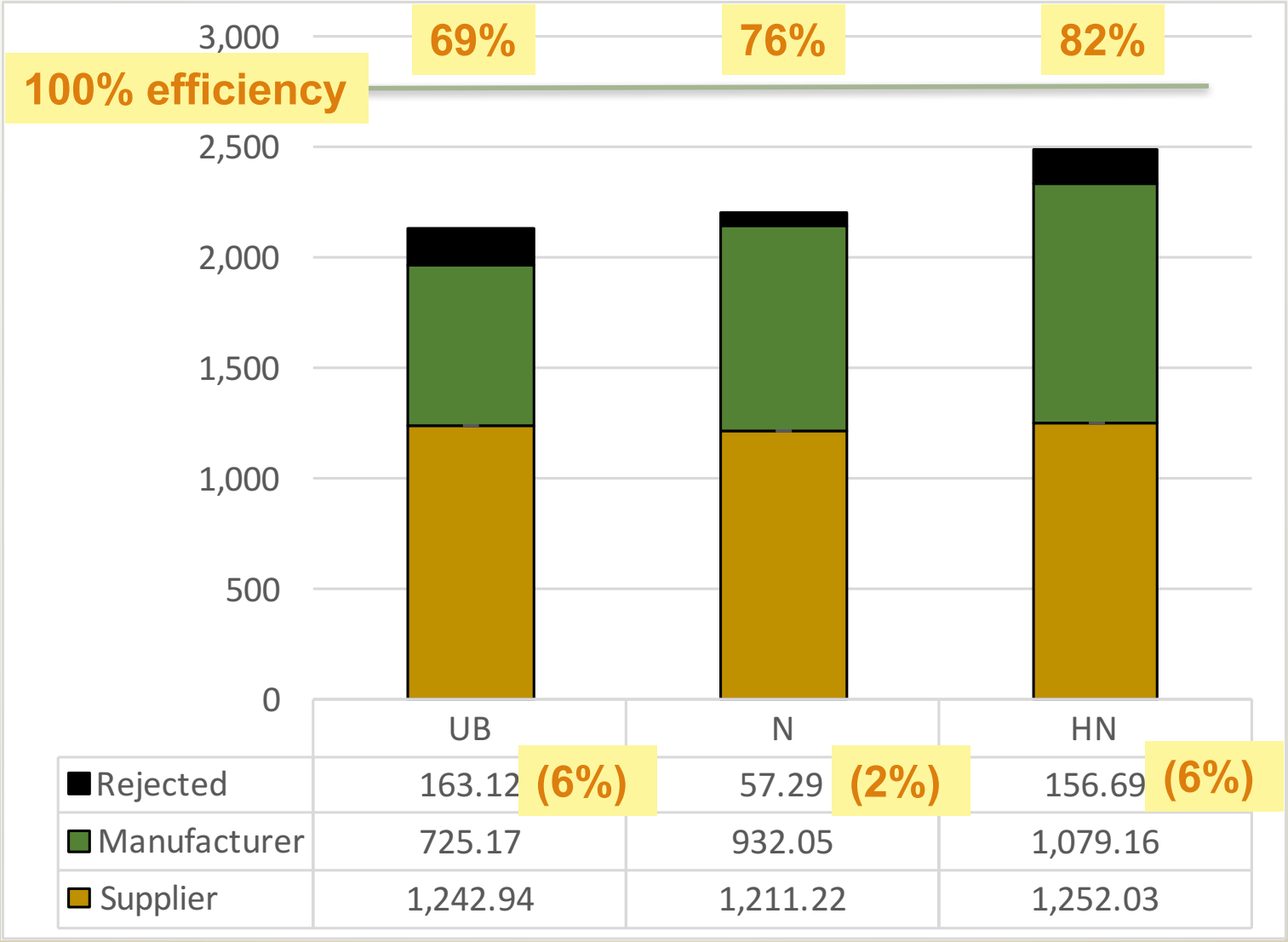
Human Buyer and Seller

Efficiency

	Contract Process		
Contract Structure	Ultimatum Offer	Negotiating Price	Negotiating Price & Order Quantity
Wholesale Price (Davis & Hyndman 2017)	63%	63%	77%
Buyback (Coordinating) Becker-Peth et al. (2017)	69%	76%	82%

