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# Inventories, Financial Metrics, Profits, and Stock Returns in Supply Chain Management

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## 1. Introduction

This chapter studies the role of inventory in supply chain management and in its impact in the book value and market value of firms. We elaborate on the idea that inventory models can be useful for implementing inventory policies for the different stages of a supply chain. In section 2, the role of inventory in supply chain management is discussed. In section 3, we provide a discussion of existing inventory models that have been developed to model real systems.Many authors have proposed mathematical models that are easy to implement in practical situations. We provide a simple classification of these models based on stocking locations and type of demand.

In section 4, we address the empirical question of whether inventory level decisions should be focused on efficiency (i.e., minimum inventory levels) or on responsiveness (i.e., maximum product availability). To answer this, we analyze the US agribusiness (food) sector during 35 years. This sector weights about 10% of the complete US market, and has been chosen by the authors for two reasons. Inventory levels in agribusinesses could be considered more critical due to the highly perishable nature of food products, and because the sample includes firms considered as mature (Jensen (1988)). Mature firms are expected to have already fine tuned their inventory level positions. Using regression analysis, empirical results show that both, the growth in inventories[1] and capital expenditures in year *t*, negatively affect stock returns in *t+1* at 1% level of significance. Further, while property, plant and equipment represents 70% of total invested capital compared to inventories representing 30%, a 1% change in inventories has an economic impact similar to a 1% investment in capital expenditures. This emphasizes the economic importance of managing inventories.

## 2. The role of inventory in supply chain management

According to Chopra and Meindl (2007), inventory is recognized as one of the major drivers in a supply chain, along with facilities, transportation, information, sourcing, and pricing. In

[1] Inventories and inventory level are used interchangeably

this chapter we investigate the relationship between inventories and the value of firms (i.e., as measured by financial accounting metrics and stock prices returns). It turns out that the investment in inventory is an important component of Return of Invested Capital (ROIC) and of its corresponding weighted average cost of capital. We elaborate on those measurements, emphasizing their relationship with inventories, in section 4.

Inventory exists in the supply chain because there is a mismatch between supply and demand. In any supply chain there are at least three types of inventories: raw materials, work-in-process, and finished products. The amount of these types of inventories held at each stage in the supply chain is referred to as *the inventory level*. In general, there are three main reasons to hold inventory (Azadivar and Rangarajan (2008)):

1. Economies of scale: placing an order usually has a cost component that is independent of the ordered quantity. Therefore, a higher frequency of orders may increase the cost of setting up the order. This may even cause higher transportation costs because the cost of transportation per unit is often smaller for larger orders.
2. Uncertainties: as products are moved within the supply chain, there exists variability between the actual demand and the level of inventories being produced and distributed. Therefore, inventories help mitigate the impact of not holding sufficient inventory where and when this is needed.
3. Customer service levels: inventories act as a buffer between what is demanded and offered.

So, one of the main functions of maintaining inventory is to provide a smooth flow of product throughout the supply chain. However, even if all the processes could be arranged such that the flow could be kept moving smoothly with inventories, the variability involved with some of the processes would still create problems that holding inventories could resolve.

From the above reasons, it becomes clear that the level of inventory held at the different stages of the supply chain has a close relationship with a firm's competitive and supply chain strategies. For instance, inventory could increase the amount of demand available to customers or it could reduce cost by taking advantage of economies of scale that may arise during production and distribution. Moreover, we argue that the inventory held in a supply chain significantly affect the value of the firm, as it will be discussed in section 4.

### 2.1 Supply chain strategy

As we have discussed, determining inventory levels at the different stages of the supply chain is an important part of the supply chain strategy, which in turn, must be aligned with the firm competitive strategy. Fisher (1997) presents an interesting framework that helps managers understand the nature of the demand for their products and devise the supply chain strategy than can best satisfy that demand. This framework lays out a matrix that matches product characteristics as follows: between *functional products* (e.g., predictable demand, like commodities) and *innovative products* (e.g., unpredictable demand, like technology-based products); and supply chain characteristics: *efficient supply chains* (whose primary purpose is to supply predictable demand efficiently at the lowest possible cost) and *responsive supply chains* (whose primary purpose is to respond quickly to unpredictable demand in order to minimize stock-outs, forced markdowns, and obsolete inventory). This idea is illustrated in Figure 2.1.

From Fisher's framework it becomes clear that a supply chain cannot maximize cost efficiency and customer responsiveness simultaneously. This framework identifies a market-driven basis for strategic choices regarding the supply chain drivers. Therefore, as far as inventory, some questions arise as to whether inventory strategies should be focused on efficiency (minimizing inventory levels) or on responsiveness (maximizing product availability). This is the empirical question addressed in this chapter (section 4), but before that inventory systems and models are discussed in section 3.

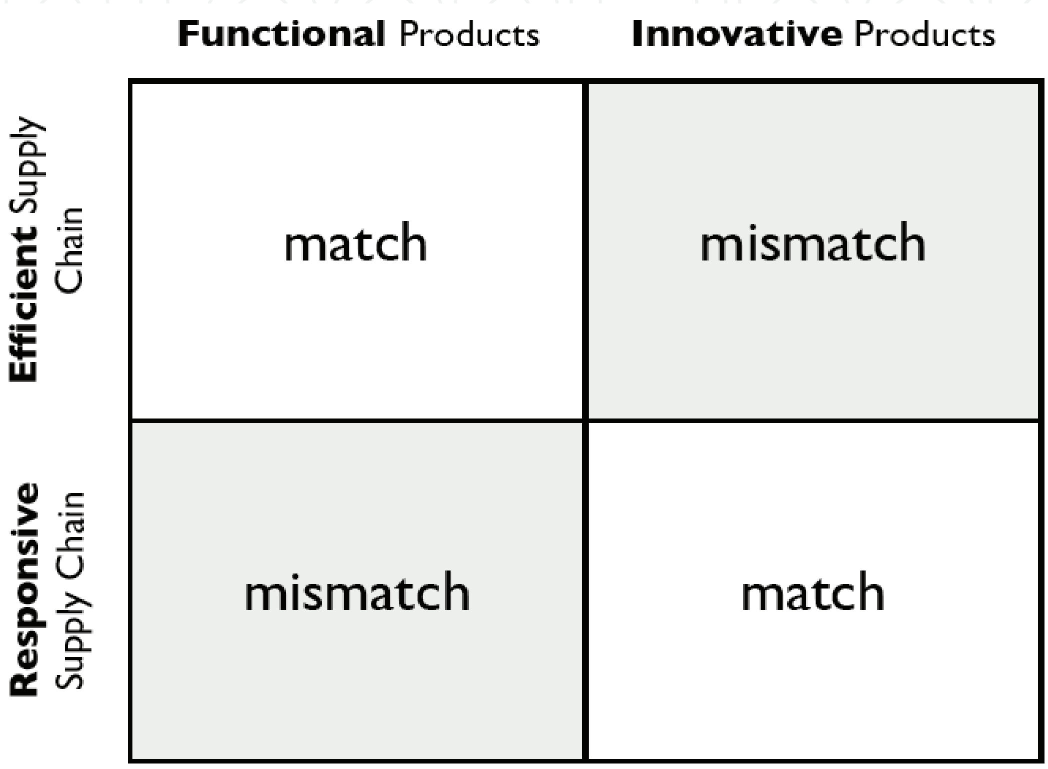


Fig. 2.1. Matching supply chain with products (adapted from Fisher (1997))

## 3. Design of the appropriate inventory systems in a supply chain

In designing an inventory system, there are two main decisions to make: how often and how much to order. The goal is to determine the appropriate size of the order without raising cost unnecessarily; otherwise the firm value might deteriorate.

A major criterion in determining the appropriate level of inventory at each stage in the supply chain is the cost of holding the inventory. In trying to avoid disruptions, this cost might exceed the potential loss due to shortage of goods. On the other hand, if lower levels are maintained in order to decrease the holding cost, this might result in more frequent ordering as well as losses of customer trust and losses due to disruptions in the supply chain. Thus, designing an inventory system to determine the appropriate level of inventory for each stage in the supply chain requires analyzing the trade-off between the cost of holding inventory and the cost of ordering (typically known as setup cost).

Azadivar and Rangarajan (2008) present an interesting discussion of factors in favor of higher and lower inventory levels. Some of their discussion is summarized in Figure 3.1.

