Overview: In the context of a decentralized supply chain management system, the implementation of efficient inventory replenishment policies relies heavily on the ability of the different supply chain agents (i.e., retailers, manufacturers and suppliers) to forecast future demand and adjust inventory levels accordingly. Lack of demand information and poor visibility of inventory positions throughout the system lead to suboptimal operations in terms of costs (excessive inventory) and service level (in the form of unsatisfied demand and backorders).

There exists an extensive body of work in the supply chain management literature dedicated to measure the value of information sharing and to study the design of contractual agreements to support the exchange of demand and inventory data among different supply chain members. The goal of this paper is to contribute to this literature by shedding some light on how information sharing impacts two key sources of system volatility: (i) inventory variability and (ii) demand forecast variability (in the form of mean-squared forecast errors). In particular, our work provides a simple characterization of the tension between these two forms of variability as well as the underlying mechanism that connects them.

Motivating and supporting our analysis is the observation that the operating costs associated to a inventory replenishment policy can be divided in two components:

·) Direct Cost Effect: On one hand, a replenishment policy impacts the evolution of inventory levels and therefore has a direct effect on a firm’s holding and backordering costs. Traditionally, the literature on inventory theory has focused almost exclusively on minimizing this cost effect, which under some mild stationarity assumptions on the cost structure and demand process can be quantified through the volatility of inventory levels.

·) Indirect Cost Effect: On the other hand, we also expect inventory replenishment orders to impact the cost structure of upstream firms and suppliers that replenish these orders. Indeed, the empirical literature on supply chain management and the bullwhip effect (see Lee et al. (1997)-(2004) and references therein) has argued for a long time that order volatility is one of the fundamental drivers of system inefficiencies and inventory costs; in the form of unplanned purchase of supplies, inefficient utilization of production capacity and overtime, excess warehousing and transportation, among many other factors. Thus, one should expect that an increase in order volatility should translate into higher procurement and inventory costs in the long run†.

Contrary to the direct cost effect, our impression is that this indirect cost effect has received much less attention in the inventory management literature, possibly because it materializes gradually over time and therefore can be less visible and much harder to quantify. However, forward-looking firms should make an effort to internalize the relationship between ordering decisions and their suppliers’ performance and costs. In establishing this connection we argue that what matters is not the volatility of the order process per se but rather the volatility of the forecast error of these

† For example, if a retailer’s orders are more volatile and unpredictable then an upstream supplier would be forced to build more flexibility into its production system increasing operating costs and, as a result, raising the wholesale price that charges the retailer.
orders as computed by upstream supply chain members. The point here is that the inefficiencies mentioned in the previous paragraph are not directly driven by the fluctuations of a firm’s orders but rather they are triggered by the inability of its suppliers to anticipate these orders and optimize production and distribution accordingly. In other words, what matters is the root mean squared forecast error (MSFE) experienced by upstream suppliers as they forecasts their orders.

Motivated by the previous discussion, in this paper we address the following research questions:

- How inventory and MSFE volatilities depend on the demand forecast and inventory replenishment processes of a firm?

- Is it possible to characterize an “Efficient Frontier” between these two sources of variability by identifying optimal inventory replenishment strategies? Furthermore, what is the structure of such an optimal policy?

- Finally, what is the value of information sharing and how does it affect the ordering process of a firm?

**Summary of Methodology and Results:** We formalize these research questions by analyzing a two-tier supply chain with a single retailer and a single supplier similar to the one used by Gavirneni et al., 1999, Lee et al., 2000, or Chen and Lee, 2009 to study issues regarding inventory management and supply chain costs under information sharing.

In our model, we assume that the retailer observes a demand driven by a stationary and invertible moving average process of possibly infinite dimension. We also assume that the retailer places periodic inventory replenishment orders the the supplier and that these orders are also represented by a stationary and invertible moving average process of infinite dimension. In this setting, and under natural inventory stability considerations, we investigate the relationship between the volatility of the retailer’s inventory levels and the MSFE of the orders that she places to the supplier.

For the case in which the retailer is able (and willing) to share demand information with the supplier, we provide a complete characterization of these two sources of volatility and their relationship. To illustrate, Figure 1 depicts the Efficient Frontier associated to an optimal replenishment policy and compares it to two benchmark policies based on popular demand forecasting methods: Exponential Smoothing and Moving Average. As we can expect, the efficient frontier Pareto dominates the performance of the other two policies (i.e., produces simultaneously lower inventory and MSFE volatilities). The figure also shows that the use of a suboptimal forecasting policy can have a severe effect on performance.

We extend our analysis to situations in which the retailer is unable (or unwilling) to share demand information with the supplier, we provide a complete characterization of these two sources of volatility and their relationship. To illustrate, Figure 1 depicts the Efficient Frontier associated to an optimal replenishment policy and compares it to two benchmark policies based on popular demand forecasting methods: Exponential Smoothing and Moving Average. As we can expect, the efficient frontier Pareto dominates the performance of the other two policies (i.e., produces simultaneously lower inventory and MSFE volatilities). The figure also shows that the use of a suboptimal forecasting policy can have a severe effect on performance.

We extend our analysis to situations in which the retailer is unable (or unwilling) to share demand information with the supplier and show that information sharing does not always add value. We also show that the question of identifying conditions under which information sharing does offer value reduces to a delicate analysis of the invertibility (in a time series sense) of a specific stationary process. While the tools for checking invertibility numerically are available, a theoretical analysis of the problem has proven to be very challenging. At this point, we can only conjecture a number

---

1In the context of an infinite-horizon, periodic-review, two-tier inventory management system.
of properties that an optimal replenishment policy should satisfy under no information sharing. Although more work needs to be done to provide a complete theoretical characterization of an optimal policy under no information sharing, we formulate a non-linear optimization problem that can be used to approximately compute a solution that has shown good numerical performance.

References