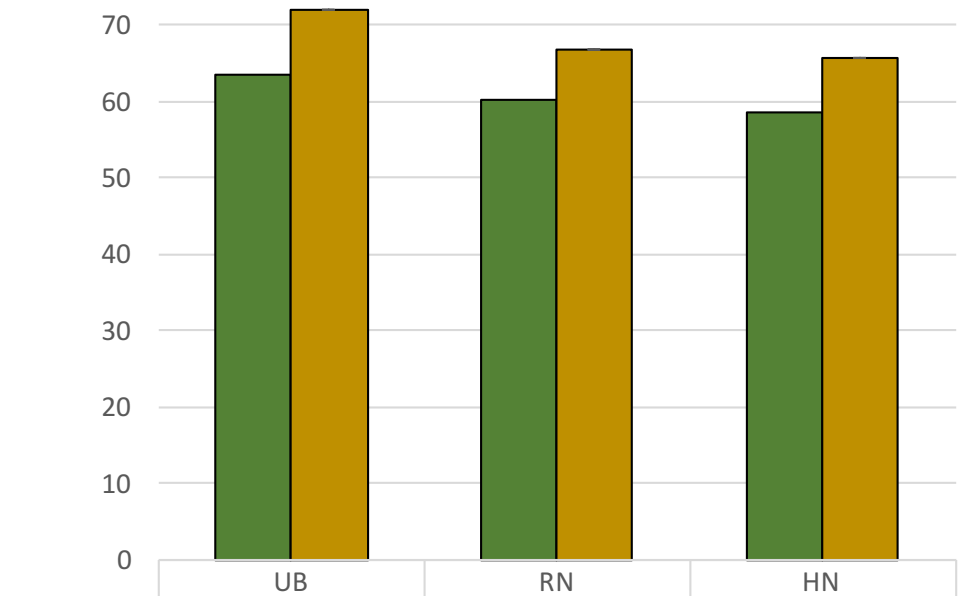
Negotiation Contract Improves Efficiency

(Becker-Peth, Katok and Thonemann working paper)



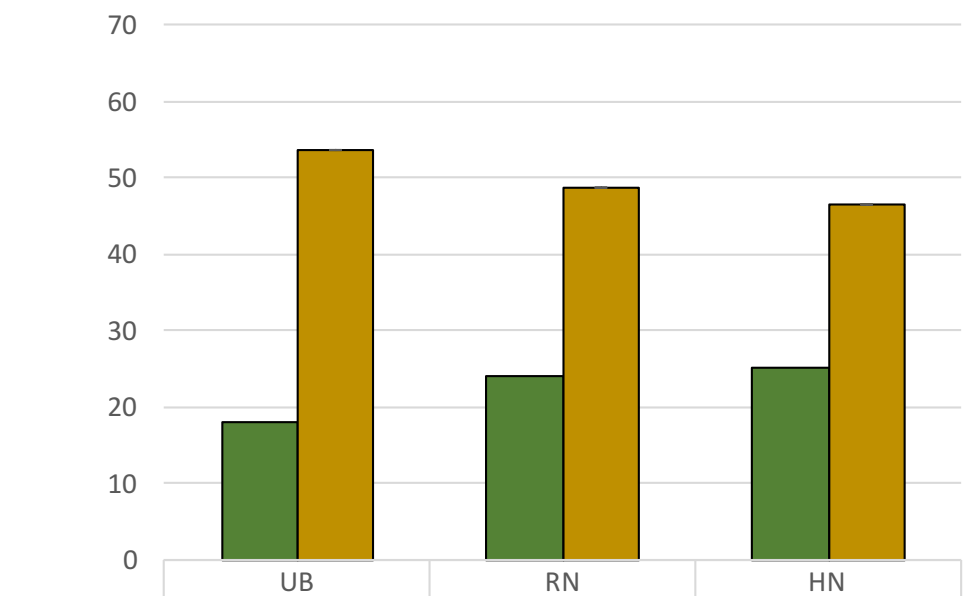
Wholesale Prices and Buybacks: Observed and Efficient

