Orders, inventories, and stability: using control theory to quantify behavior and the bullwhip effect.

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August 28, 2012

Abstract

In this paper, we use linear control theory to analyze the performance of a firm operating under a generalized APIOBPCS decision support system (a variant of the order-up-to rule): such a firm will generate material orders as a function of the difference between actual inventories and their specific targets (with independent controllers for on-hand, and pipeline inventories). We contribute to the existing literature by explicitly modeling managerial behavior: we allow fractional –instead of full– adjustments to be performed in each period, thus introducing a proxy to the firms' reactiveness to changes.
We show that when these behavioral factors are taken into account, supply chain stability can no longer be guaranteed. Furthermore, we show that the necessary conditions for stability in such a system depend not only on the behavioral parameters, but also on the output being measured (i.e., a system can have both: stable orders, and unstable inventories).
Following this, we quantify the performance of the system by analyzing the effect of different demand signals on order and inventory variations. In particular, we study the transient response to a step change in demand; the magnitude of amplification under cyclical demands; and the steady-state performance as measured by the ratio of stationary order and demand variances (bullwhip measure) .
Finally, we illustrate the practical importance of this research by analyzing empirical, and experimental, data that suggests real life supply chains operate in areas of stable orders and unstable inventories, and the consequences this brings.