

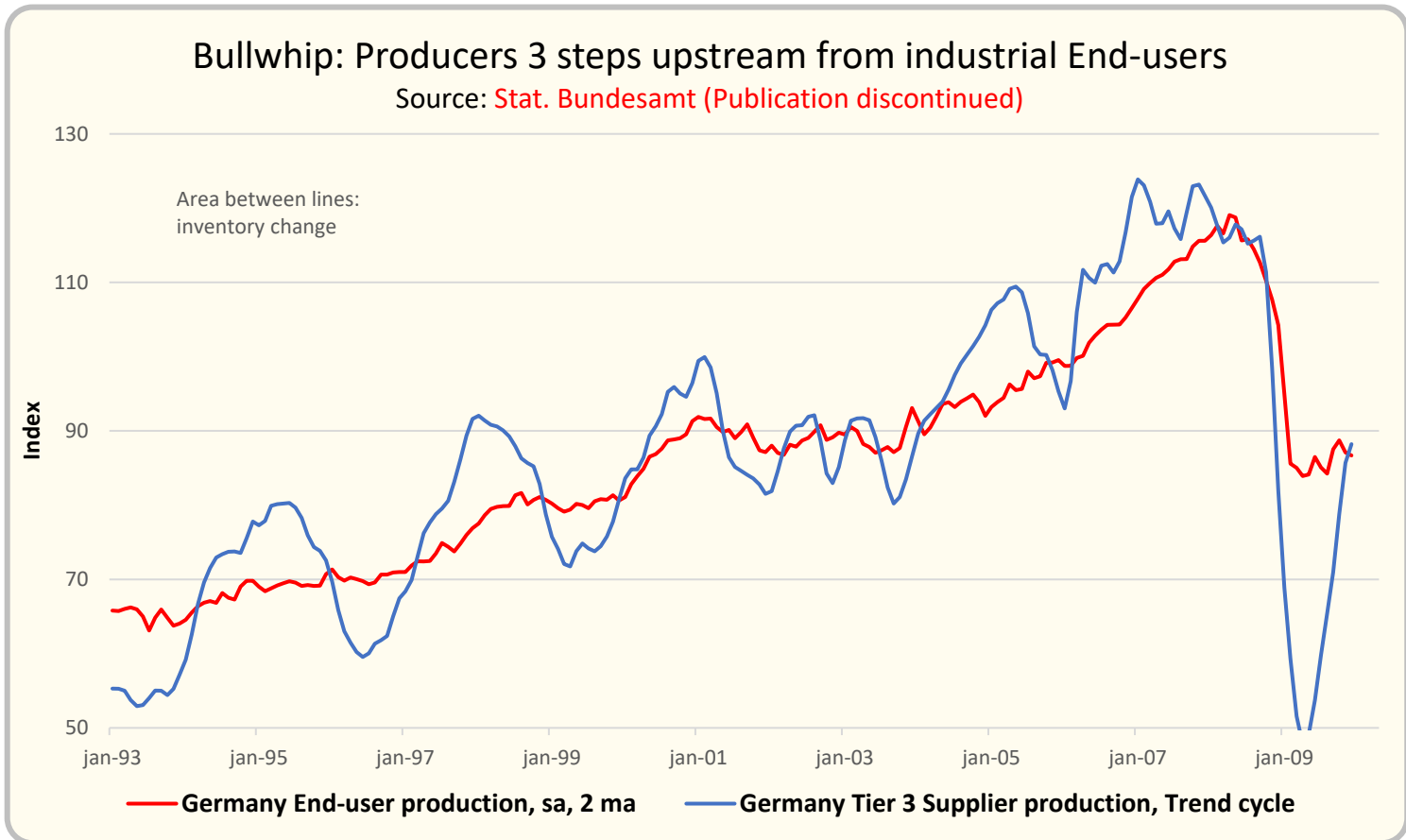


## 3. Inventory cycle and Bullwhip

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The customer is always right.

*Bullwhip:* Small change in end-user demand is amplified into big swings as one moves from the end-user upstream in the supply chain. Often, there is half dozen inventory points between the end customer and raw material supplier. In upturns, everyone tries to protect themselves from stock-outs and missed orders by keeping extra inventory. In downturns, de-stocking takes place. Bullwhip creates oscillating imbalances in supply chain. The imbalances accumulate in the order books of the producer furthest upstream.



