# Economic waves due to inventories in the supply chains

By: Robert Peels, Flostock

(English translation of article published on www.mejudice.nl on 26 October 2012)

A close understanding of the mechanisms behind stock building in supply chains is necessary to explain the volatility of economies, according to Dutch analyst Robert Peels. The importance of such insights became clear after the 2008 Lehman bankruptcy disrupted Western economies for years. Macro-economic analysis models featuring the length of the supply chain as an additional dimension are available nowadays to understand the effect of stock policies on demand.

**High volatility in production**

High levels of volatility in industrial production and consumption are characteristic of recent economic trends and typically each country if going through a different curve of industrial production (fig 1). Although the pattern jumps up and down between industrial production and consumption – the two ends of a supply chain - both are inter-related: spending in end-consumer markets determines the level of demand upstream for industrial products. Macro-economists assume that the difference between the top and bottom of the supply chain is simply passive stock building or destocking. In this article I will explain how macro-economists miss an important insight by ignoring the causal effect of fluctuating inventory levels in their analyses (1).

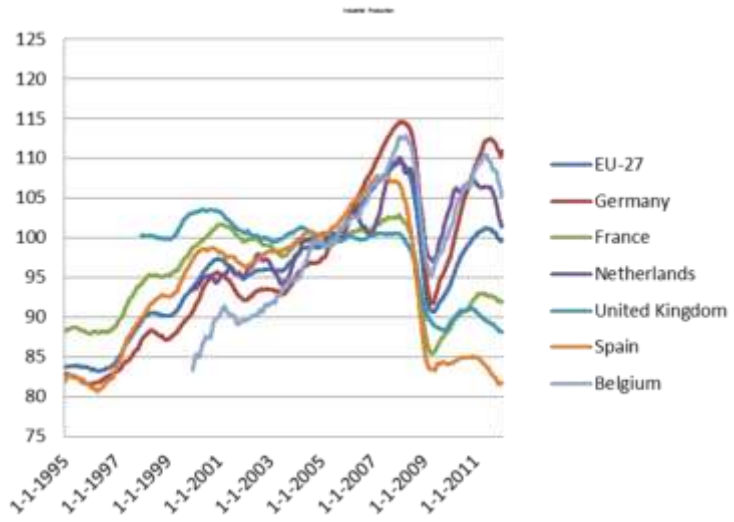


*Figure 1. Industrial production for a number of European countries. Source: Eurostat.*

**Flostock and the Lehman Wave**

A Dutch research team consisting of Jan Fransoo and Maxi Udenio of Eindhoven University of Technology, and the article's author, Robert Peels (then employed by Royal DSM), discovered that demand volatility caused a bullwhip effect throughout the supply chain. This effect, coined the Lehman Wave, was triggered by the bankruptcy of global bank Lehman Brothers at the end of 2008 (2). Reduced credit availability forced many companies to release cash by lowering their inventory

levels. As a result, a wave of global destocking occurred *high up* in the supply chain, although demand in consumer markets remained fairly stable. This was the bullwhip effect *where any growth or reduction* in demand is amplified throughout the chain after only a minor change in the end market.


*Figure 2. The Lehman Wave was a composite bullwhip, caused by synchronized and cumulative destocking throughout the long supply chains of the global industry. Upstream sales of products therefore waved around the end-market trend curve for a number of years. Figure 2 illustrates this behaviour showing Europe's construction output. Flostock's computer model reached an astonishing accuracy of 94 percent in predicting upstream demand thirty months into the future.*

The effect of a ten percent destocking throughout the supply chain accumulated to a demand dip of fifty to sixty percent for firms at the start of the chain early in 2009. The subsequent recovery in stock positions in combination with the elasticity of the supply chain caused overshoot, which transformed into a second dip and peak as illustrated in figure 2. This Lehman wave can be observed in industrial production performance across the world.

In order to predict the behaviour throughout the many layers of a supply chain and analyze the expected volatility, a computer model was built in System Dynamics software (3).

**Stock depth of the supply chain**

The inventory of all companies in a supply chain is a proxy for the length of the chain. In general, every company maintains two to three months of sales in stock (either as raw materials, production, finished products or stock in transport). With the average supply chain consisting of five or six companies, the stock depth can be as large as one year's worth of sales. An economy consists of supply chains selling to each other. Shell, for example, ships naphtha to SABIC, which produces monomers for Royal DSM, selling resins to AkzoNobel, delivering paint to Unilever, which in turn sells packaged food to retailers for sale to end customers. This paper will show that the supply chain with its differing inventory levels is the link between expenditures at end-market level and industrial production at the beginning. A sound analysis of these effects will explain why this bullwhipping occurs.

