Empirical Newsvendor Biases: Are Target Service Levels Achieved Effectively and Efficiently?

Anna-Lena Sachs

Joint work with Michael Becker-Peth, Stefan Minner and Ulrich Thonemann

CMAF FFT webinar

12/11/2021

Marketing Analytics & Forecasting

Lancaster University Management School

Food waste is a global challenge

Friday 02 September 2016

LANCASTER GUARDIAN

News | Traffic and Travel | Crime | Weather | Politics | Business | E

We could feed whole countries with the amount we waste in the UK

In the retail sector alone, 1.6m tonnes of perfectly edible food goes in the bin.

https://www.lancasterguardian.co.uk/news/we-c
feed-whole-countries-amount-we-waste-uk-6589

MAY 18, 2019

the japan times

NATIONAL

Japanese convenience stores tackle food waste issue; households and restaurants slow to get on board

Unsold food items from convenience stores are seen piled up in Chiba Prefecture. | KYODO

https://www.japantimes.co.jp/news/2019/05/18/national/japanese-convenience-stores-tackle-food-waste-issue-households-restaurants-slow-get-board/#.XlaagWj7SUk

The Guardian

Food

Americans waste 150,000 tons of food each day – equal to a pound per person

Research shows people with healthy diets rich in fruit and vegetables are the most wasteful and calls for better education for consumers

Oliver Milman

@olliemilman

Wed 18 Apr 2018 19.05 BST

https://www.theguardian.com/environment/2018/apr/18/americans-waste-food-fruit-vegetables-study

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Large amounts of food are wasted






Bulk consumer 19%

End consumer 39%

	Harvest	Post-harvest	Processing	Distribution	
Losses	5%	9%	14%	14%	
Probability of avoiding losses	Low	Low	10%	90%	70%

All numbers based on empirical study by WWF, 2015

Source: https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Studie_Das_grosse_Wegschmeissen.pdf

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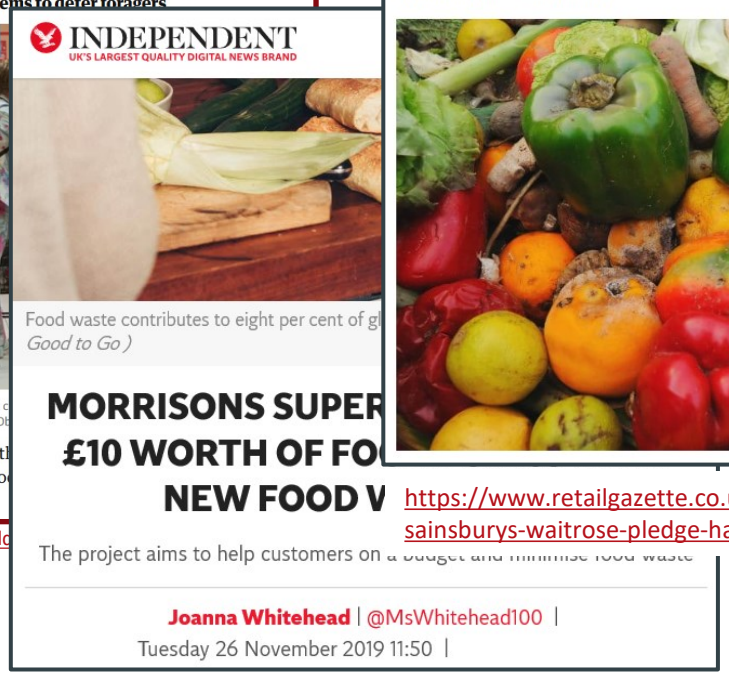
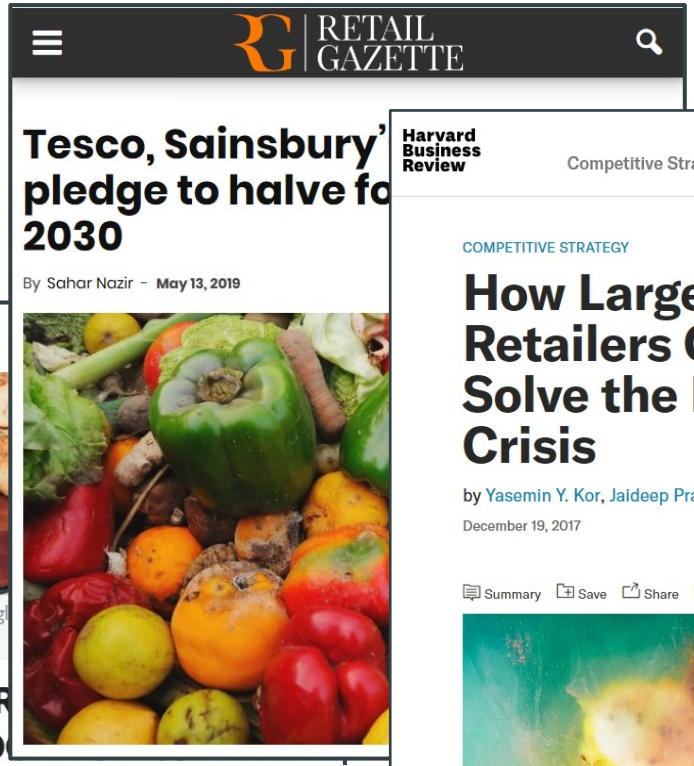
Potential solutions