Wholesale Prices (w)



	UB	RN	HN
Observed	63.61	60.12	58.58
Efficient	71.92	66.75	65.62

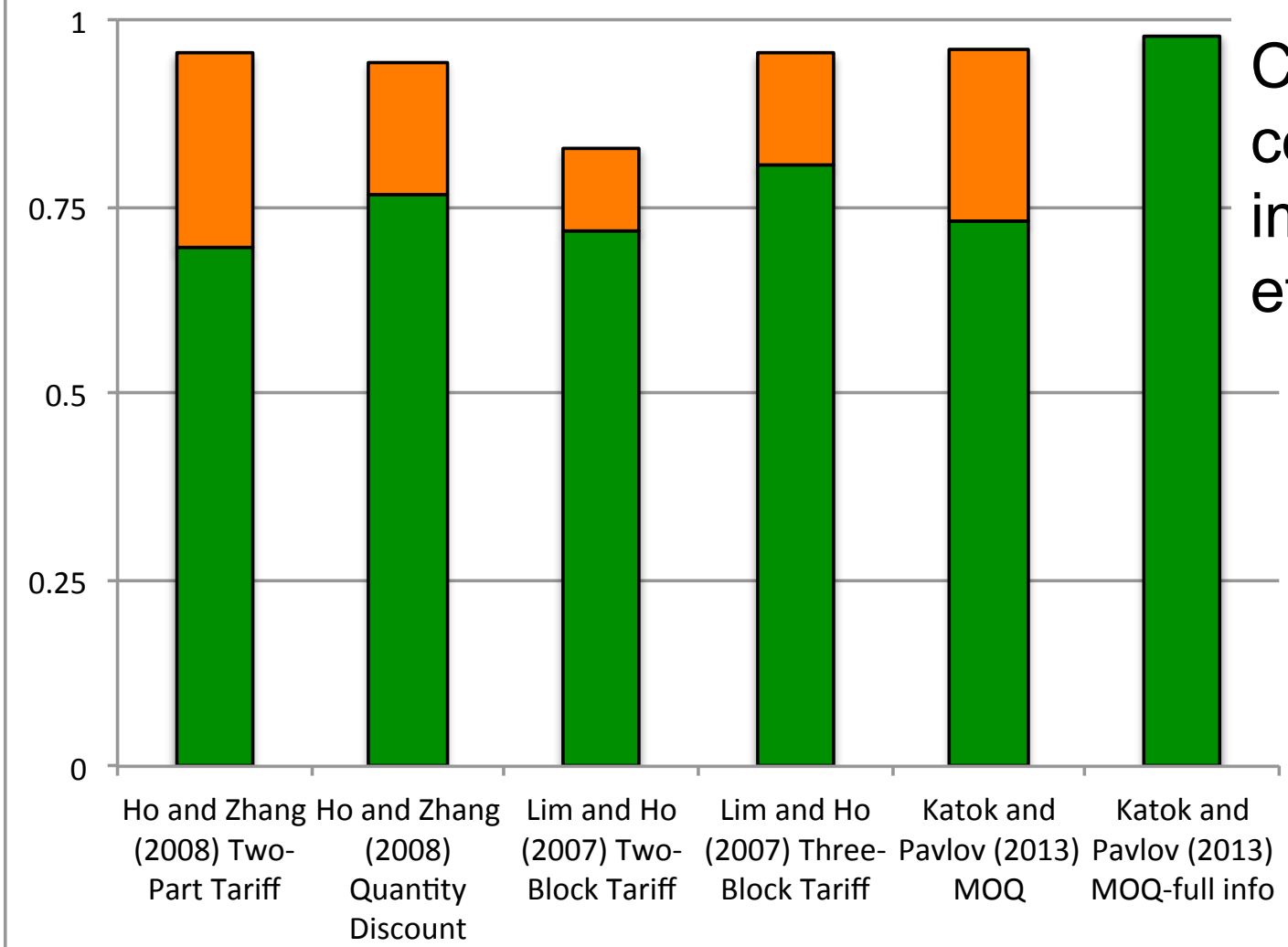
Rebate (b)