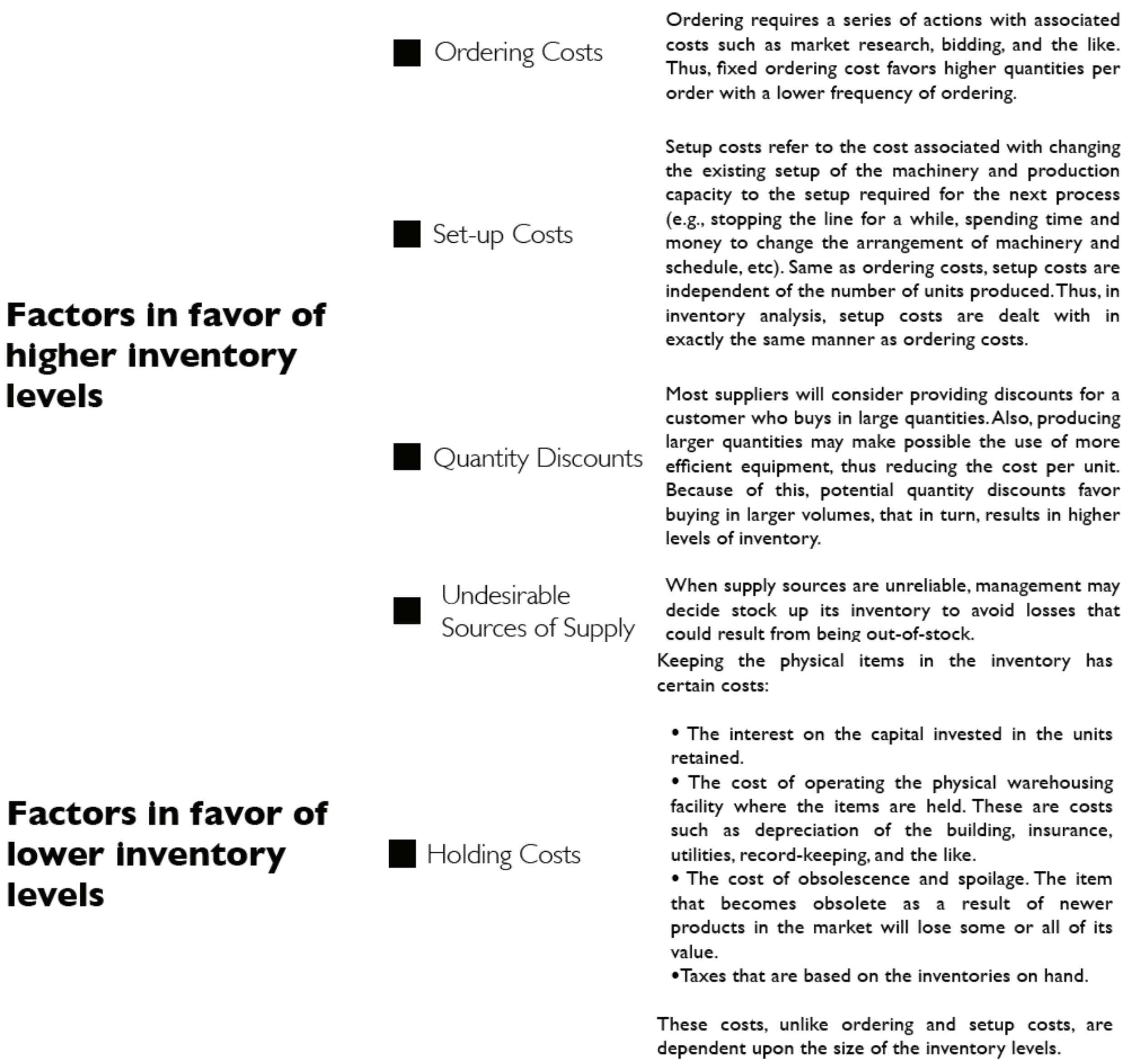


Fig. 3.1. Factors affecting the level of inventory (summarized from Azadivar and Rangarajan (2008))

### 3.1 A classification framework of inventory models

Inventory models are mathematical models of real systems and are used as a tool for calculating inventory policies for the different stages of a supply chain. Currently, small and medium companies seem to be characterized by the poor efforts they make optimizing their inventory management systems through inventory models. They are mainly concerned with satisfying customers' demand by any means and barely realize about the benefits of using scientific models for calculating optimal order quantities and reorder points, while minimizing inventory costs and increasing customer service levels. As far as large companies, some of them have developed stricter policies for controlling inventory. Though, most of these efforts are not supported by scientific (inventory) models either. Many authors have proposed mathematical models that are easy to implement in practical situations and can be used as a basis for developing inventory policies in real systems. This section presents a brief discussion of existing inventory models that have been developed to model real systems. We provide a simple classification of these models based on the following two criteria (a table summarizing the literature on inventory models is presented at the end of the section):

1. Stocking locations: this criterion refers to the number of stages used as a stocking location. That is, when inventory is held at only one stage, this system is referred to as a single-stage model. When more than one stage is considered as stocking location, these systems are called multi-echelon[2] inventory models (or supply chain inventory models).
2. Type of demand: this refers to customer demand. It may be deterministic or stochastic. The first is when the demand is fixed and known. In stochastic demand, uncertainties are considered and modeled using some known probability distribution.

### 3.1.1 Deterministic inventory systems

In this type of models it is assumed that the demand is fixed and known. The most fundamental of all inventory models is the so-called Economic Order Quantity (EOQ). EOQ was first introduced by Ford Whitman Harris in 1913, an engineer at Westinghouse Electric Co. (Harris (1990)), and is used to determine purchasing or production order quantities while considering the trade-off between fixed ordering and holding costs. The basic EOQ model assumes that the demand rate (demand per time unit) is constant, inventory shortages are not allowed, and replenishments leadtimes are constant.

Let us now explain how this system is designed. In inventory management, in addition to considering the purchasing unit cost of an item ($c$), managers must also consider the fixed cost of ordering (placing) an order and the cost of holding the inventory at the warehouse. The order cost ($k$), is the sum of all the fixed costs incurred every time an order is placed. This cost is also known as purchase or setup cost. According to Piasecki (2001), "these costs are not associated with the quantity ordered but primarily with physical activities required to process the order". The order cost comprises issues such as the cost for entering the order, approval steps, processing the receipt, vendor payment, time inspecting incoming products, time spent searching and selecting suppliers, phone calls, etc. The holding cost ($h$) represents the cost of having inventory on hand (e.g., investment and storage) and is calculated as follows,

$$h = I \times c, \tag{3.1}$$

where $c$ is the unit cost of the item and $I$ is an annual interest rate that usually includes: opportunity cost, insurances, taxes, storage costs, and spoilage, damage, obsolescence and theft risk costs.

As shown by Harris (1990), these costs significantly affect the order quantity decision ($Q$). For example, in order to take advantage of quantity discounts offered by some suppliers, companies tend to purchase large volumes each time they order. Nevertheless, while this approach may minimize the fixed cost of placing the order, it increases the cost of holding that amount of inventory. Therefore, it is important to study the trade-off between these costs. Figure 3.2 illustrates this concept.

[2] Hillier and Lieberman (2010) define an echelon of an inventory system as "each stage at which inventory is held in the progression through a multi-stage inventory system".