https://www.theguardian.com/world
food-waste-by-supermarkets



https://www.independent.co.uk/life-style/food-and-drink/morrisons-food-waste-app-download-too-good-to-go-recycling-a9218031.html



https://www.retailgazette.co.uk/sainsburys-waitrose-pledge-halve

https://hbr.org/2017/12/how-large-food-retailers-can-help-solve-the-food-waste-crisis

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Relevance

Leftover inventory

Annual waste

- 10 % of fresh products
- 11 Mio. t in Germany annually

Stockouts

Up to 30 % for perishable products

- 45% substitution
- 55% lost sales

Sources: Buzby et al., 2009; Kranert et al., 2012; Corsten and Gruen, 2003; ECR, 2003

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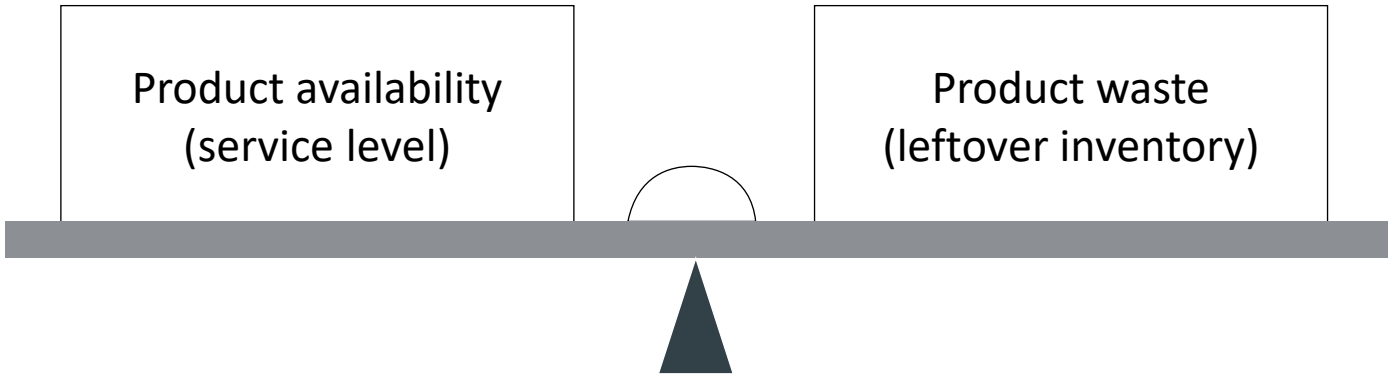
The newsvendor model



Assumptions

- Products are perishable
- Order must be chosen before observing demand
- Demand is stochastic (uncertain)
- Order arrives before store opens
- Leftover inventory at the end of the season has to be discarded or can be sold at salvage value

Source: http://clipart-library.com/clipart/qcBbER4c5.htm

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Setting from customer‘s point of view

Picture sources: https://openclipart.org/detail/280013/man-with-japanese-shopping-cart
https://www.wiwo.de/unternehmen/handel/deutschlands-baecker-das-tankstellen-broetchen-ist-schon-nach-ein-paar-stunden-pappe-/25431446.html

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Manufacturer‘s and retailer‘s point of view

Manufacturer

- Manufacturer delivers new products
- Collects leftover inventory from the previous day

Sales data analysis

- Demand forecasting
- Inventory optimization

Production of order quantity

- Manufacturer delivers new products
- Collects leftover inventory from the previous day

Retailer

Shop opens

Shop closes

Shop opens

Setting

Supply Chain

Manufacturer

Bakery products

Leftover inventory

Retailer

Bakery products
Lifetime=1 day

Standard newsvendor problem

Multigrain bread	Wheat bread
Selling price=2 £	Selling price=2 £
Manufacturing cost=1.5 £	Manufacturing cost=1.2 £
Minimum in-stock probability=0.7	Minimum in-stock probability=0.7

Newsvendor with aggregate service level

Multigrain bread	Wheat bread
Selling price=2 £	Selling price=2 £
Manufacturing cost=1.5 £	Manufacturing cost=1.2 £