	UB	RN	HN
Observed	18.06	23.95	25.04
Efficient	53.65	48.64	46.52

… but **sellers still don't accept enough risk to coordinate the channels**.

BOM Studies of Contracting in the Bilateral Monopoly Setting



Coordinating contracts do not improve efficiency.

Examples of other BOM topics

The Handbook of Behavioral Operations Management

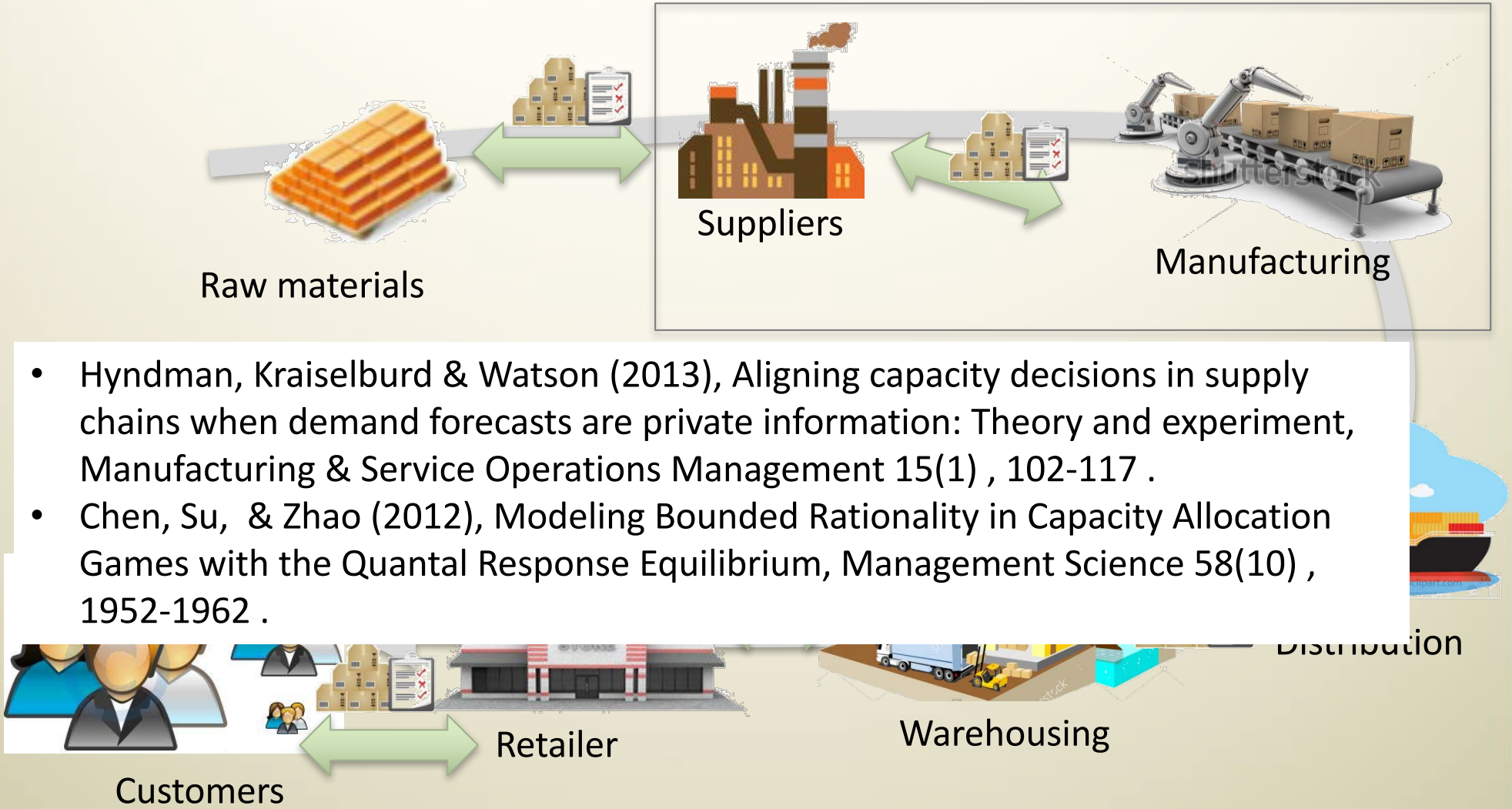
Edited by Donohue, Katok and Leider

To be published by Wiley (soon)

Supply Disruptions

- Gurnani, H., Ramachandran, K., Ray, S., and Y, Xia (2013). Ordering behavior under supply risk: an experimental investigation, Manufacturing & Service Operations Management, 16(1), 61-75.
- Chaturvedi, A., Beil, D., and E. Katok, Split Award Auctions: Insights from Theory and Experiments, Management Science, forthcoming.

Capacity Planning