Tier 3: German special steel for demanding transmission and engine components. Three steps from end-user industries, Motor vehicles and Machinery.



# What upturns and downturns are made of

93 macro cycles in 21 OECD economies 1973-2000\*

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## Contribution to downturn, whole duration (average of all downturns)

- ✓ 50 % **Inventories** \*\*
- ✓ 50 % Private investment
- ✓ Consumers and Government, net: 0 %

## Contribution to upturn, first 4 quarters (average of all upturns)

- ✓ 50 % Consumers
- ✓ 20 % **Inventories** \*\*; after mild and modest downturns. After severe recessions: 50 %.
- ✓ 20 % between Government and Private investment

## Origins of inventory changes

*Actions:* To keep inventory-sales ratio at target. Also speculative, precautionary and liquidity related actions.

*Unavoidable result:* order/production/material flow imbalances in supply chain. Correction actions lead to Bullwhip, amplified oscillation in the chain. In steeper downturns, *lowering of target inventories* takes place creating another round of order reductions and stronger oscillation.

Inventories definitely have a key role in forming business cycles. In a feedback loop, inventory changes are both a cause and effect of bullwhip. But is inventory/bullwhip-cycle a triggering cause at economy's some *turning points*?

\* Sources: IMF(2002), NBER working papers, IIE, Own estimates.

\*\* In national accounts, inventories are often combined with 'balancing items', the slack in accounts. Inventory variation in GDP accounts is probably understated when considering 'all material in the tube', i.e. total material stock&flow.



## Inventory cycle and Bullwhip

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Pronounced, inventory/bullwhip-cycle is seen in steel. Whatever the triggering cause of downturn, inventory liquidation in supply chain begins. Steel and steel component purchases are cut abruptly in order to reach rapidly target inventory level. The cuts proceed upstream in the supply chain via orders, are amplified after every step and finally accumulate in steel producers' order books.

Estimate on steel's supply chain effect is obtained by comparing steel supply to the market with steel end-users' production (next page).

The longer the production chain from steelworks to end-product, the stronger the variation. For steel on average, end-user industry demand changes are multiplied by a factor of 2-3.

Transmission components of special steel go through 4-5 major production phases from raw steel to finished vehicle or machine, often in locations far apart. Consequently, engineering steel has one of the strongest cyclical variations in industry.

Similarly, supply chain effects are seen in total industry and, obviously, in GDP. Amplitude is lower because these are respectively Tier 1.8\*\* and OEM\* suppliers. However, economists can not find effects of *bullwhip* on GDP level (the significance of inventories is confirmed). In spite of the tight correlation between industrial production and GDP *and* synchronous variation of total industry with its cyclical branches, it is claimed aggregation *may* wipe out the micro level variations. Due to measurement problems, there is no definite answer to the issue.

On pages 6-7, experience of a Tier 3 special plastics producer.

\* Tiers:

**OEM:** An original equipment manufacturer. Makes a *final product for the consumer*.

**Tier 1** companies are direct suppliers to OEMs. **Tier 2** companies are direct suppliers to Tier 1, etc. Industry as a whole is roughly an *average* Tier 1.8 supplier and GDP's *Private consumption* consists, by analogy, of OEM products. Tier structure depends only on how industry's production is organised: if a producer has the whole supply chain incorporated, it is an OEM producer. Like the former Soviet economy. 'We have no business cycles and no bankruptcies', the leaders used to remind. But they too had bullwhip - hidden in the industrial complexes.