Minimum in-stock probability=0.7

Picture sources: https://www.wiwo.de/unternehmen/handel/ofen-aus-bei-baeckereiketten-pleitewelle-im-broetchen-business/24994338.html
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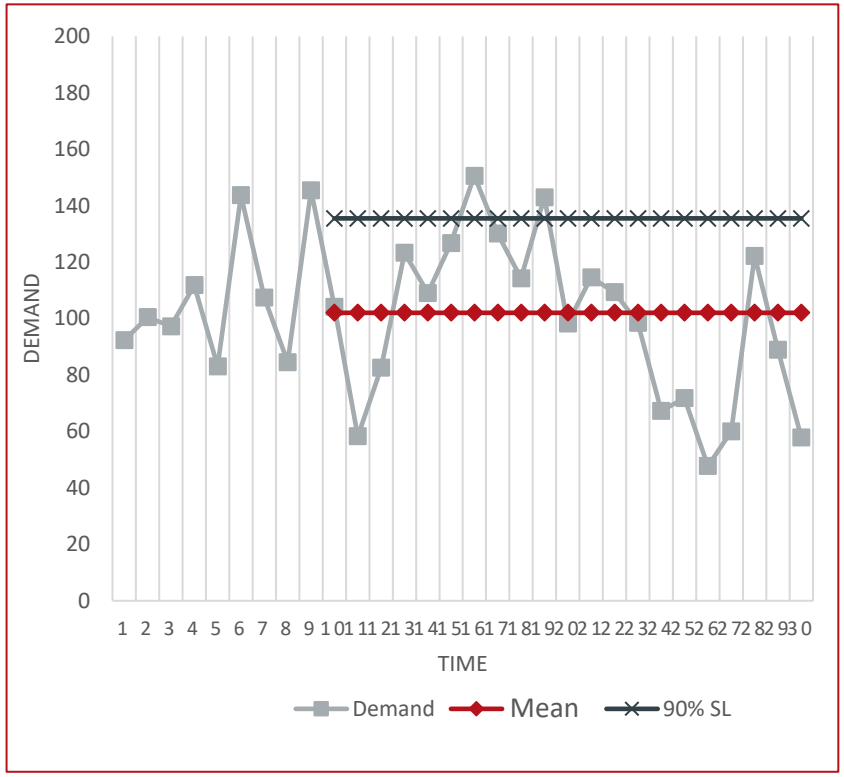
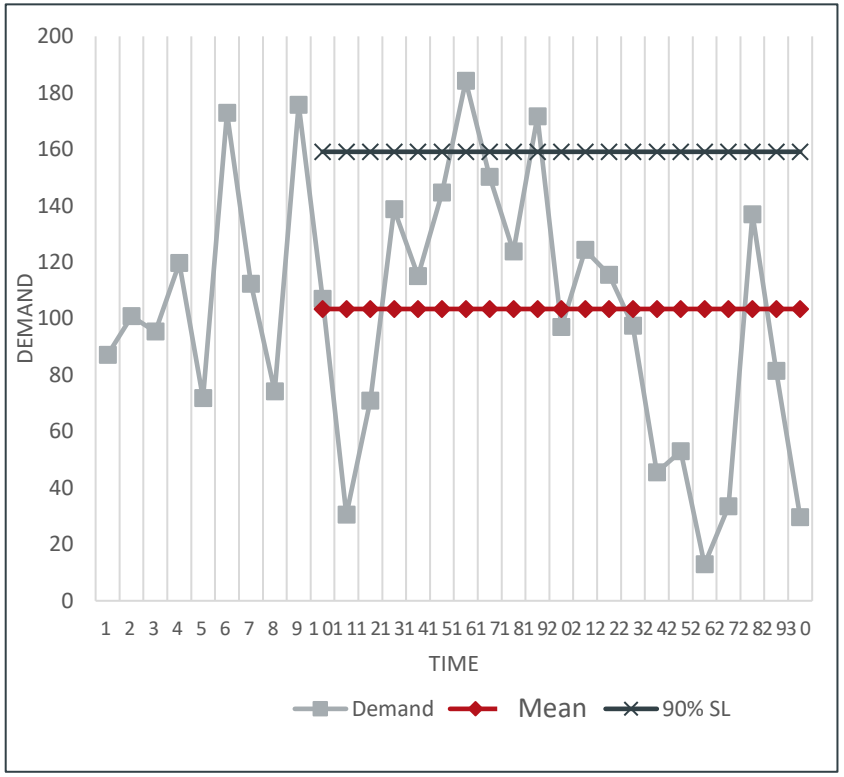
Impact of demand variability