**Stock over sales**

Any company in a supply chain maintains inventory to be able to fulfill demand. When turnover rises, stock levels are increased: desired inventory is generally determined based on actual turnover. Imagine AkzoNobel raises its inventory levels, which results in additional demand for DSM upstream. This temporary rise in sales makes DSM react by increasing its own inventory levels, which translates as higher demand for the next firm up the supply chain. SABIC, DSM's supplier, experiences the combined increase of both AkzoNobel's active stocking and DSM's additional ordering to maintain its stock over sales ratio. However, these extra sales do not stem from a growth of the end market, but are just a temporary uplift in demand because of a rise in desired inventory levels further down the supply chain. Every company in the chain reacts to this stock building effect and pushes it through the chain. This trend thus results in waving inventory levels, which are magnified the higher up the supply chain a company is positioned (see figure 3). The more companies between the end market and a supplier, the larger the stock depth and the more volatile the demand at the supplier's level (4). This effect is an important driver of the cyclicality in the basic industries. For decreasing stock levels, the effects accumulate in the opposite direction.

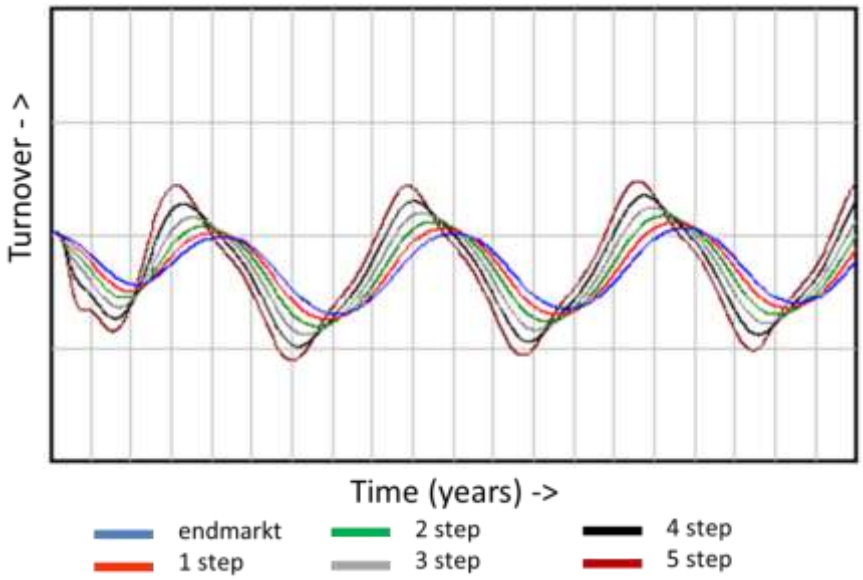


*Figure 3. Composite destocking and restocking effects on demand for firms in different positions in the supply chain. Source: Flostock.*

**Macro-economics**

The supply chain exaggerates volatility in the end markets, not only at an individual company level, but also in macro-economic environments. For the purpose of this article, end-market consumption is defined as a combination of retail, construction, company and government capital expenditures, and exports minus imports. Sales data series for these categories can be obtained from Eurostat and are corrected for their non-industrial production parts by adding weight factors. Together, they build the end market curve to evaluate industrial production output using the Flostock model.

The model consists of a 3-step supply chain with a large stock depth and long lead times. Incoming orders are smoothed over time in each step of the supply chain, while inventory is managed in line with the desired stock over sales ratio. The effects of the 2008 Lehman Wave are included with a ten percent destocking desire. Based on this design, a number of examples of industrial production forecasts for Germany (figure 4), Spain (figure 5) and the European Union (figure 6) will be presented and discussed next. Each graph features the combined industrial production-related consumption at the end-market level for the country under investigation (blue line). Based on these expenditures, an industrial production forecast is generated by the model (red line). This data is compared with the Industrial production performance as published by Eurostat (green line) (figure 4 -5 -6)

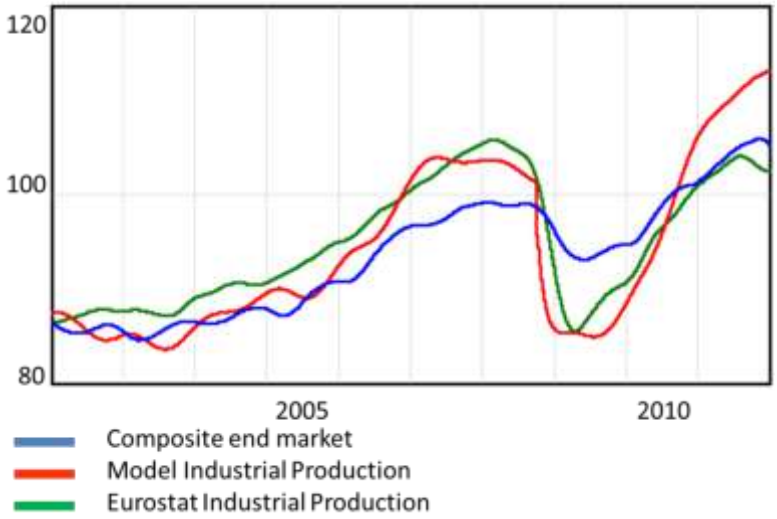


*Figure 4. Comparison of German's end-market consumption as indicated by Eurostat (blue line), the model forecasted (red line) and actual industrial production figures (green line), explaining the recent German "Wirtschaftswunder".*