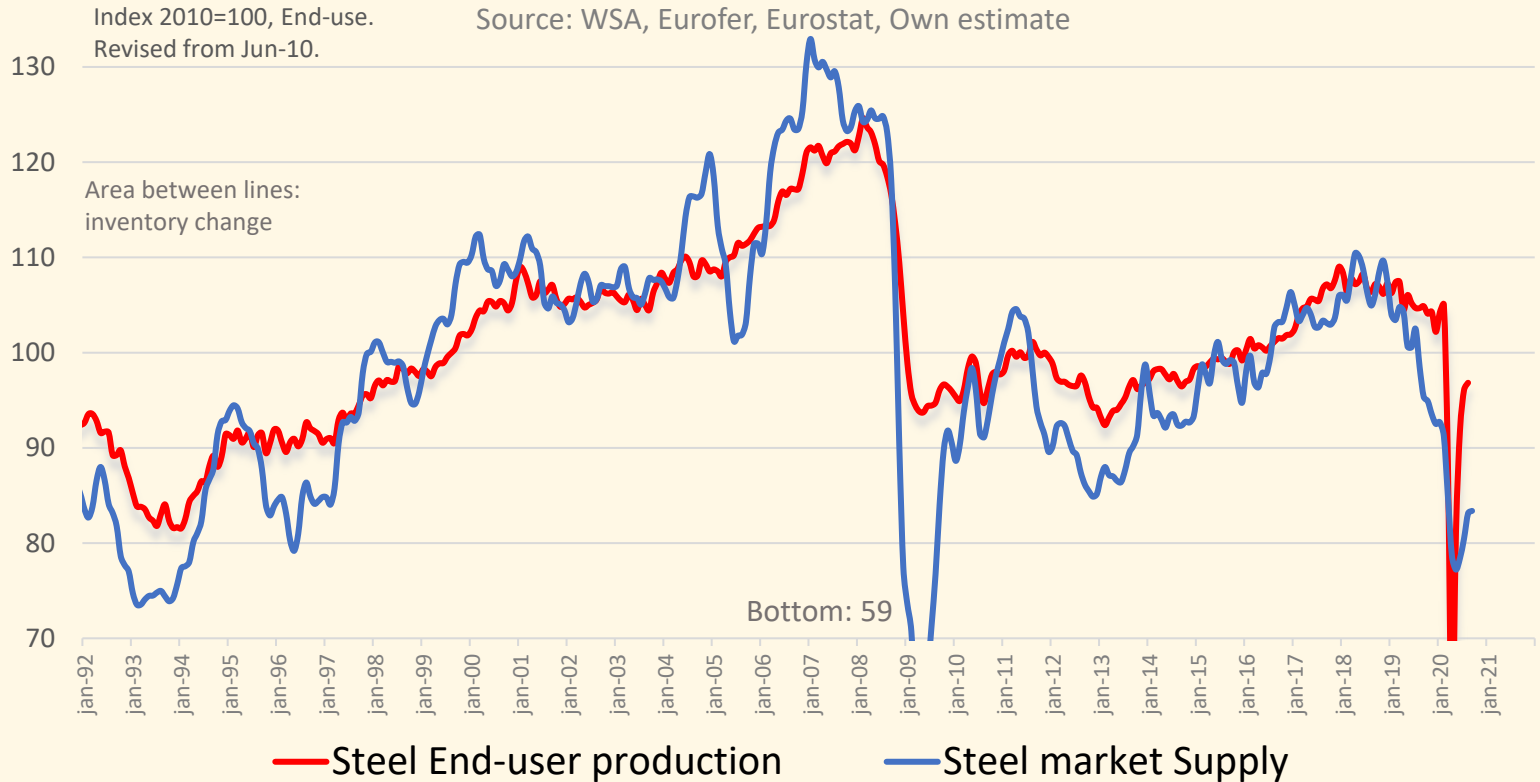
\*\* Total industry Tier 1.8: rough estimate of *average supply chain length* from all 2-position industrial branches.

**Steel End-use:** Steel consumption weighted production of Construction, Motor vehicles, Machinery, Metal goods, Appliances and Other (incl. Energy).

**Steel supply:** EU28 steel production less net exports.

## EU Steel Market Supply vs Steel End-use/Sep

Supply: EU production + Imports less Exports





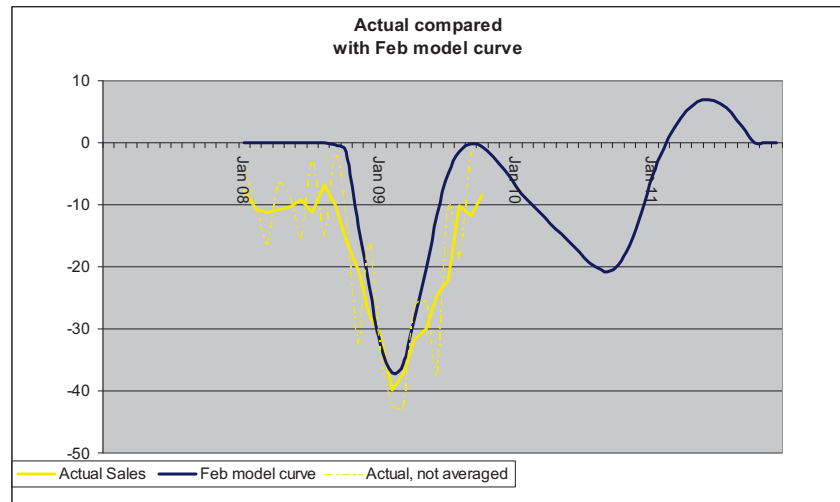
## Inventories in supply chain - The DSM experience

*The Lehman wave*, DSM NeoResins & Eindhoven University of Technology.