Donuts



Cake



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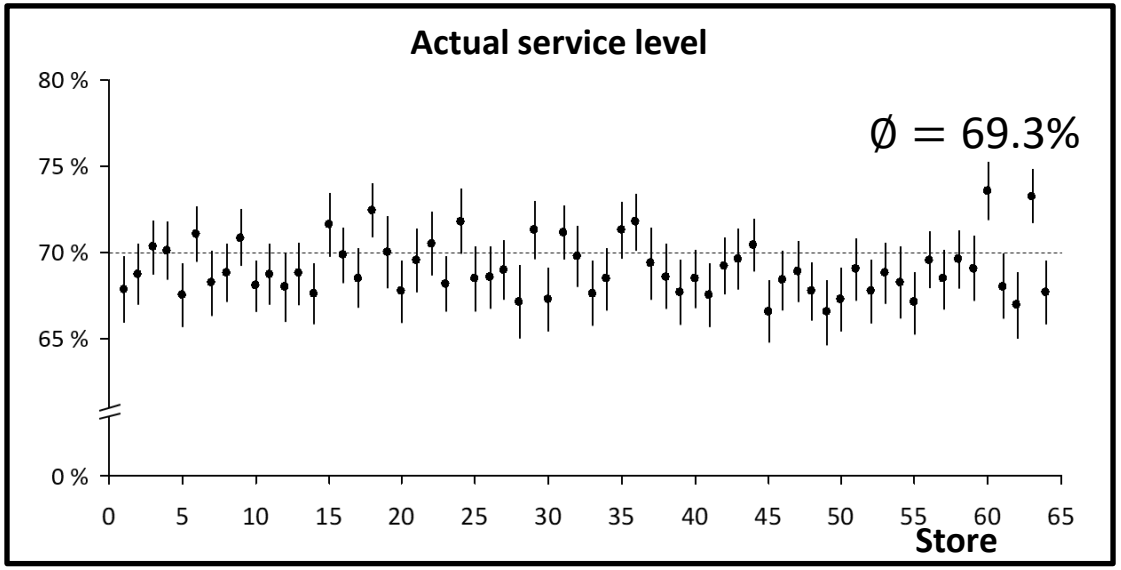
Empirical data

- **Data collected**
  - 64 retail stores open Monday – Saturday (8 am to 8 pm)
  - Hourly sales data from the retailer for Dec. 2010 to Dec. 2012
  - Daily order quantities
- **23 bakery products**
  - 11 breads, 4 rolls, 8 pastries
  - 16 make & 7 buy products
- **Vendor Managed Inventory System**
  - Aggregate service level target $\hat{\alpha} = 70\%$
  - Payment based on Sales
- **Discard leftover inventory**
- **Censored demand** information



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Product overview

Product type	Category	i	Mean demand	Critical ratio	SL_i	ABC	Mean order
Bread	Make	1	21.99	31.0%	77.4%	A	25.03
		2	10.01	52.9%	78.6%	C	12.96
		3	10.87	57.3%	76.0%	C	13.68
		4	8.64	67.1%	74.0%	C	11.13
		5	5.84	70.0%	72.1%	C	7.92
		6	5.73	53.4%	69.0%	C	7.47
		7	13.01	53.8%	66.1%	B	16.10
		8	5.41	54.4%	77.9%	C	7.49
	Buy	9	9.85	11.1%	77.6%	C	9.90
		10	18.11	11.9%	77.8%	B	20.02
		11	14.31	11.8%	68.9%	B	18.21
Rolls	Make	12	11.02	21.3%	68.1%	C	14.72
		13	16.22	27.2%	72.9%	A	21.64
		14	7.59	58.7%	72.2%	C	9.63
	Buy	15	39.72	11.8%	78.6%	A	41.73
Pastry	Make	16	4.95	25.9%	67.0%	C	6.93
		17	7.94	34.2%	47.5%	B	8.95
		18	9.83	40.5%	57.3%	B	12.15
		19	11.35	42.3%	66.1%	B	13.98
		20	6.93	37.0%	61.9%	C	8.32
	Buy	21	25.26	11.0%	65.4%	A	24.05
		22	10.80	17.4%	58.1%	A	11.75
		23	8.61	17.6%	66.3%	B	11.43