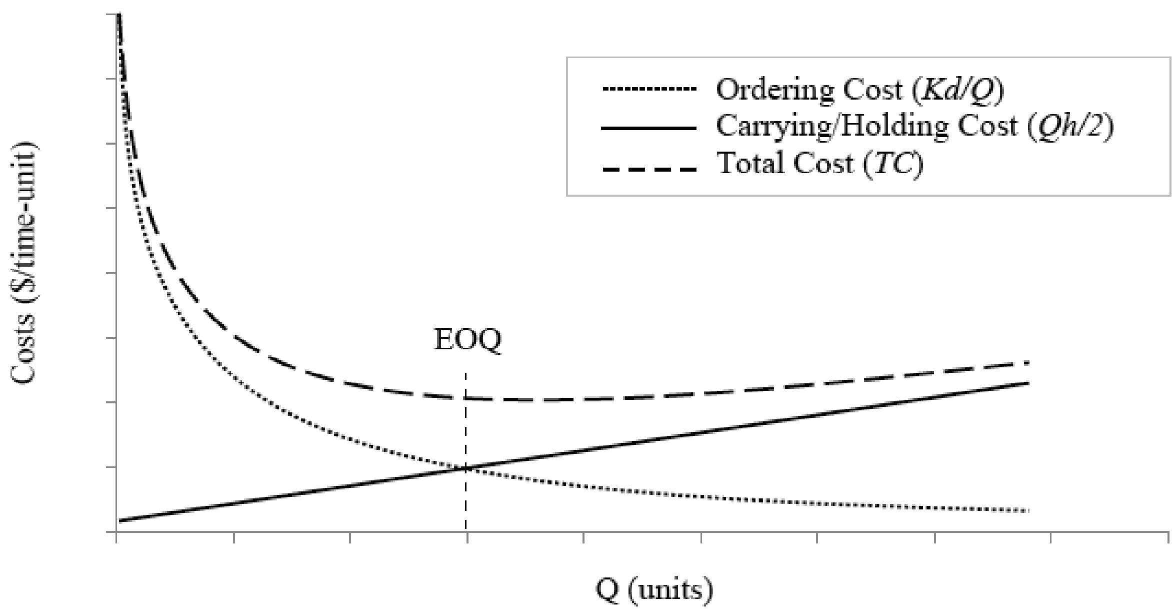


Fig. 3.2. The inventory costs tradeoff

From Figure 3.2, the total cost per time unit is the sum of the ordering and the holding costs. The ordering cost per time unit is calculated as the product between the ordering cost ($k$) and the number of orders placed in a time unit ($d/Q$), where $d$ represents the demand per time unit The holding cost per time unit is computed as the product between the average inventory level ($Q/2$) and the holding cost ($h$). The objective is to minimize the Total Cost per time unit ($TC$),

$$TC(Q) = \frac{kd}{Q} + \frac{hQ}{2}. \tag{3.2}$$

It can easily been shown that the order quantity that minimizes the total cost per time unit is the minimum value of the $TC$ function. That is, the point at which the tangent or slope of the curve is zero. The optimum order quantity ($Q^*$) is then given by,

$$Q^* = \sqrt{\frac{2kd}{h}}\ , \tag{3.3}$$

and, since the demand rate is constant, the time between orders (e.g., how often an order of size $Q$ is to be placed) can be calculated as follows,

$$T^* = \frac{Q^*}{d}. \tag{3.4}$$

An important characteristic of the EOQ formula is its robustness [3] (Silver, Pyke and Peterson (1998)). Observe from Figure 3.2 that the total cost curve is significantly flat in the region

[3] Robustness refers to the insensitiveness of the EOQ to errors in the input parameters

surrounding the EOQ. This implies that a reasonable positive or negative deviation from the optimal quantity does not have a big impact on the total cost per time unit. Due to this, it is safe to assume that the EOQ is very insensitive to misestimates on the input parameters. Additionally, the EOQ represents a good starting solution for more complex models (Nahmias (2001)). This is why the EOQ represents a simple, yet effective way of determining an inventory policy. Moreover, although the basic EOQ model assumes a deterministic demand, some authors have shown that using it in stochastic environments, instead of more sophisticated approaches, does not result in a considerable increase in the cost of policies. Zheng (1992) demonstrates that the maximum relative error bound is 12.5%. Furthermore, Axsäter (1996) states that the increase is no more than 11.80%. Considering the cost and time required to develop inventory policies with more complex methodologies and software, we found that it is perfectly justified to take advantage of the simplicity of the deterministic EOQ formula even in stochastic situations.

Extensions to the basic EOQ include the consideration of shortage costs, inclusion of quantity discounts, and the extension to the case of finite production rate. The reader is referred to Chopra and Meindl (2007), Nahmias (2001), Hillier and Lieberman ( 2010), and Silver, Pyke and Peterson (1998) for more detailed texts on these extensions. Finally, the EOQ has been applied successfully by some companies. For instance, Presto Tools, at Sheffield, UK, obtained a 54% annual reduction in their inventory levels (Liu and Ridgway (1995)).

*Leadtime and Reorder Point*

Another important parameter to consider when designing an inventory system is the so-called leadtime. Since orders are not received at the time they are placed, the time between when an order is placed and the time when is received is called leadtime. If a company waits until the inventory is completely depleted, the inventory will be out of stock during the leadtime. Therefore, orders need to be placed before the inventory level reaches zero. In order to overcome this situation, the order is placed whenever the inventory level reaches a level called the reorder point. In deterministic inventory models (e.g., EOQ), it is assumed that the leadtime is constant and known. In stochastic inventory systems, the leadtime could be a random variable (this will be discussed in section 3.1.2). According to Azadivar and Rangarajan (2008), two methods can be used to determine when an order should be placed: (1) the time at which the inventory will reach zero is estimated and the order is placed a number of periods equal to the leadtime earlier than the estimated time; (2) the second approach is based on the level of inventory. In this approach, the order is placed whenever the inventory level reaches a level called the reorder point (ROP). This means that if the order is placed when the amount left in the inventory is equal to the reorder point, the inventory on hand will last until the new order arrives. Thus the reorder point is that quantity sufficient to supply the demand during the leadtime. If we assume that both the leadtime ($L$) and the demand are constant, the demand during the leadtime is constant too, and the ROP can be calculated as follows:

$$ROP = L \times d \ . \qquad (3.5)$$

This concept is illustrated in Figure 3.3.

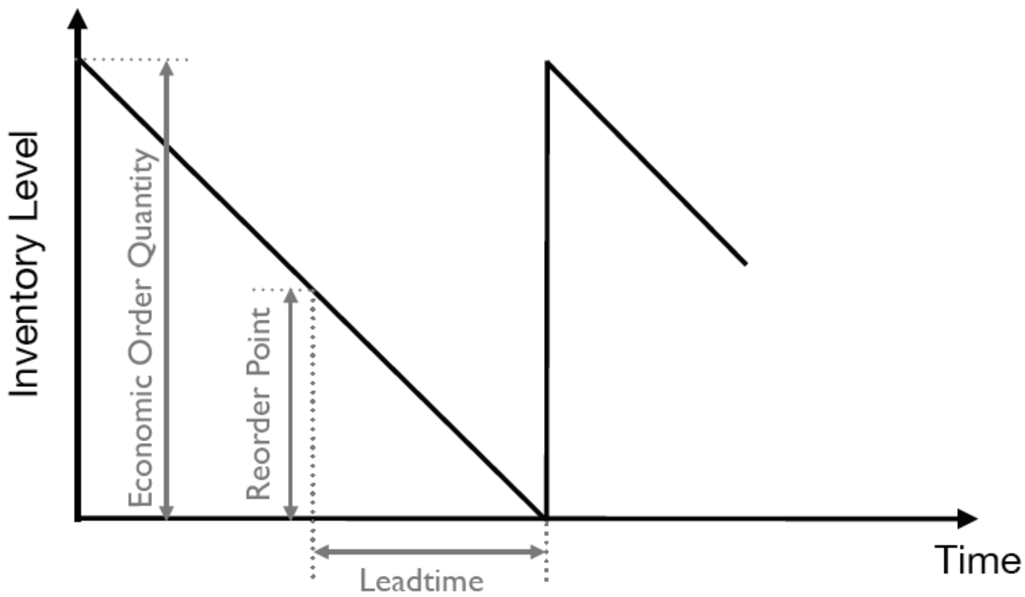


Fig. 3.3. Graphical representation of the reorder point and leadtime

### 3.1.2 Stochastic inventory systems

In section 3.1.1, it was assumed that the demand rate is constant and known. Also, it was assumed that the quantity ordered would arrive exactly when expected. These assumptions eliminated uncertainties and allowed simple solutions for designing inventory systems. In this section, we now study the case when uncertainties are present in modeling the inventory system, as in most real situations. For instance, if new orders do not arrive by the