- Hyndman, Kraiselburd & Watson (2013), Aligning capacity decisions in supply chains when demand forecasts are private information: Theory and experiment, Manufacturing & Service Operations Management 15(1) , 102-117 .
- Chen, Su, & Zhao (2012), Modeling Bounded Rationality in Capacity Allocation Games with the Quantal Response Equilibrium, Management Science 58(10) , 1952-1962 .

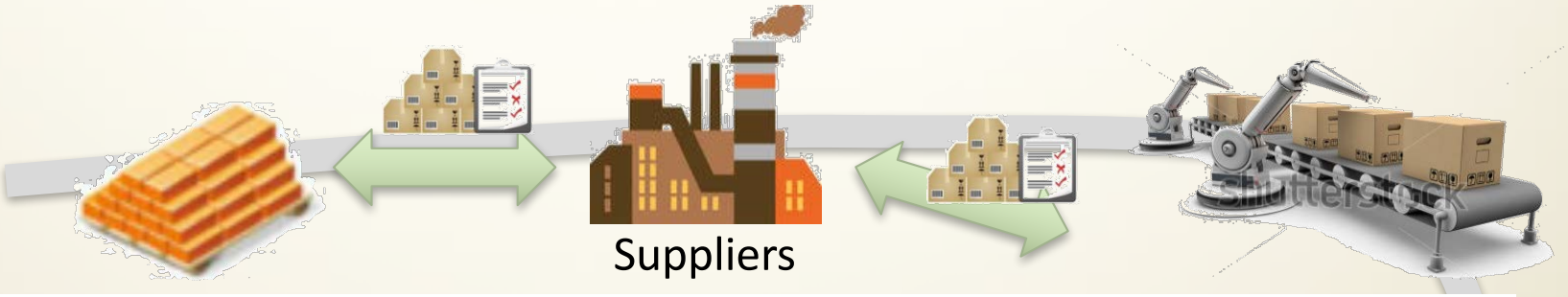
Distribution Networks

- Rapoport, A., Gisches, E. J., & Mak, V. (2014). Distributed decisions in networks: Laboratory study of routing splittable flow. Production and Operations Management, 23, 314-331.
- Mak, V., Gisches, E. J., & Rapoport, A. (2015). Route vs. segment: An experiment on real-time travel information in congestible networks. Production and Operations Management, 24, 947-960.