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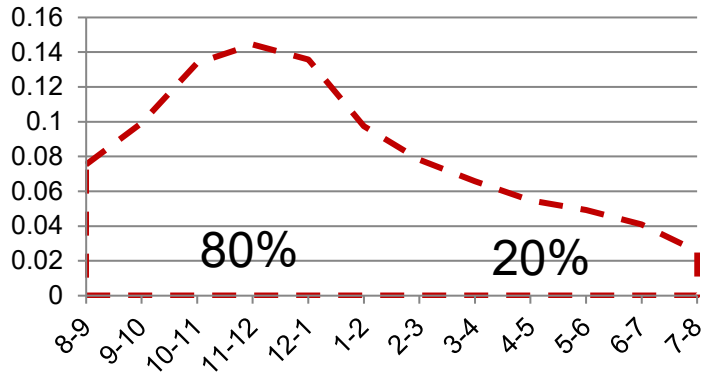
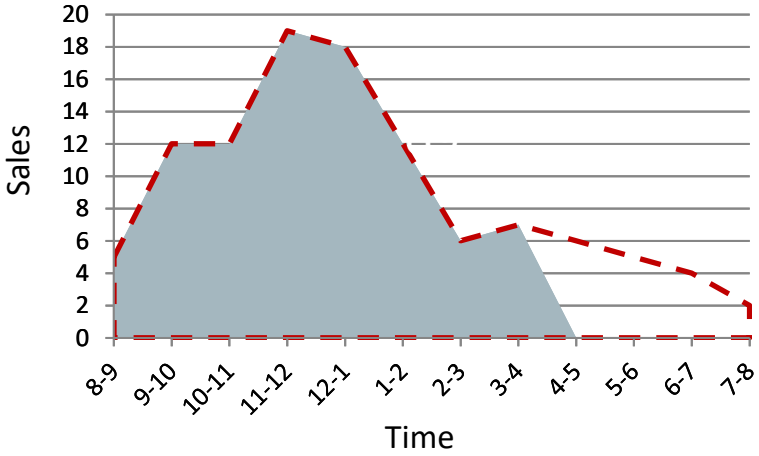
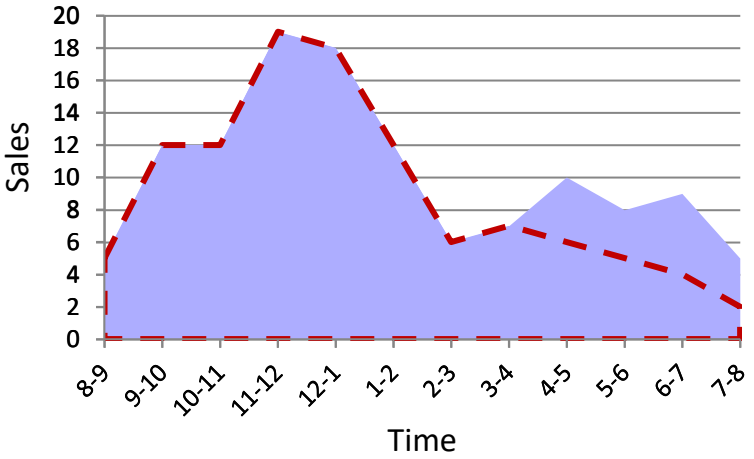
Demand estimation in stockout situations



Unobservable lost sales



Substitution



Lau & Lau (1996) to estimate lost sales

Karabati et al. (2009) to estimate substitution rates

The supplier has no access to hourly sales data!

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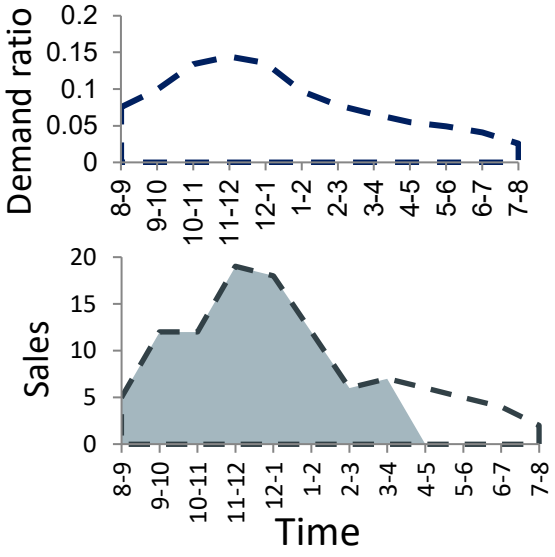
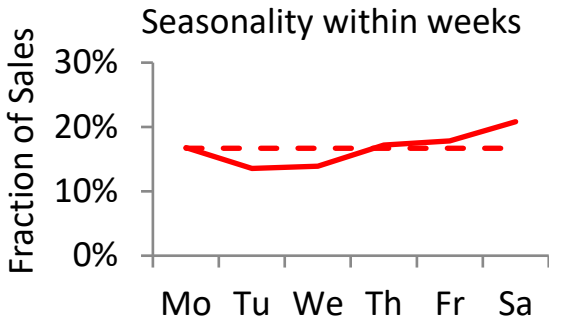
Analytical model

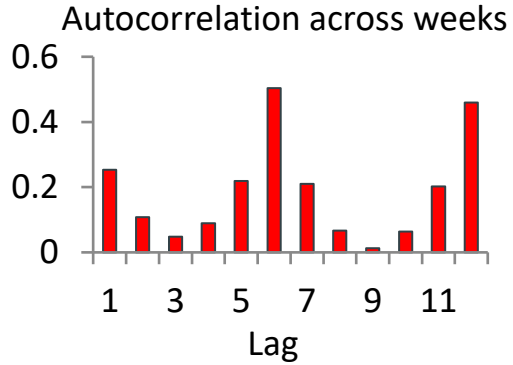
Demand estimation

- Daily sales data (Wecker, 1978; Bell, 1981)
- Hourly sales data (Lau and Lau, 1996)