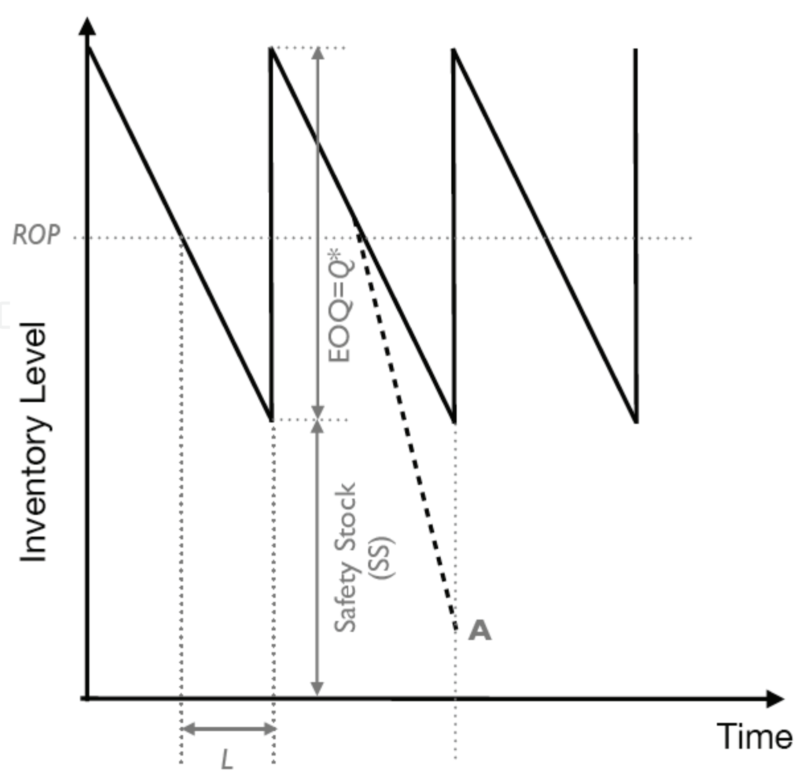


Fig. 3.4. Illustration of the concept of SS

time the last unit in the inventory is used up, then the company will be short for the next person demanding units from inventory (this is called stockout). And, if customers are not willing to wait for the next order arrival, this will cause loss of goodwill, and therefore loss of profit. Stockouts occur whenever the leadtime exceeds the reorder point. In order to overcome this situation, companies need to design inventory systems so they carry sufficient inventory to satisfy demand when the forecast has been exceeded due to system variability. The amount of inventory carried for these situations is called safety stock (SS). Chopra and Meindl (2007) formally define the SS as the "inventory carried to satisfy demand that exceeds the amount forecasted for a given period". Figure 3.4 illustrates the SS concept.

As shown in Figure 3.4, when the ordered units ($Q^*$) arrive, there are still a number of units left in inventory (equivalent to *SS*). Point **A** indicates the possible variation of demand. Observe that even if demand changes (as in the dotted line ending in point A), the SS would still act as a buffer to maintain sufficient inventory to satisfy possible demands.

The appropriate level of *SS* is determined by two factors: (1) uncertainty of both demand and supply (e.g., leadtime). In this case, a company is exposed to uncertainty of demand during the leadtime. Thus, in designing inventory models for this situation, one must estimate the uncertainty of demand during the leadtime; and (2) the desired level of product availability. Product availability is generally measured in two ways: product fill rate and service level. Product fill rate is the fraction of product demand that is satisfied from product in inventory. This is equivalent to the probability that product demand is supplied from available inventory. Service level is the desired probability of not having stockouts during the leadtime.

Notice that when the SS is considered, the ROP is calculating as follows:

$$ROP = Ld + SS\,. \tag{3.6}$$

Unlike Eq. (3.5), the *SS* term is added to account for the variability in the system, as explained before. As the factor directly affecting our decision is the reorder point rather than the safety stock, we usually determine the best reorder point before finding the *SS*. Additionally, since stochastic behavior is considered, the *SS* could be better defined as:

$$SS = ROP - \textit{Expected value of demand during the leadtime}. \tag{3.7}$$

That is, one way of dealing with uncertain demand is to increase the reorder point to provide some safety stock if higher-than-average demands occur during the leadtime. So, to deal with uncertainties in a stochastic system, we would need to characterize the stochastic behavior of the system. In particular, we are interested in knowing the probability distribution of demand during the leadtime. The problem is that this is not an easy task. For example, if the probability density function of demand per day is denoted as $f(x)$, the density function for demand during the leadtime of $n$ days is not always a simple function of $f(x)$(Azadavir and Rangarajan (2008)). In order to illustrate the logic for calculating the SS, in this chapter, we present a case when a normal probability distribution provides a good approximation of the demand during the leadtime. The reader is referred to Azadivar and Rangarajan (2008) and Silver, Pyke and Peterson (1998) for the analysis of more complex stochastic systems.

*Continuous Review Model*

There are several review schemes that integrate a variable demand, such as the Continuous Review Model and the Periodic Review Model. In the Continuous Review Model or ($Q$, $R$)

model, an order of $Q$ units is placed when the reorder point ($ROP$) is reached. When a normal probability distribution provides a good approximation of the demand during the lead time, the general expression for the reorder point is as follows,

$$ROP = \mu_{LTD} + z \cdot \sigma_{LTD} \, , \quad (3.8)$$

where $\mu_{LTD}$ is the average demand during the leadtime, $\sigma_{LTD}$ is the standard deviation of the demand during the leadtime and $z$ is the number of standard deviations necessary to achieve the acceptable service level (the probability of not having stockout during leadtime). Notice that $z \cdot \sigma_{LTD}$ represents the safety stock.
The terms $\mu_{LTD}$ and $\sigma_{LTD}$ are obtained, respectively, as follows:

$$\mu_{LTD} = \mu_t L \, , \quad (3.9)$$

$$\sigma_{LTD} = \sigma_t \sqrt{L} \, , \quad (3.10)$$

where $\mu_t$ is the average demand on a time $t$ basis, $\sigma_t$ is the standard deviation of the demand during $t$ and $L$ is the supply leadtime.
Notice that the determination of the reorder point is based on the so-called Inventory Position ($IP$). The $IP$ provides an accurate value of the actual inventory position of a product and is calculated as follows,

$$IP = OH + SR - BO, \quad (3.11)$$

where $SR$ represents scheduled receipts (units already ordered and pipe-line inventory), $BO$ refers to back-orders and $OH$ to the actual inventory on-hand. If the control system only considers the on-hand inventory, every unit below the reorder point will trigger a purchasing order of $Q^*$ units, an undesirable and counterproductive situation (as it increases holding costs unnecessarily).

### 3.1.3 Multi-stage inventory systems

The focus of sections 3.1.1 and 3.1.2 was on single-stage models. These types of models have provided a strong foundation for subsequent analyses of multi-stage systems. However, one may ask what happens if the manufacturer is out of the stock and the rest of the supply chain relies on this manufacturer to offer finished products to its customers. Then, we see the need to extend those basic results already studied for single-stage systems to the entire supply chain. Thus, this section focuses on analyzing inventory models at multiple locations. These types of models are referred to as supply chain inventory management models or as multi-echelon inventory models, in the research literature. Figure 3.5 shows a general multi-echelon network.
One of the core challenges of managing inventory at multiple locations, as one may see in Figure 3.5, is the dependency between the different stages of the supply chain. These dependencies make the coordination of inventory difficult. The analysis of the research in this area, presented next, provides some models for different supply chain configurations.

