# EURO 2015

## Re-evaluating the bullwhip effect measurement: what are we capturing?

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# Table of Contents

# Overview of the Bullwhip Effect

## Definition

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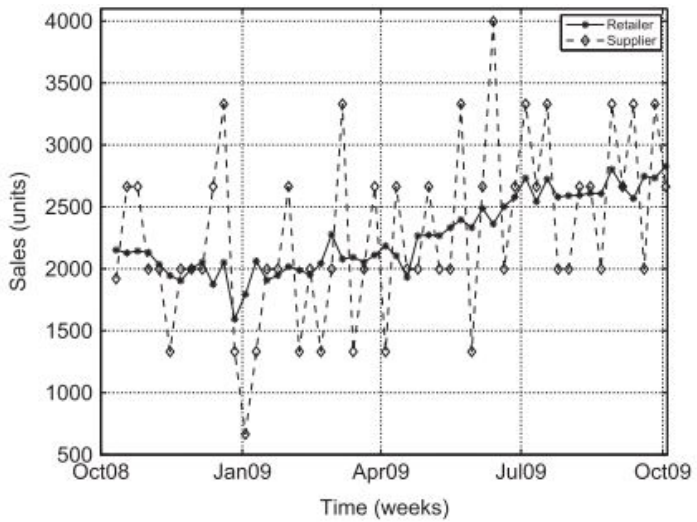

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It can have several consequences such as:

1. Excess production and raw material costs.
2. Inefficient utilization of capacity.
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# Measurement

## Bullwhip Ratio

$$Bullwhip\ Ratio\ (BR) = \frac{Var(Orders)}{Var(Demand)}$$

$$BR \begin{cases} < 1 & \text{Demand variability is dampened} \\ = 1 & \text{Demand variability is the same} \\ > 1 & \text{Demand variability is amplified} \end{cases}$$

This ratio can be used to:

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# Where are the causes reflected?

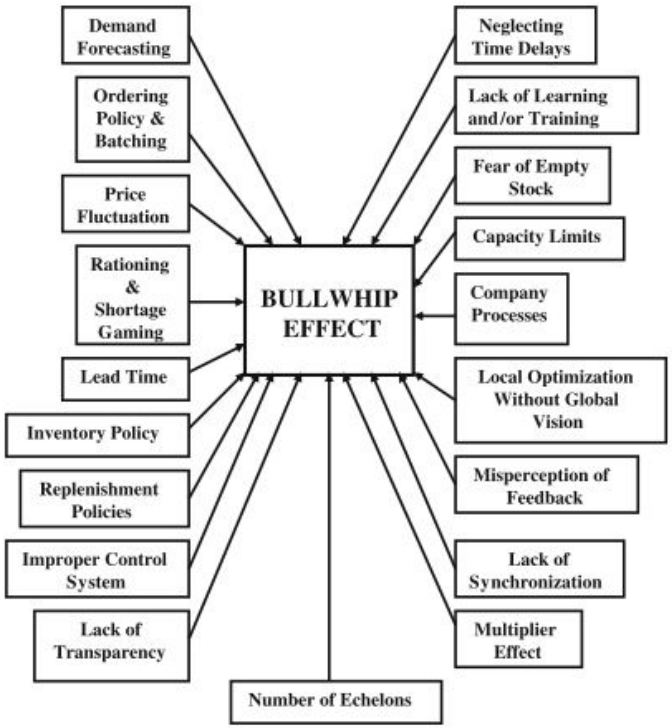


Figure: The 19 causes of the Bullwhip Effect [Bhattacharya and Bandyopadhyay, 2011]

# Where are the costs reflected?

Some supply chain costs:

- Inventory Costs
- Order Processing Costs
- Transportation Costs
- Manufacturing Costs
- Administration Costs
- Warehouse Costs
- Distribution Costs
- Capital Costs
- Installation Costs

# Minimizing Variance

Minimizing the variance does not necessarily imply a reduction in costs or improvement in performance.