Robert Peels, Maximiliano Udenio et al. Published Dec 2009. <http://beta.ieis.tue.nl/node/1502>

- DSM is a Dutch producer of special materials like resins (plastics raw material) for the coating industry. They noticed the same as special steel producers have: a reduction in final demand created a substantially larger fall in their sales. When construction activity weakened, companies directly supplying the market started to cut orders and their suppliers followed. The result was sharp fall in DSM's sales, much larger than the decline in final demand.
- DSM's resin production is three steps upstream from the end-users (OEM's). They estimate a molecule from their warehouse travels 250 days before reaching the end-use in a building. If you consider supply chain as a tube filled with material and it takes 8 months for each item to reach the destination, 12% reduction in a month's purchases *across the supply chain* creates a shortfall of one month's sales for the supplier furthest upstream. You take away 12% of the material, in the whole length of the tube. Or differently: your 8 months' production is in the tube, 12% of that. 'Tube' here is not only inventories on shelves and factory floors and yards but also material being processed, transported, temporarily stored or taken away and returned by stockholders.
- DSM noticed the phenomenon in connection of Lehman crash. Eindhoven University of Technology made research on this bullwhip-effect and created a purchasing flow model. The model, a calculation with real customers' purchasing data and parameters, predicted reliably DSM's actual sales fall (next page). This is important because it shows bullwhip is built-in in all supply chains. The unavoidable amplification is later on magnified by supply chain actors' overreactions in their sales and purchasing plans.
- After de-stocking has passed the whole chain, rebound with restocking begins provided there is no further deterioration in final demand. Raw material supplier's sales return to the level of end customers' production and bounce above it – according to the model and industry's experiences.

based on the prediction by Euroconstruct in December 2008 that the market would decline 10% in 2009 and recover in 2010. The blue line is the calculated model curve, using only data available in February 2009. The yellow curve was made in October 2009 and shows the actual DSM sales, 3-month moving average, corrected for seasonal impact by taking the difference with 2007.



**Figure 8. Modeled and actual sales curves in segment 1 supplying to construction market, based on construction market forecasts issued in December 2008**

Note that the model accurately forecasts the timing of the trough in the sales curve in February 2009. The position of the trough is actually very robust to many of the parameters in the system, and is primarily a result of the structure and the decision making behavior in the supply chain. Furthermore, the depth of the trough has also been forecasted very well. Note that this depth is primarily dependent on the cumulative de-stocking (both active and reactive) and the decline in sales in the end market.

Later, it turned out that the construction market forecasts issued in December 2008 were too optimistic and an updated forecast was issued by Euroconstruct in June 2009. Figure 9 shows the same actual sales curves as Figure 8, but with an updated modeled sales curve, based on the updated construction market data. The updated modeled curve shows a stronger dip in 2009 and only little recovery in 2010 and 2011.



## Special steel and Bullwhip

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- Bullwhip is well known for special steel producers. Already a flattening out of end customers' production creates a pronounced fall in steel demand. This has been proved over several cycles. The results - amplitude and duration - are very close to DSM's one event study. Similar variation has also been found in Caterpillar's supply chain \*).
- There is a further characteristic in the supply chain: the mass in the tube is not evenly distributed nor move with desired velocity. It only accelerates or decelerates. Because of this, cyclical branch's *upturn* weakens or ends after 1.5-2 years of start because material flow now overshoots.
- Bullwhip is known for economists since 1960's, considered 'interesting' for firms but non-existent on macro level. It has been a classroom play in universities where the effect is demonstrated in a three-level distribution chain \*\*). The purpose is to show the coordination problems when delayed signal-response system is combined with human behavior – impatience, anxiety and speculation. It turns out, without information on the state of the whole supply chain - and without real customer-supplier partnership - upstream firms turn into isolated, confused supply channels at the mercy of unpredictable swings. The customer is always right even in industrial relationships.
- Lehman crash showed the duration of *the cyclical part* of downturn does not depend on the magnitude of the fall. In fact, Lehman downturn duration was shorter than cyclical average for DSM and special steel. Downstream producers overreacted and then corrected stronger than usually. Other effects of the crisis were felt thereafter for 1.5 years. The normal bouncing back did not fully take place which points to structural damages in the economy.