Retailing Issues

- DeHoratius, Gürerk, Honhon, Hyndman, "Understanding the Behavioral Drivers of Execution Failures in Retail Supply Chains: An Experimental Study Using Virtual Reality" Working Paper.
- Vorotyntseva, Hanhon, Katok, "Can Managers Plan Assortments? An Experimental Study" On-going project.

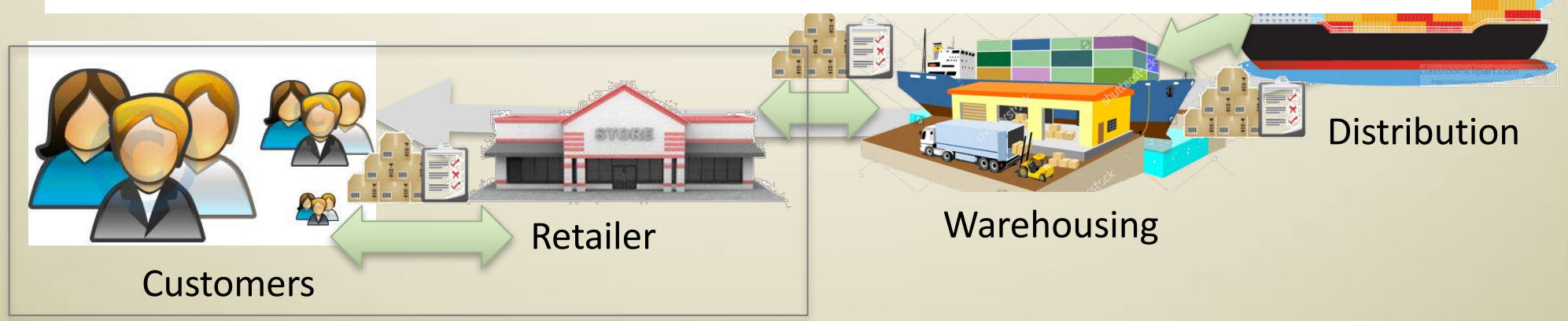
Queueing



- Kremer, M., L. Debo. 2012. Herding in a queue: A laboratory experiment. Working paper, University of Chicago Booth School of Business.
- Kremer, M., L. Debo. 2016. Inferring quality from wait times. Management Science 62(10) 3023–3038.

Strategic Consumers

- Ovchinnikov and Milner Revenue management with end-of-period discounts in the presence of customer learning , Production and operations management 21 (1), 69-84.
- Kremer, Mantin and OvchinnikovDynamic Pricing in the Presence of Myopic and Strategic Consumers: Theory and Experiment, Production and Operations Management 26 (1), 116-133