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1. No direct relationship between forecast accuracy and Bullwhip metric [Trapero et al., 2012]
2. Decreasing demand variability does not always decrease inventory costs [Ridder et al., 1998].
3. Mitigating the Bullwhip Effect does not automatically result in lower supply chain costs [Chen and Samroengraja, 2004] and [Torres and Maltz, 2010].
4. Sometimes variance reduction leads to higher costs [O'Donnell et al., 2009].
5. Variability is not the main cost driver; uncertainty is [Chen and Yano, 2010]

# Other Concerns

Other limitations regarding the Bullwhip metric such as:

1. Where are the impacts of decisions reflected?
2. How do we evaluate across the whole supply chain?
3. Where is customer satisfaction factored in?

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Variance highly penalizes extreme values and outliers.

# Promotions

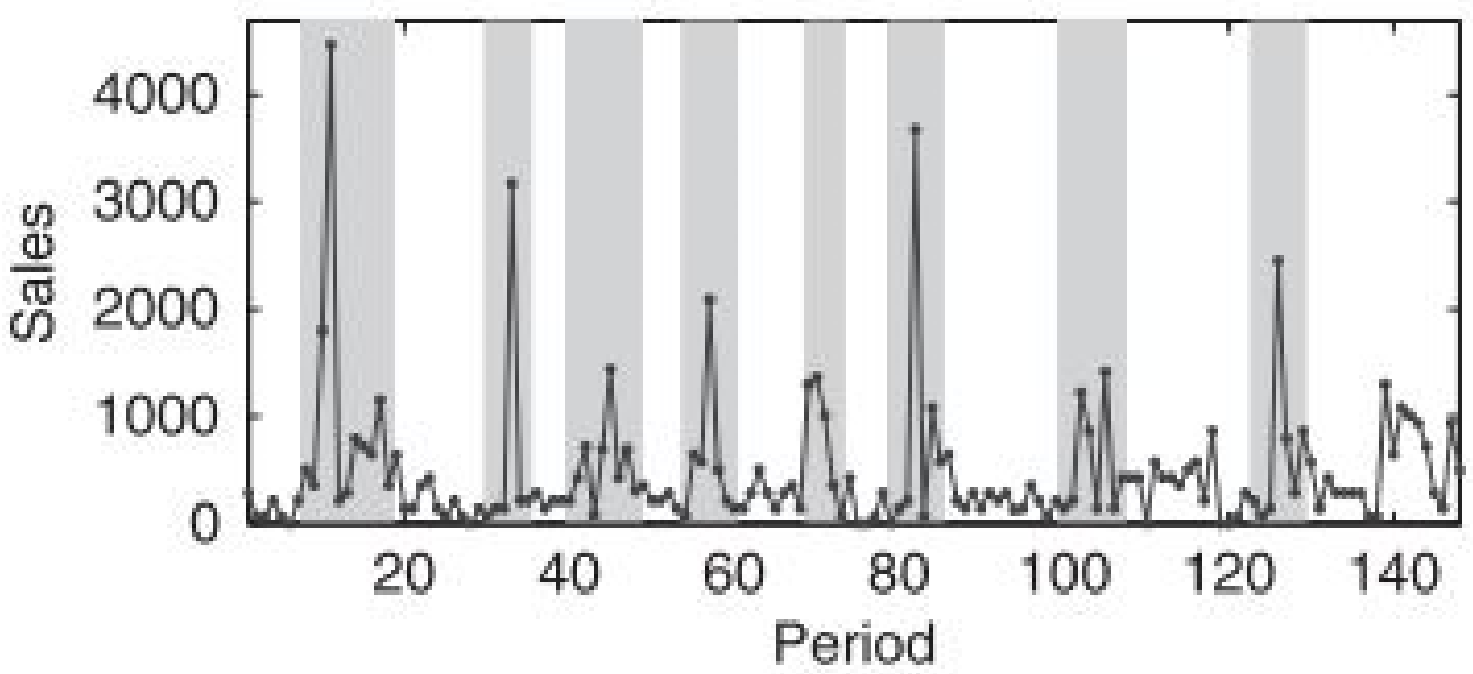


Figure: Sales in the presence of promotions [Trapero et al., 2014].