Forecasting





Similar to van Donselaar (2006, 2010)

Inventory optimization

$$\max_{q_i} \sum_{i=1}^{N} E_{Y_i}[\Pi_i(q_i)]$$

$$s.t. \bar{\alpha} \geq \hat{\alpha}$$

Service level of a product

- ↓ in its overage costs
- ↑ in its underage costs
- ↓ in its demand variability

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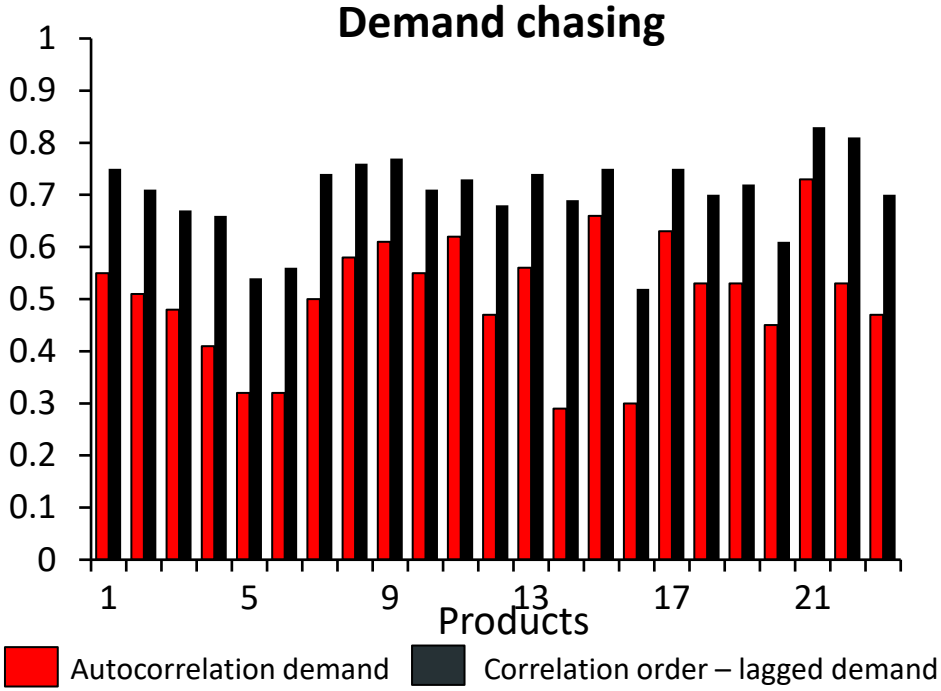
RESULTS: Biases in forecasting

Behavioral forecasting



Lau & Bearden (2013)

Single exponential smoothing

$$\hat{\mu}_{i,t+1} = \eta\tilde{y}_{i,t} + (1-\eta)\hat{\mu}_{i,t}$$

System Neglect (Kremer et al. 2011)

- If η should be small: people overreact to recent demand
- If η should be high: people underreact to recent demand

Our setting:

- Optimal η is small
- Decision maker overreacts

Variable	Mean
Optimal smoothing factor	0.25
Empirical smoothing factor	0.44

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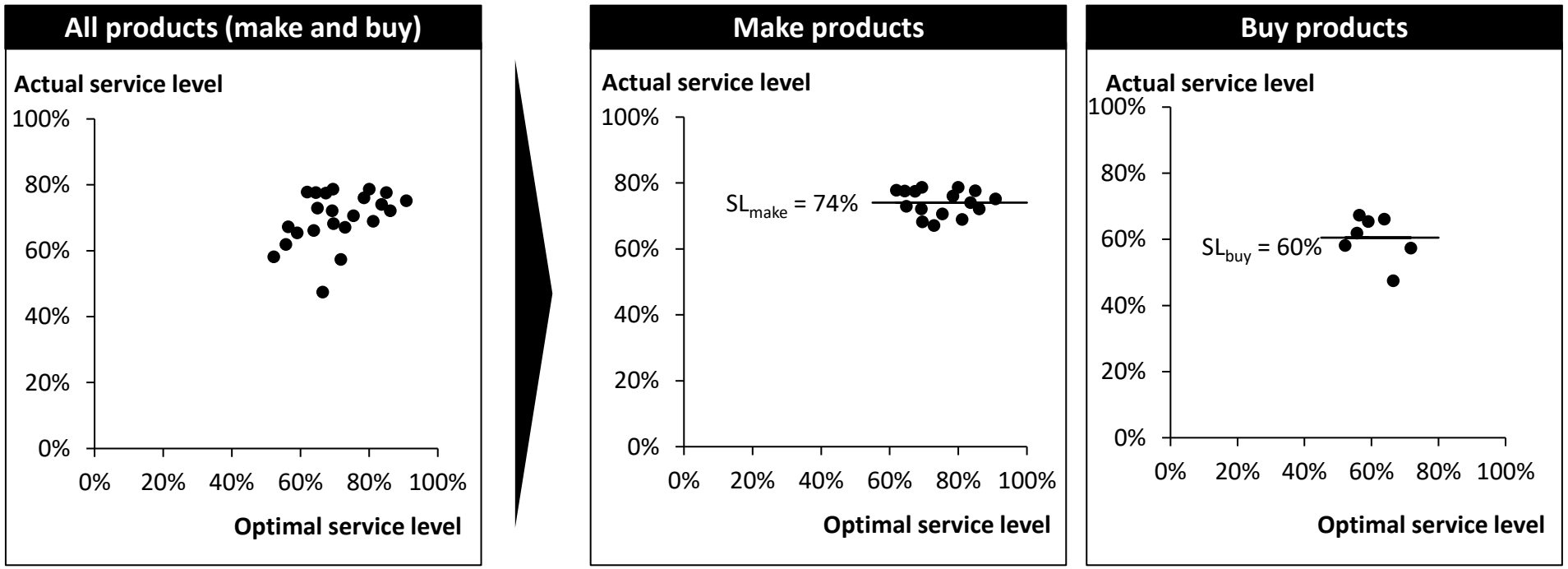
RESULTS: Biases in inventory management