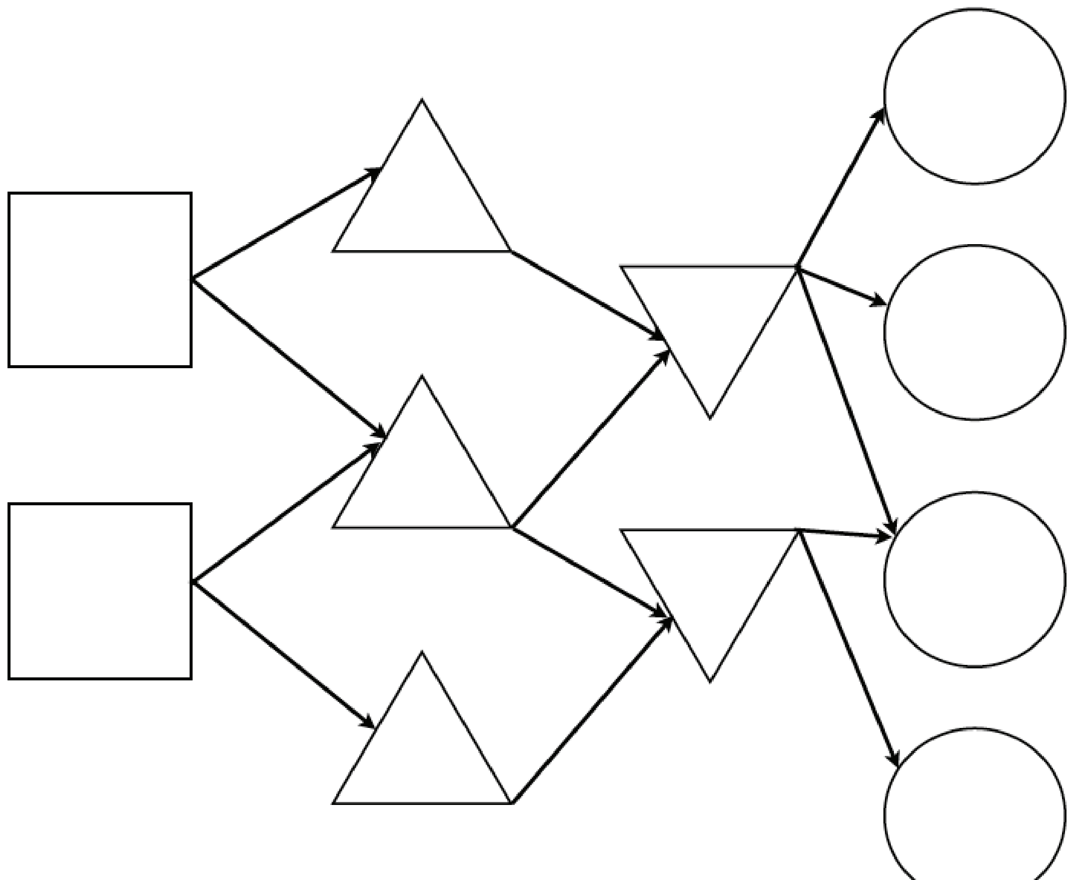

Fig. 3.5. A general multi-echelon network (extracted from Azadivar and Rangarajan, 2008).

The first inventory policies for multi-stage systems were presented by Clark and Scarf (1960) and Hadley and Whitin (1963). Determination of optimal inventory policies for multi-stage inventory systems is made difficult by the complex interaction between different levels, even in the cases where demand is deterministic. Given this, several researchers have developed different approaches to find effective solutions to these problems. Schwarz (1973) concentrated on a class of policies called the basic policy and showed that the optimal policy can be found in a set of basic policies. He proposed a heuristic solution to solve the general one-warehouse multi-retailer problem. Rangarajan and Ravindran (2005) introduced a base period policy for a decentralized supply chain. This policy states that every retailer orders in integer multiples of some base period, which is arbitrarily set by the warehouse. Recently, Natarajan (2007) proposed a modified base period policy for the one warehouse, multi-retailer system. He formulated the system as a multi-criteria problem and considered transportation costs between the echelons.
Roundy (1985) introduced the so-called power-of-two policies. He presented a 98% effective power-of-two policy for a one-warehouse, multi-retailer inventory system with constant demand rate. In this class of policies, the time between consecutive orders at each facility is a power-of-two of some base period. Several researchers have used the power-of-two policies for multi-stage inventory systems that do not incorporate supplier selection. These policies have proven to be useful in supply chain management since they are computationally

efficient and easy to implement. Maxwell and Muckstadt (1985) developed a power-of-two policy for a production-distribution system. Roundy (1986) extended his original 98% effective policy to a general multi-product, multi-stage production/inventory system where a serial system is a special case. Federgruen and Zheng (1995) introduced algorithms for finding optimal power-of-two policies for production/distribution systems with general joint setup cost. For the stochastic cases, Chen and Zheng (1994) presented lower bounds for the serial, assembly, and one-warehouse multi-retailer systems.

For the serial inventory system, Schwarz and Schrage (1975) and Love (1972) proved that an optimal policy must be nested and follow the zero-ordering inventory policy. A policy is nested provided that if a stage orders at any given time, every downstream stage must order at this time as well. The zero-ordering inventory policy refers to the case when orders only occur at an inventory level of zero. Muckstadt and Roundy (1993) developed a power-of-two policy for a serial assembly system and proved that such a policy cannot exceed the cost of any other policy by more than 2% for a variable base period. They introduced an algorithm to solve the problem along with the corresponding analysis of the worst-case behavior. Sun and Atkins (1995) presented a power-of-two policy for a serial system that includes backlogging. They reduced the problem with backlogging to an equivalent one without backlogging and used Muckstadt and Roundy's algorithm to solve this transformed problem. For serial systems with stochastic demand, an echelon-stock ($R$,$nQ$) policy for compound Poisson demand was introduced by Chen and Zheng (1998).

Most recently, Rieksts, Ventura, Herer and Daning (2007) developed power-of-two policies for a serial inventory system with a constant demand rate and incremental quantity discounts at the most upstream stage. They provided a 94% effective policy for a fixed base planning period and a 98% effective policy for a variable base planning period. Mendoza and Ventura (2010) presented a mathematical model for a serial system. This model determines an optimal inventory policy that coordinates the transfer of items between consecutive stages of the system while properly allocating orders to selected suppliers in stage 1. In addition, a lower bound on the minimum total cost per time unit is obtained and a 98% effective power-of-two (POT) inventory policy is derived for the system under consideration. This POT algorithm is advantageous since it is simple to compute and yields near optimal solutions.

Some authors have considered multi-criteria approaches to multi-stage inventory systems. Thirumalai (2001) modeled a supply chain system with three companies arranged in series. He studied the cases of deterministic and stochastic demands and developed an optimization algorithm to help companies achieve supply chain efficiency. DiFillipo (2003) extended the one-warehouse multi-retailer system using a multi-criteria approach that explicitly considered freight rate continuous functions to emulate actual freight rates for both centralized and decentralized cases. Natarajan (2007) studied the one-warehouse multi-retailer system under decentralized control. The multiple criteria models are solved to generate several efficient solutions and the value path method is used to display tradeoffs associated with the efficient solutions to the decision maker of each location in the system.

Finally, Table 3.1 provides a simple classification of the inventory models discussed in this chapter. Notice that this table is not intended to cover the vast literature on inventory models, and it is rather presented to summarize the literature discussed in this chapter.

| Author(s) | Stocking Locations | | Type of Demand | |
|---|---|---|---|---|
| | Single | Multiple | Deterministic | Stochastic |
| Axsäter (1996) | X | | | X |
| Chen and Zheng (1994) | | X | | X |
| Chen and Zheng (1998) | | X | | X |
| Clark and Scarf (1960) | | X | X | |
| Federgruen and Zheng (1995) | | X | X | |
| Harris (1990) | X | | X | |
| Love (1972) | | X | X | |
| Maxwell and Muckstadt (1985) | | X | X | |
| Ventura and Mendoza (2009) | X | | X | |
| Mendoza and Ventura (2010) | | X | X | |
| Muckstadt and Roundy (1993) | | X | X | |
| Natarajan (2007) | | X | X | X |
| Rangarajan and Ravindran (2005) | | X | | X |
| Rieksts et al. (2007) | | X | X | |
| Roundy (1985) | | X | X | |
| Roundy (1986) | | X | X | |
| Schwarz (1973) | | X | X | |
| Schwarz and Schrage (1975) | | X | X | |
| Sun and Atkins (1995) | | X | X | |
| Thirumalai (2001) | | X | X | X |
| Zheng (1992) | X | | X | X |

Table 3.1. Summary of inventory models

### 3.2 Inventory management in practice

The models presented before may seem to be unrealistic for practical purposes. Regarding this, Azadivar and Rangarajan (2008) stated: "One may wonder, given the many simplifications made in developing inventory management models, if the models are of value in practice. The short answer is a resounding "Yes"! ". Although all models are not applicable in all situations, the models presented in the preceding sections have served as a basis for developing models for practical situations with excellent results. Table 3.2 summarizes some examples of inventory management applications in practice.

Most of the inventory models presented earlier may be easily implemented using spreadsheets. The information typically comes from an enterprise resource planning systems (ERP) and companies must be able to develop frameworks that allow proper use of that information when it comes to develop inventory management systems. Additionally, there are some other inventory management (and optimization) software available, independent of the ERP systems. Some of these have been developed by: i2 Technologies, Manhattan Associates, SAP and Oracle.