# Statistical Limitations

These factors distort the Bullwhip measure:

1. Sample size [Nielsen, 2013]
2. Aggregation [Cachon et al., 2007] and [Chen and Lee, 2012]
   - Product
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2. Seasonality

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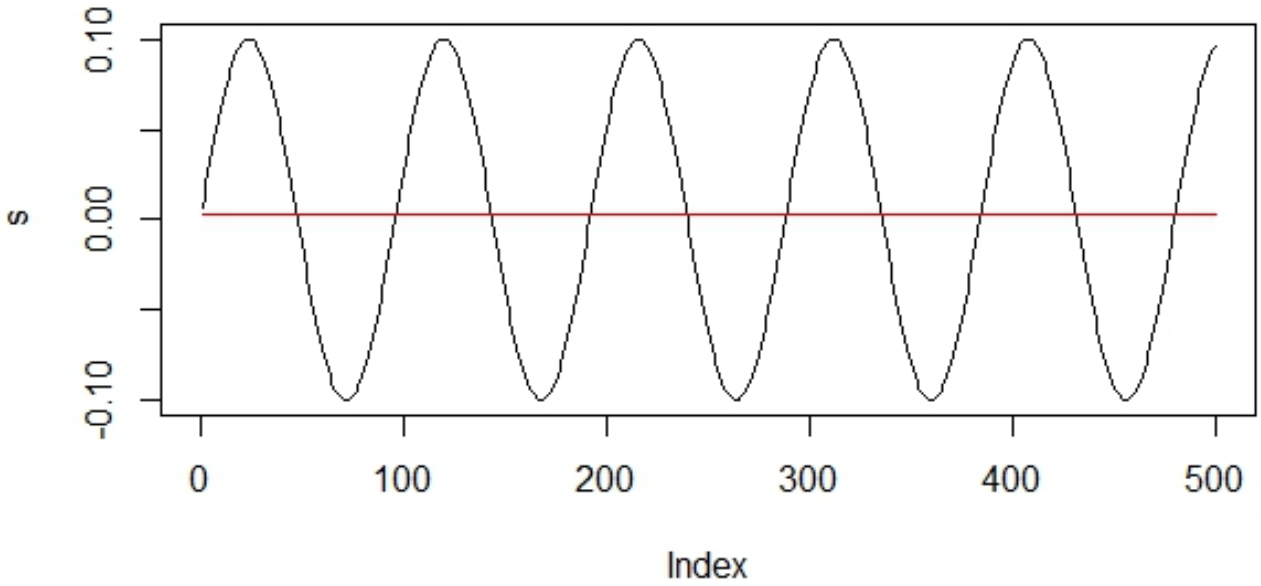

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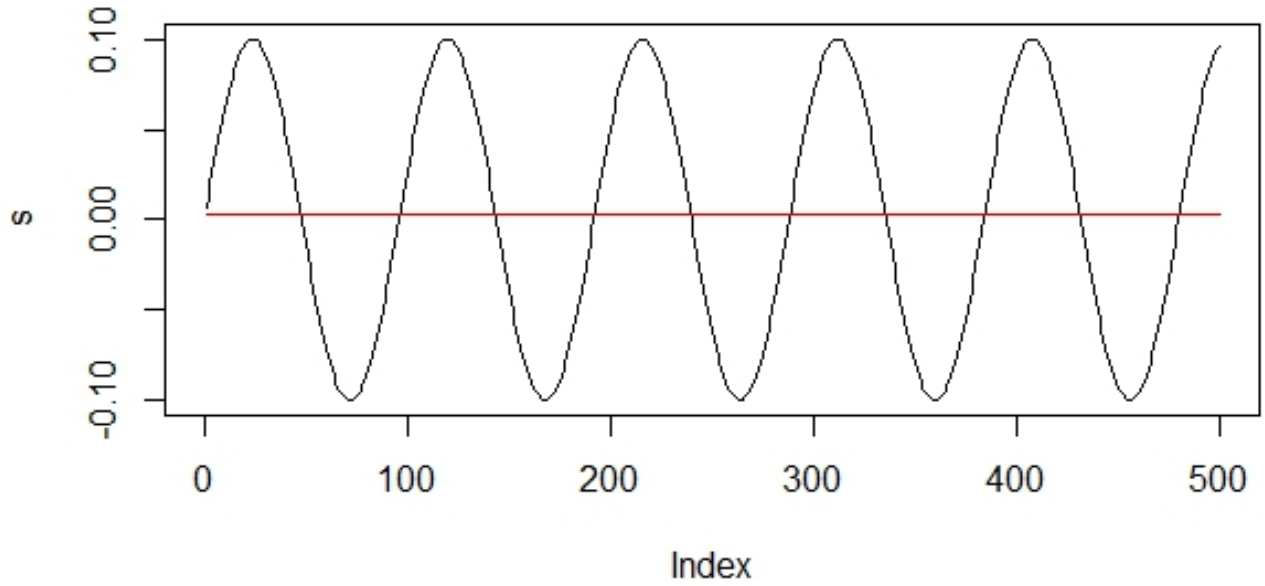