Group aggregation

$$\bar{\alpha} = \frac{n_{make}}{n_{make} + n_{buy}} \alpha_{make} + \frac{n_{buy}}{n_{make} + n_{buy}} \alpha_{buy}$$



Inventory error minimization

Psychological cost of leftovers (4.2) > Psychological cost of stockouts (3.0)

(similar to Ho et al. 2010)

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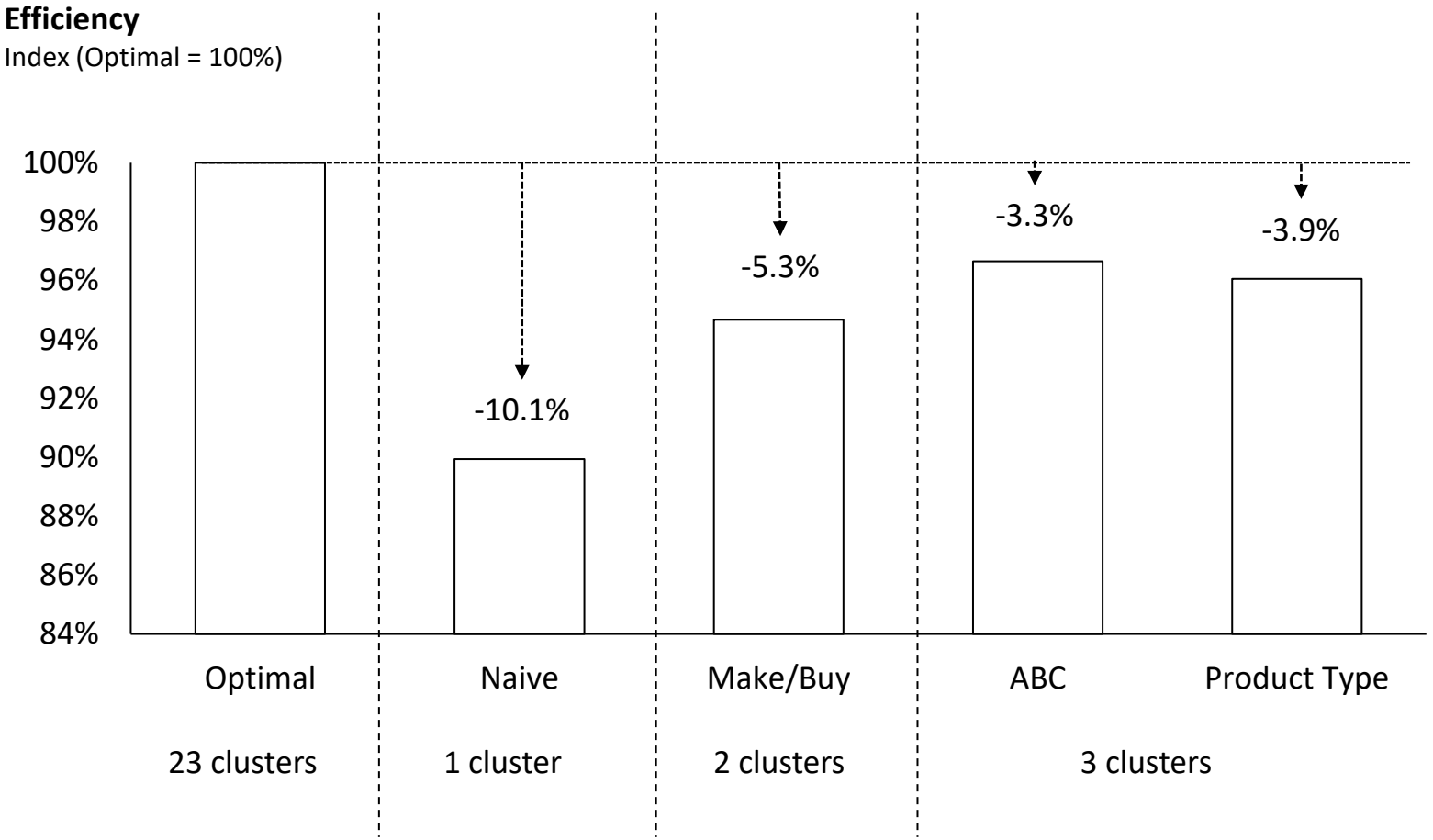
Other groupings