The preceding sections emphasize the relevance of inventory in supply chain management. However, there are other factors impacting supply chain management not covered in this chapter. For instance, with the advent of global supply chains, the location of facilities and transportation modes can have a significant impact on inventory levels and it is recommended that these factors should be taken into consideration when optimizing

| Reference | Company | Comments |
|---|---|---|
| Lee and Billington (1995) | HP | • Goal: Inventory Management in decentralized SC for HP Printers<br>• Inventory reduction of 10%-30% |
| Lin, Ettl, Buckley, Bagchi, Yao, Naccarato, Allan, Kim and Koening (2000) | IBM | • Goal: Decision support system (DSS) for global SC (inventory) management<br>• Approx. $750 million in inventory and markdown reductions |
| Koschat, Berk, Blatt, Kunz, LePore and Blyakher (2003) | Time Warner | • Goal: Optimize printing orders and distribution of magazines in three stage SC<br>• Solutions based on the newsvendor model<br>• $3.5 million increase in annual profits |
| Kapuscinski, Zhang, Carbonneau, Moore and Reeves (2004) | Dell Inc. | • Goal: Identify inventory drivers in SC for better inventory management at Dell DCs<br>• Expected savings of about $43 million; 67% increase in inventory turns; improved customer service |
| Bangash, Bollapragada, Klein, Raman, Shulman and Smith (2004) | Lucent Technologies | • Goal: DSS tool for inventory management of multiple products<br>• Solution based on (s, S) policies<br>• $55 million in inventory reductions; fill rates increased by 30% |
| Bixby, Downs and Self (2006) | Swift & Co. | • Goal: Production management at beef products facilities; DCC tool for sales<br>• Solution adapts production plans based on inventories and customer orders dynamically<br>• $12.74 million in annual savings; better sales force utilization |

Table 3.2. Examples of inventory management applications (extracted from Azadivar and Rangarajan, 2008)

inventory levels in the SC. For an overview of the issues in transportation and inventory management, see Natarajan (2007) and Mendoza and Ventura (2009). Finally, there is an increasing concern about risks involved in the supply chain. Some of these risks are: disruptions during the transfer of products due to uncontrollable events, uncertain supply yields, uncertain supply lead times, etc. Incorporating these factors is fundamental for companies to be able to develop alternative supply strategies in case of disruptions. Rangarajan and Guide (2006) and Tang (2006) discuss some challenges presented by supply chain disruptions and review the relevant literature in this area.

## 4. Inventory and the value of the firm

The empirical question of whether inventory level decisions should be focused on efficiency (i.e., minimum inventory levels) or on responsiveness (i.e., maximum product availability) remains. High inventory levels increases the responsiveness of the supply chain but

decreases its cost efficiency because of the holding cost. Inversely, if inventory levels are too low, shortages may occur resulting in customer dissatisfaction and potential loss of sales. To explore this problem, in this section we elaborate on the relationship between inventory and the value of firms as measured by financial accounting metrics and stock prices returns.
The accounting value[4] of a firm could be proxy by total Invested Capital at a given point in time. Invested Capital (*IC*) is defined as,

$$IC = E + D - C, \tag{4.1}$$

where *E* is equity, *D* is total debt or liabilities with financial cost, and *C* is cash and short-term investments. *D* minus *C* is known in finance as *net* debt.
Given the basic accounting equation (assets equals liability plus equity), as Figure 4.1. illustrates, *IC* is equivalent to assets *minus* liabilities without cost (suppliers included) *minus* cash and short-term investments. Or simply, *IC* is

$$IC = AR + INV - AP + PP\&E + OA - OL, \tag{4.2}$$

where *AR* is accounts receivable, *INV* is inventories, *AP* is accounts payable, *PP&E* is net[5] property, plant, and equipment, *OA* is other assets, and *OL* is other liabilities without financial cost. Assuming *OA* equals *OL*[6], *IC* is reduced to *AR+INV-AP+PP&E*. *AR+INV-AP* is known as net operating working capital (*NOWC*). Thus, in its simplest expression, *IC,* the book value of a firm equals *NOWC* + *PP&E*.

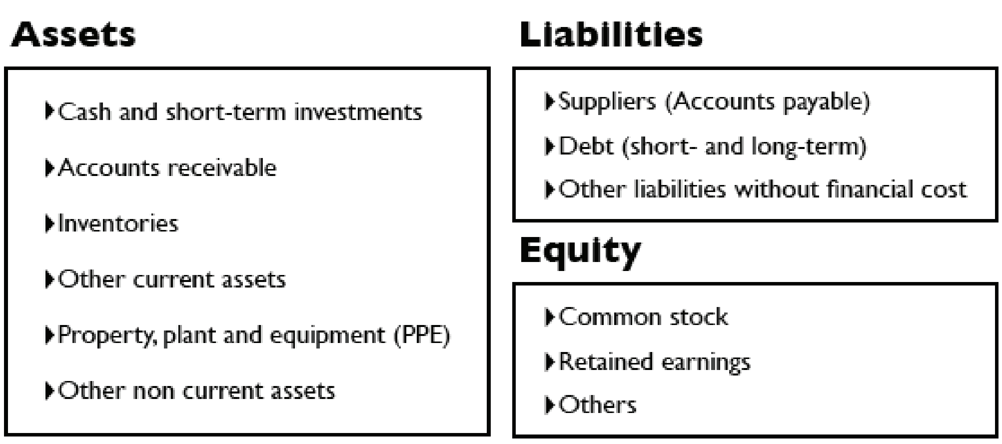


Fig. 4.1. A simplified balance sheet

Table 4.1 provides statistics for *IC* and its main components for American firms in the food sector (i.e., agribusinesses) categorized following a 3-digit SIC code classification as in Trejo-Pech, Weldon and House (2008) and Trejo-Pech, Weldon, House and Gunderson (2009). Table 4.1 comprises 35 years of financial results reported by all US agribusiness firms. This sector weights about 10% of the complete US market in terms of market capitalization, and has been chosen by the authors for two reasons. Inventory levels in agribusinesses could be considered more critical due to the highly perishable nature of food products, and because

[4] Book value and accounting value are term used interchangeably in the research literature and by practitioners
[5] Net of accumulated depreciation
[6] This is not a strong assumption considering that the absolute values of these items in the balance sheet of an average firm are not materially - relevant relative to total assets

the sample includes firms considered as mature (i.e., food processing and beverage firms) as per Jensen (1986). Mature firms are expected to have already fine tuned their inventory level positions. Table 4.1 shows *AR*, *INV*, and *AP*, and their corresponding changes (e.g., *ΔAR* is *AR* in time *t* minus *AR* in *t-1*), all scaled by *IC*. *PP&E* divided by *IC* and the corresponding *ΔPP&E/IC* are also presented in the table. The change in gross *PP&E* is commonly known as *CAPEX* or capital expenditures.

| | Mean | Std. Dev. | CV |
|---|---|---|---|
| AR/IC | 19.15% | 37.82% | 1.97 |
| INV/IC | 30.75% | 46.80% | 1.52 |
| AP/IC | 19.84% | 92.59% | 4.67 |
| ΔAR/IC | 1.33% | 22.07% | 16.62 |
| ΔINV/IC | 2.41% | 24.64% | 10.21 |
| ΔAP/IC | 1.70% | 27.70% | 16.26 |
| PP&Enet/IC | 70.54% | 59.45% | 0.84 |
| CAPEX/IC | 16.23% | 21.09% | 1.30 |

**Notes:** The sample includes all firms listed on the New York stock Exchange, American Stock Exchange, and NASDAQ from **1970 to 2004** with available data in both the Center for Research in Security Prices (CRSP) from the University of Chicago and S&P's Compustat (COMPUSTAT) data bases (total 8,553 agribusiness/year observations). Accounts receivable (*AR*), is COMPUSTAT item 2; Inventories (INV) is COMPUSTAT item 3; Accounts payable (AP) is COMPUSTAT item 70; PP&Enet (net of accumulated depreciation) is COMPUSTAT item 8; CAPEX is COMPUSTAT item 30. All variables are deflated by Invested Capital, defined as in equation 4.1, where debt is long term debt, COMPUSTAT item 9, short-term debt is COMPUSTAT item 34, and cash is COMPUSTAT item 1. The food sector is categorized following a 3-digit SIC code classification. The sector comprises the following industries: bakery (SIC 205); beverages (SIC 208); canned, frozen, and preserved fruits, vegetables (SIC 203); dairy (SIC 202); fats and oils (SIC 207); grain mill (SIC 204); meat (SIC 201); miscellaneous food preparations and kindred (SIC 209); sugar and confectionery (SIC 206); tobacco (SIC 21); food service (SIC 5810 and 5812); retailers (SIC 5400 and 5411); and wholesalers (SIC 5140, 5141, and 5180). **CV** is coefficient of variation.