Forecasting

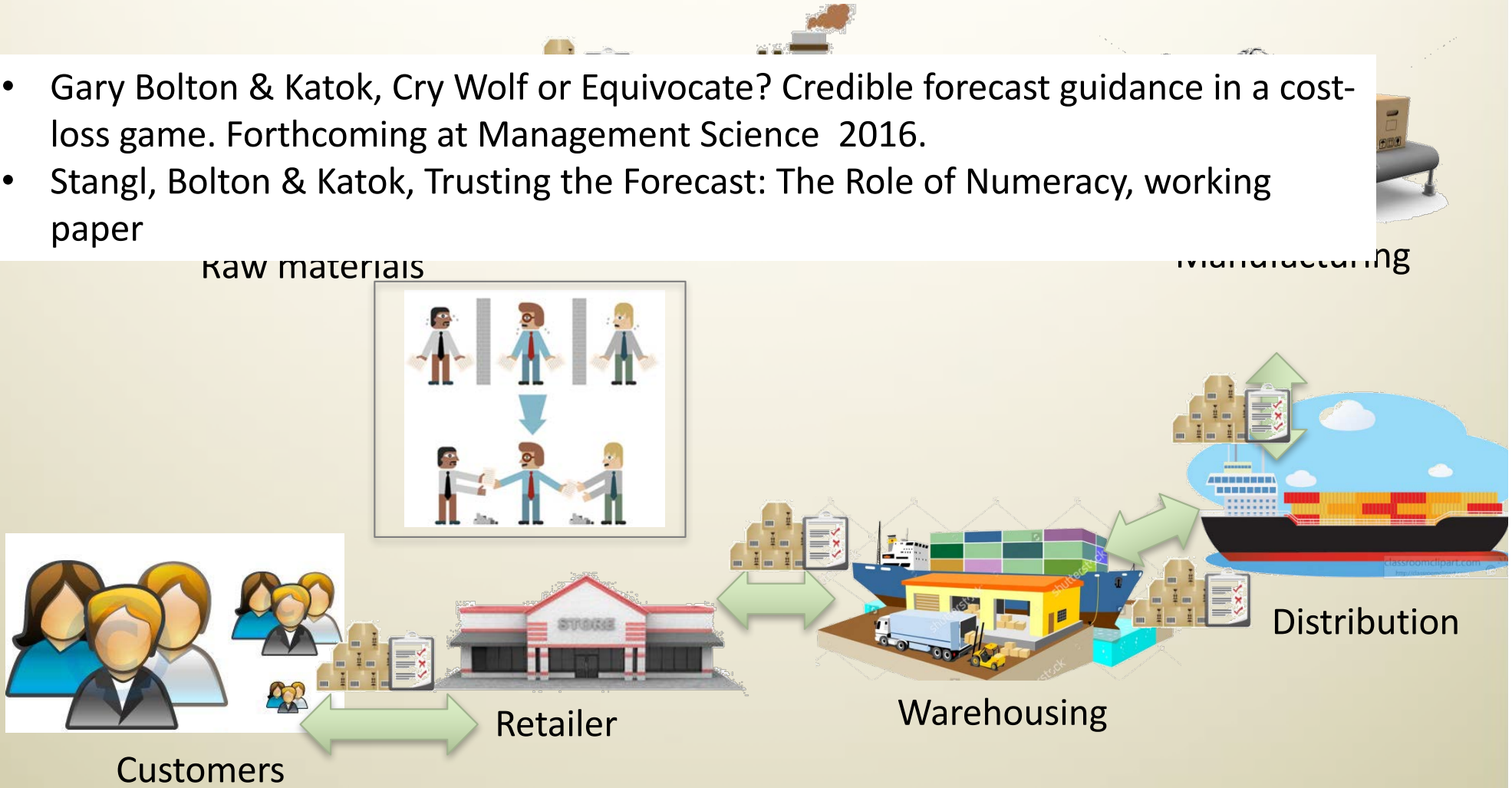
- Kremer, M., Moritz, B., & Siemsen, E. (2011). Demand forecasting behavior: System neglect and change detection. Management Science, 57(10), 1827-1843.
- Kremer, M., Siemsen, E., & Thomas, D. J. (2015). The Sum and Its Parts: Judgmental Hierarchical Forecasting. Management Science, forthcoming.
- Moritz, B., Siemsen, E., & Kremer, M. (2014). Judgmental forecasting: Cognitive reflection and decision speed. Production and Operations Management, 23(7), 1146-1160.

Information Sharing (Trust)

- Ozer, Zheng and Chen (2011) Trust in Forecast Information Sharing, Management Science 57(6) 1111-1137.

Trusting the Forecast

- Gary Bolton & Katok, Cry Wolf or Equivocate? Credible forecast guidance in a cost-loss game. Forthcoming at Management Science 2016.
- Stangl, Bolton & Katok, Trusting the Forecast: The Role of Numeracy, working paper



Conclusion

- Experimental Economics had a great deal of impact.
- These methods are successfully used in many disciplines.