\*) WSJ Jan 27, 2010 / Timothy Aeppel

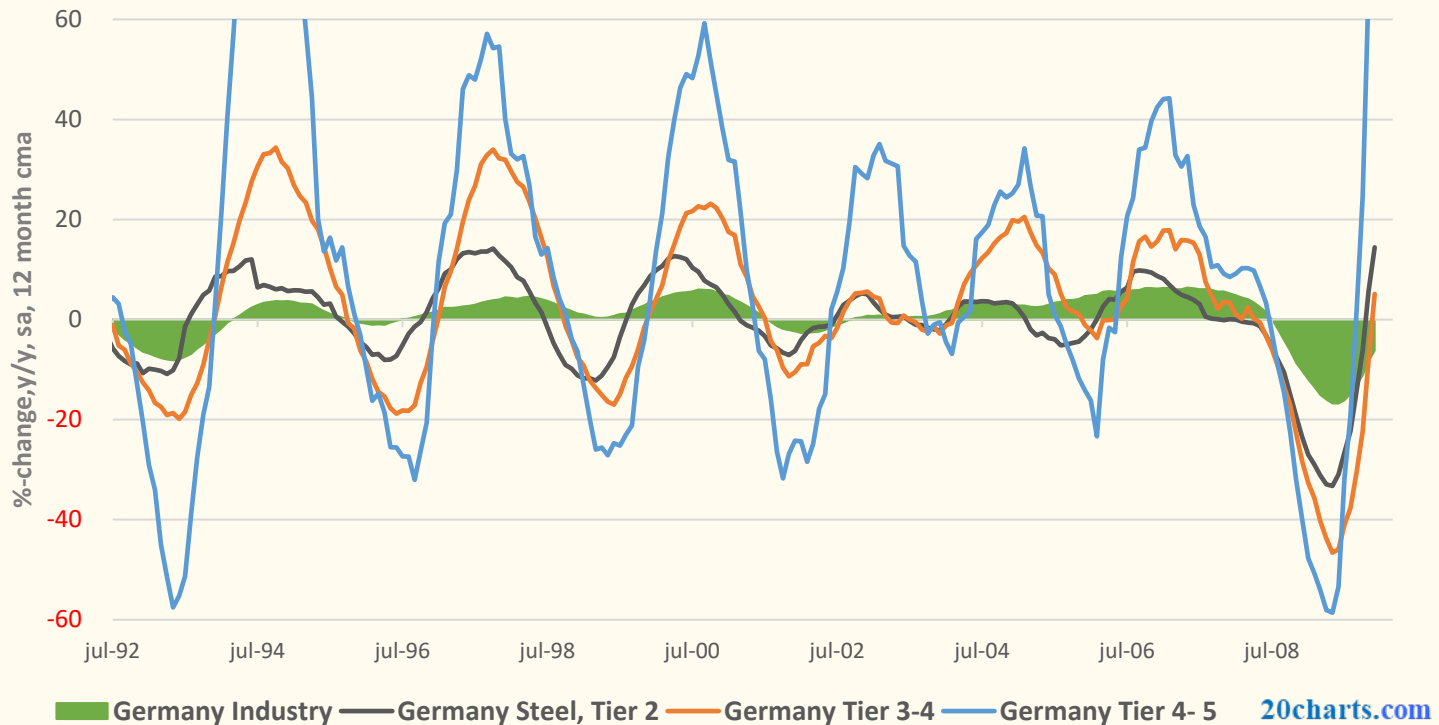
\*\*\*) See e.g. <http://www.beergame.org/the-game>



Bullwhip effect depends on the tier level and purchasing practices, not on branch. By knowing only the length of downstream supply chain, it is possible to predict producer's behavior in the cycle.

## Germany: Production volatility vs Length of supply chain

Source: All steel data: Stat. Bundesamt. Publication discontinued.



Germany [Steel total](#): production of all steel products. Average supply chain length from steel mill to final product is estimated to 2-3 steps. Germany [Tier 3-4](#): Engineering steel production. Germany [Tier 4-5](#): Bearing steel production. Source, Tiers 2-5: Statistisches Bundesamt, *Eisen und Stahl*. Publication discontinued in 2009.