Variability or Uncertainty?

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- Variability represents the spread of the data around its mean.
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- Variability is not always stochastic.
- Variance as a measure of uncertainty can give counter-intuitive results [Fleischhacker and Fok, 2015].
- Uncertainty, not variability, is the main cost driver.
- Demand uncertainty is what ought to be studied.
- The bullwhip ratio measures variability, not uncertainty.

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# Conclusion

- This study aims at showing what the measure represents and what it doesn't.
- The Bullwhip metric should capture uncertainty.
- More metrics should be used to reflect the performance, depending on what should be monitored.

# Conclusion

Any Questions?

Thank you

Ranjan Bhattacharya and Susmita Bandyopadhyay. A review of the causes of bullwhip effect in a supply chain. *The International Journal of Advanced Manufacturing Technology*, 54:1245–1261, 2011.

Gérard P Cachon, Taylor Randall, and Glen M Schmidt. In search of the bullwhip effect. *Manufacturing & Service Operations Management*, 9(4):457–479, Fall 2007.

Fangruo Chen and Rungson Samroengraja. Order volatility and supply chain cost. *Operations Research*, 52(5):707–722, 2004.

Frank Youhua Chen and Candace Arai Yano. Improving supply chain performance and managing risk under weather-related demand uncert. *Management Science*, 56(8):1380–1397, 2010.

Li Chen and Hau L. Lee. Bullwhip effect measurement and its implications. *Operations Research*, 60(4):771–784, July-August 2012.

Adam J. Fleischhacker and Pak-Wing Fok. On the relationship between entropy, demand uncertainty and expected loss. *European Journal of Operational Research*, 000:1–6, 2015.

Erland Hejn Nielsen. Small sample uncertainty aspects in relation to bullwhip effect measurement. *International Journal of Production Economics*, 146:543–549, 2013.

T. O'Donnell, P. Humphreys, R. McIvor, and L. Maguire. Reducing the negative eeffect of sales promotions in supply chains using genetic algorithms. *Expert Systems with Applications*, 36(4):7827–7837, 2009.

Ad Ridder, Erwin van der Lann, and Marc Salomon. How larger demand variability may lead to lower costs in the newsvendor problem. *Operations Research*, 46(6):934–936, 1998.

Octavio Carranza Torres and Arnold B. Maltz. Understanding the

financial consequences of the bullwhip effect in a multi-echelon supply chain. *Journal of Business Logistics*, 31(1):23–41, 2010.

Juan R. Trapero, Nikolaos Kourentzes, and Robert Fildes. Impact of information exchange on supplier forecasting performance. *Omega*, 40:738–747, 2012.

Juan R. Trapero, Nikolaos Kourentzes, and Robert Fildes. On the Identification of Sales Forecasting Models in the Presence of Promotions. *Journal of the Operational Research Society*, pages 1–9, 2014.

Xiaolong Zhang. Inventory control under temporal demand heteroscedasticity. *European Journal of Operational Research*, 182:127–144, 2007.