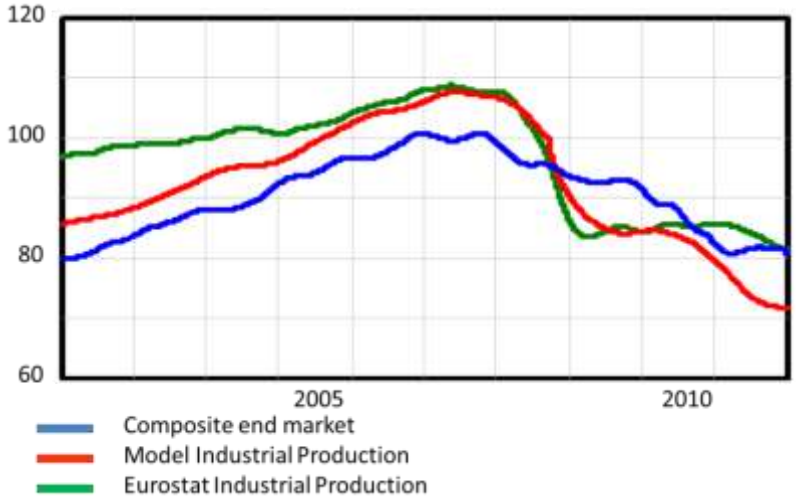


*Figure 5. The downward trend in Spain's end-market consumption caused a steady decrease in industrial production. Calculated industrial production (red line) matches Spain's actual performance*

*from 2008 to 2010 (green line), but deviates prior to 2005 and after 2011. This suggests that certain factors have not been taken into account: while Spain's consumption strongly increased from 2000 to 2008, its industrial production grew at a much slower pace, indicating a significant growth in the import of finished products.*

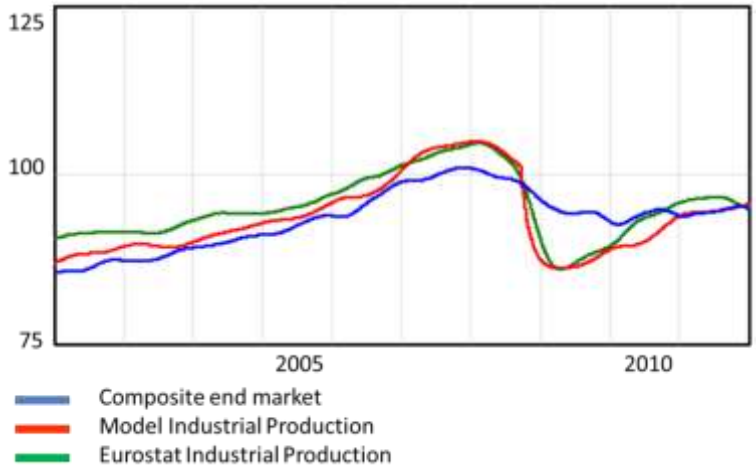


*Figure 6. Industrial production and end-market consumption for EU-27 countries. While overall consumption (blue line) decreased since the 2005-2007 bubble, it remained rather stable for a number of years after. This indicates that when industrial production's waviness dampens out, it will remain stable and not fall into a second dip as long as end-market demand remains flat.*

The length of the supply chain (stock depth) and the Lehman Wave both need to be included to calculate industrial production levels based on end-market consumption. The Lehman wave is of eminent importance, as it was the major event that prompted all stock cycles to synchronize simultaneously. Processes at micro and meso levels then became visible at a macro level because of this synchronized action. The strong volatility in upstream industrial production cannot be explained without this perspective on stock building and its profound effects. This also shows that inventory should be managed, because it acts as a driver for part of industrial production. CBS, the Dutch statistical bureau, has included inventory data in its reports since 2010 based on Flostock's insights.

The supply chain connects industrial production and end-market consumption, for which models are now available to calculate and, to a certain degree, predict industrial consumption. Although a new dip in Europe's economic performance is possible, for example if consumer confidence plummets further, we now can show that this dip will not be caused as a direct result of the global destocking that started with Lehman Brothers going bankrupt. The Lehman Wave has subsided.

Author Peels calls for an extended scope of supply chain models, especially where used by European policy makers. The volatility in industrial production cannot be explained on a macro-economic level without including stock depth in the analysis. Better models will improve knowledge of macro-economic trends and aid in the policy-making process.

**References**

1. This article was also published in Dutch on www.mejudice.nl, "Economists in debate", on 26 October 2012
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3. Flostock BV was founded in 2011 to commercialize the newly-developed forecasting model. An exclusive license has been granted to Flostock by Eindhoven University of Technology.
4. Bruinshoofd, Allard, Gerard Van Leeuwe & Tim Legierse, 2009, "De rol van kredietkrapte en voorraadcycli in de wereldhandelsimplosie." ("The role of credit scarcity and inventory cycles on the implosion of world trade") *Kwartaalschrift Economie*, vol 6(4)