Table 4.1. Main invested capital components for US food supply chain for the 1970/2004 period

Notice that *NOWC* represents almost one third (30.06%) of *IC* (the value of firms), with inventory being the most important component, 30.75% of *IC* (*AR* and *AP* are practically cancelled out). The remaining 70% is represented by *PP&E*. While *PP&E* represents the highest portion of the book value of agribusiness, its variability, measured by the coefficient of variation (CV), across all agribusiness is the lowest among of all other *IC* components (i.e., 0.84 compared to 1.97, 1.52, and 4.67).

Results in Table 4.1 also show that the change (values on time *t* minus values on *t-1*) of inventory levels is the most relevant among all *NOWC* components, meaning that agribusinesses find more difficult to stabilize their inventories growth in comparison to the growth of *AR* and *AP*. Most importantly, while agribusinesses grow *PP&E* relative to *IC* at a higher rate compared to *NOWC* components (*CAPEX*, 16.23%), *CAPEX* presents very low variability across all agribusinesses in the sample (1.3 CV for *CAPEX* compared to 10.21 for change in inventories).

Thus, inventory is the most important component of *NOWC*, representing one third of the book value of agribusinesses. The other 70% book value of the firm, represented by *PP&E*

has the lowest variability among all *IC* components across agribusinesses. Inventory also changes at the highest rate among all other two *NOWC* components. We will further address the importance of changes in these variables in section 4.1.

*Profitability*

Accounting operating profitability is commonly measured by the financial metric known among practitioners as *NOPAT* (net operating profits after taxes *but before interest*). Some authors call this metric *NOPLAT* (net operating profits less adjusted taxes), and others call it simply *EBIAT* (earnings before interest and after taxes) (Baldwing (2002)). *NOPAT* is estimated as,

$$NOPAT = EBIT \quad \text{x} \quad (1\text{-}Tr), \tag{4.3}$$

where *EBIT* is earning before interest and taxes and *Tr* is the effective income tax rate (i.e., income taxes divided by earnings before income taxes). The exclusion of interest from *NOPAT* allows us to use this proxy as one free of financial costs, or more simply as pure *operating* in nature. How do inventories affect *NOPAT*? At least in two ways: first, the cost of inventories, which might be a function of inventory levels is embedded in the cost of goods sold, and hence, in *EBIT*. Second, obsolete inventory expenses and provisions might also be considered a function of inventory levels and affect *EBIT* as well.
For convenience, *NOPAT* is divided by *IC* to obtain the metric known as Return on Invested Capital (*ROIC*).[7] Thus,

$$ROIC = \frac{NOPAT}{IC}. \tag{4.4}$$

*ROIC* provides managers with a metric in percentage terms, on an annual basis, which is very convenient for decision making. *ROIC* measures the operating benefits of a firm relative to the amount of invested capital, with the refinement that *IC* contains only items with financial costs (refer to equations 4.1 and 4.2). This refinement is very important, and makes *ROIC* superior for decision making purposes to other very common profitability metrics such as *ROE* (return on equity), *ROA* (return on total assets), and so on. We elaborate more on this idea below.
The financial cost of a firm, hence of *IC*, comes from two sources, the cost of debt and the cost of equity. It turns out that the financial cost of *IC*, in percentage terms and on an annual basis, is the well known Weighted Average Cost of Capital or better known among financial practitioners as *WACC*, estimated as,

$$WACC = rd \times wd \times (1 - T_r) + re \times we, \tag{4.5}$$

where *rd* is the cost of net debt, *wd* is the weight of net debt relative to total net debt plus equity, *re* is the opportunity cost of equity, and *we* is the weight of equity relative to total net debt plus equity. *re* is usually estimated by using an asset pricing model, such as the Capital Asset Pricing Model (CAPM) by Sharpe (1964); the 3-Factors model by Fama and French

[7] Other names for ROIC, commonly used are ROI (return of investment) and ROCE (Return of capital employed)

(1993), and Fama and French (1992); the 4-Factors model incorporating the momentum factor by Carhart (1997), among others. While practitioners commonly use CAPM (Bruner, Eades, Harris and Higgins (1998)), researchers are more comfortable with a multifactor asset pricing model. According to CAPM, the opportunity cost of equity, *re*, depends upon the systematic risk of the firm, which is measured by the "market beta". The market beta is the coefficient of a simple OLS regression of excess firm stock returns (*re*) over a risk free rate security ($r_f$), as the dependent variable, and the excess returns of a diversified portfolio (the market) over $r_f$. Equivalently, the market beta for firm $i$ is estimated by dividing the covariance of firm returns ($r_i$) and market returns ($r_m$), $COV_{ri,rm}$, by the variance of market returns, $VAR_{rm}$. Thus,

$$\beta_i = \frac{COV_{ri,rm}}{VAR_{rm}} . \tag{4.6}$$

Then, as the opportunity cost of equity, *re*, depends upon risk expectations captured by $\beta$, CAPM assumes that *re* should be equal to the risk free rate ($r_f$) offered by a security issued by the government plus a market premium, which equals the market return in excess over the risk free security, $r_m$-$r_f$, multiplied for the firm's beta. This is expressed as,

$$r_e = r_f + \beta_i \times (r_m - r_f) . \tag{4.7}$$

Notice that the financial cost of *net* debt [defined as total debt minus cash and short term investment (the two terms at the end of equation 4.1)] equals net interest paid by firms, precisely the item excluded in the estimation of *NOPAT*. The financial cost of equity, on the other hand, is not included on the calculation of profits in the official income statements. Thus, by estimating *NOPAT* managers have an operating performance metric free of financial costs. Further, by equation 4.4, profitability is scaled by *IC*, the same investment base used to estimate *WACC*.

Hence, it then makes sense to compare *ROIC* and *WACC* since one represents the operating benefits and the other represents the cost over the same investment base, *IC*.[8] As long as *ROIC* equals *WACC* in a given period, the value of the firm should remain unchanged since the firm would be generating profits according to expectation of both equity owners and debtors. This comparison could not be done with the other financial accounting metrics referred to above.[9]

In Table 4.2, we present summary statistics related to profitability for US agribusinesses. The operating benefit of a typical US agribusiness has been 9.4% on average during the 35 years period. This number is above the average WACC of a public US American firm. Clarke and De Silva (2003) present a summary of several studies, where *re*, the cost of equity has been between 5 and 6%. The cost of debt, *rd*, is lower than *re* by definition (i.e., residual risk and tax shield in equation 4.5).

[8] ROIC minus WACC is referred to as Economic Value Added (EVA) margin

[9] Financial analysts that emphasize the use of cash flows (e.g., cash flow from operations or free cash flow) over accounting profits (e.g., *NOPAT*) might be tempted to estimate a cash flow metric scaled by *IC*. As cash flows already include changes in working capital and/or CAPEX, the metric estimated by using cash flows should not be compared with WACC for decision making purposes.

| | Mean | Median | CV |
|---|---|---|---|
| IC | 550.333 | 75.892 | 0.14 |
| NOPAT | 79.246 | 275.543 | 3.48 |
| ROIC | 9.4% | 10.4% | 1.11 |

Notes: Data base characteristics explained in notes Table 4.1. *IC* and *NOPAT* are expressed in million USD as of 2004. *NOPAT* is estimated as in equation 4.3. *EBIT* is COMPUSTAT item 178. Details of *IC* estimations are specified in the notes at the bottom of Table 4.1. CV stands for coefficient of variation.

Table 4.2. Summary statistics of selected items for the US food supply chain for the 1970/2004 period

*Market Value of the Firm*

The market value of the firm (FV) captures not only the fundamental or accounting characteristics of the enterprise, but also investors ' expectations. This metric is defined as,

$$FV = MCap + D - C\,, \tag{4.8}$$

where *MCap*, market capitalization, is defined as stock price times the number of shares outstanding. While in *IC* (equation 4.1) equity is assessed at book value, in *FV* this value is "updated" according to what investors believe the firm's equity is worth at market value.[10]
In Table 4.3 we present summary statistics of the book value of equity and its market value for the US food sector.

| | Mean | Median | Std. Dev. | CV |
|---|---|---|---|---|
| Book Value of Equity | 309.304 | 46.809 | 1,052.086 | 3.40 |
| Market Capitalization | 1,127.496 | 62.329 | 6,082.294 | 5.39 |
| Market Firm Value | 1,368.525 | 99.374 | 6,582.137 | 4.81 |
| P/BV | 2.358 | 1.327 | 15.096 | 6.40 |

Note: Data base characteristics explained in notes Table 4.1. Values in million USD as of 2004, expect P/BV, the stock price divided by the book value of shares. Market capitalization is stock price at the end of calendar year, COMPUSTAT item 24 times number of common shares outstanding, COMPUSTAT item 25. The book value of equity is COMPUSTAT item 60.