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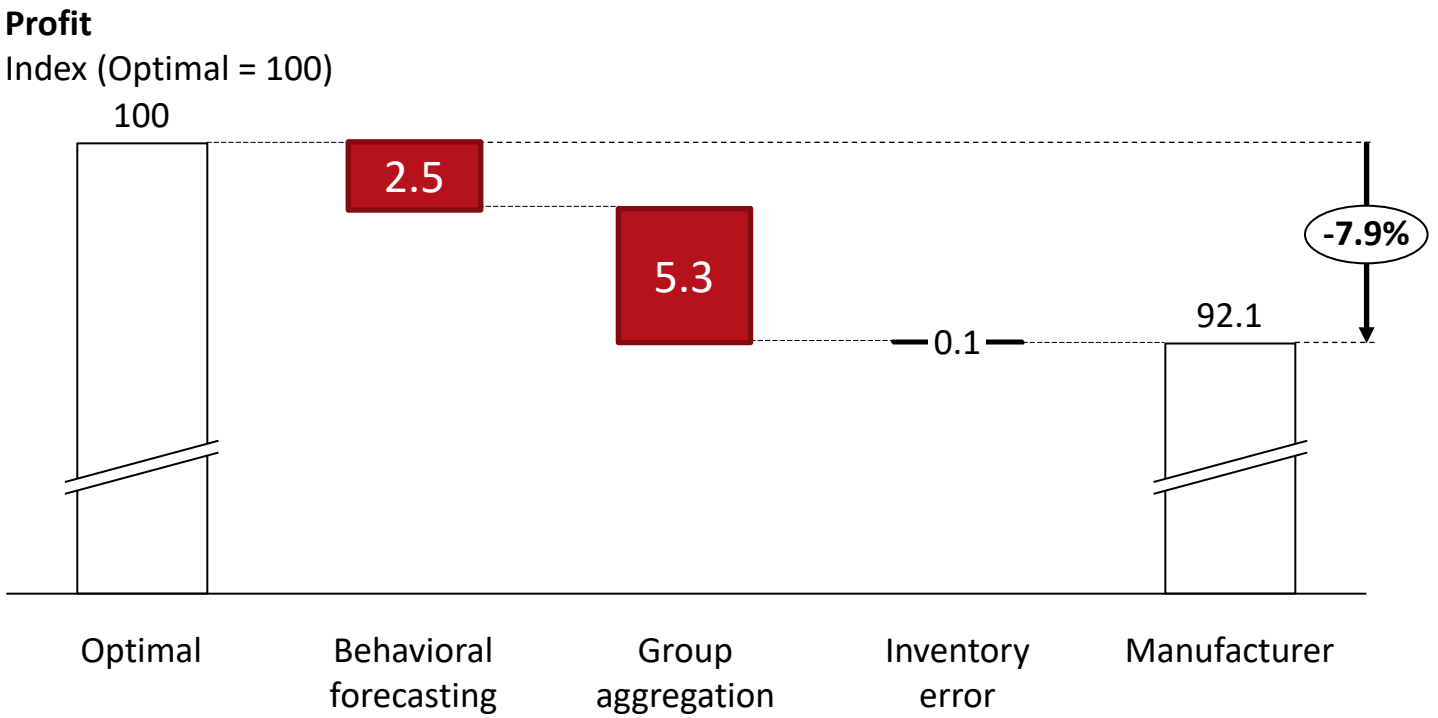
Effects of decision biases on expected profits



If substitution takes place, order quantities differ by 1.1% on average and the realized profit would be 0.6% higher than the optimal solution without substitution.

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Summary

Main results

New model and analytical insights for aggregate SL contract

Behavioral biases observed in the lab also in the real world

Managerial insights

Reduce decision biases by educating managers

Individual service level targets increase profits

Limitations and future research

Assumptions

Decision support tools

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Thank you for your attention!

Anna-Lena Sachs

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