Table 4.3. Summary statistics of selected items for the US food supply chain for the 1970/2004 period

In the following section we investigate how inventories and other *IC* components affect the market value of firms. To proxy the market value of equity we use stock returns or the changes in stock prices. Annual stock returns are estimated by compounding monthly returns obtained from the CRSP data base. Further, we compare *IC* components in *t* with stock returns in *t+1* to assess the reaction of investors to reported financial metrics.

[10] Debt could also be considered at market value. But since debt securities are not as liquid as equities, it is common to use the book value of debt. In addition, in equation 4.9 financial analysts make an adjustment, especially for firms consolidating results from their subsidiaries. Thus, it is common to multiply the multiple P/BV by Minority Interest (Equity, in the balance sheet).

### 4.1 Regression models

To investigate the impact of *NOWC* components in *t* on stock returns in *t+1* (i.e., how efficiently firms manage operating working capital in *t* and how stock prices react in *t+1*) we run the following OLS regression.

$$R_{i,t+1} = \alpha + \beta_1 \times \Delta INV / IC_{i,t} + \beta_2 \times \Delta AR / IC_{i,t} + \beta_3 \times \Delta AP / IC_{i,t} + \varepsilon_{i,t} \quad (4.9)$$

where $R_{i,t+1}$ represents stock return of agribusiness *i* one year after the agribusinesses had reported their financial statements. *ΔINV/IC, ΔAR/IC,* and *ΔAP/IC* represent the change in inventories, in accounts receivable, and in accounts payable relative to invested capital, as defined previously.
Results are shown in Table 4.4.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| $\alpha$ | 0.1580 | 0.0061 | 26.0428 | 0.0000 |
| $\beta_1$ | (0.0969) | 0.0295 | (3.2871) | 0.0010 |
| $\beta_2$ | (0.0549) | 0.0302 | (1.8154) | 0.0695 |
| $\beta_3$ | (0.0003) | 0.0254 | (0.0129) | 0.9897 |

Size of sample: 8,553 firm/year observations. Database as defined in notes of Table 4.1. In model 4.9 stock returns are buy-and-hold returns calculated as $BHR_{i,t} = \Pi^{12}_{j=1}(1+r_{i,j})-1$, where BHRi,t is the buy-and-hold compound annual return for firm *i* in year *t*, and $r_{i,j}$ is CRSP monthly rate of return inclusive of dividends and all other distributions over month *j*. Year refers to fiscal year as defined in Compustat. The return accumulation period starts four months after the end of the agribusiness' fiscal year. Returns used in this model are *t+1*returns following financial statements reported in *t*. Other variables have been defined previously in this chapter.

Table 4.4. Results for regression model (4.9)

As results for regression model (4.9) show, stock price returns in *t+1* are significantly affected by the growth of inventories in *t* at 1% significance level. Further, the sign of the coefficient is negative, implying that a growth in inventory levels negatively affects stock returns. A growth in account receivables also affects negatively stocks returns, but at 10% level of significance, and with a lower coefficient compared to inventories. This is important, since while both, a change in inventories and a change in accounts receivable have a similar impact in terms of cash flow, it seems that investors are more concerned about a change in inventory levels. Finally, according to results in Table 4.4, a change in accounts payable has no significant effect on stock returns.
Our second model tries to investigate how stock returns in *t+1* are affected not only by *NOWC* components, but also by *CAPEX*, a change in sales, and accounting profits. The model has,

$$R_{i,t+1} = \alpha + \beta_1 \times \Delta INV / IC_{i,t} + \beta_2 \times \Delta Sales_{i,t} + \beta_3 \times ROIC_{i,t} + \beta_4 \times CAPEX_{i,t} + \varepsilon_{i,t} \quad (4.10)$$

where *ΔSales* is growth in sales (from *t-1* to *t*), ROIC is profitability return, as defined before, and *CAPEX* is the growth in gross *PP&E*.
Table 4.5 presents results. First, change in inventories and *CAPEX* relative to *IC* are very significant and negatively affect stock returns in *t+1*. More importantly, while *PP&E*

represents 70% of *IC* compared to inventories representing 30%, a 1% change in inventories has an economic impact similar to a 1% change of *PP&E* (*CAPEX*). This illustrates the economic importance of managing inventories. It might seem surprising that sales growth (from *t-1* to *t*) does not have a significant impact on stock returns in *t+1*. However, profits, as measured by ROIC is significant and positively affects stock returns in *t+1*. Thus, being profits a function of both revenues and expenses, this results should not be surprising, as growth in sales is accompanied by growth in total expenditures.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| $\alpha$ | 0.1767 | 0.0076 | 23.1008 | 0.0000 |
| $\beta_1$ | (0.1123) | 0.0252 | (4.4526) | 0.0000 |
| $\beta_2$ | 0.0007 | 0.0023 | 0.2964 | 0.7669 |
| $\beta_3$ | 0.0174 | 0.0110 | 1.5858 | 0.1128 |
| $\beta_4$ | (0.1276) | 0.0291 | (4.3930) | 0.0000 |

Size of sample: 8,553 firm/year observations. Database as defined in notes of Table 4.1. In model 4.10 stock returns are buy-and-hold returns calculated as $BHR_{i,t} = \Pi^{12}_{j=1} (1+r_{i,j})-1$, where BHRi,t is the buy-and-hold compound annual return for firm *i* in year *t*, and $r_{i,j}$ is CRSP monthly rate of return inclusive of dividends and all other distributions over month *j*. Year refers to fiscal year as defined in Compustat. The return accumulation period starts four months after the end of the agribusiness' fiscal year. Returns used in this model are *t+1*returns following financial statements reported in *t*. Other variables have been defined previously in this document. Variable Sales in model 4.10 is COMPUSTAT item 12. We use the change from *t-1* to *t* of this variable scaled by *IC*.

Table 4.5. Results for regression model (4.10)

## 5. Conclusions

Inventory exists in the supply chain because there is a mismatch between supply and demand. In this chapter, the role of inventory in supply chain management has been highlighted. It has also been shown that inventory models can be useful for implementing inventory policies for the different stages of a supply chain. Section 3 provides a brief discussion of existing inventory models that have been developed to model real systems. Many authors have proposed mathematical models that are easy to implement in practical situations and can be used as a basis for developing inventory policies in real systems. We provide a simple classification of these models based on stocking locations and type of demand.

We also provide an empirical analysis on the relationship among financial metrics, inventory, and the value of firms. We use for this analysis accounting and stock prices from US agribusinesses during the 1970-2004 period. Summary statistics show that inventory is the most important component of Net Operating Working Capital, representing one third of the book value of American agribusinesses. The other 70% book value of the firm, represented by PP&E has the lowest variability among all IC components across agribusinesses. Inventory also changes at the highest rate among all other two IC components.

Using regression analysis we investigate the impact of the growth of *NOWC* components in *t* on stock returns in *t+1* (i.e., how efficiently firms manage operating working capital in *t* and how stock prices react in *t+1*). We find that stock price returns in *t+1* are significantly affected by the growth of inventories in *t* at 1% of significance level. Further, the sign of the coefficient is negative, implying that a growth in inventory levels negatively affects stock returns. A growth in accounts receivable also negatively affects stocks returns, but at 10% level of significance, and with a lower coefficient compared to inventories. This is important, since while both, a change in inventories and a change in accounts receivable have similar impact in terms of cash flow, it seems that investors are more concerned about a change in inventory levels. Results also show that changes in accounts payable have no significant effect on stock returns.

When we incorporate *CAPEX* in the regression analysis, we find that change of inventories and *CAPEX* relative to *IC* are very significant and negatively affect stock returns in *t+1*. More importantly, while *PP&E* represents 70% of *IC* compared to inventories representing 30%, a 1% change in inventories has an economic impact similar to a 1% change of *CAPEX*. This illustrates the economic importance of managing inventories.

From the analysis provided in this chapter it is clear that inventory plays a key role in the market value of firms. Therefore, managing inventories is important as it allows a company to determine the appropriate amount of inventory to hold, so that the firm value is not affected by excess or unnecessary inventory levels in the supply chain. Although the mathematical models presented in section 3 are not applicable in all situations, they serve as a framework for developing models for practical situations.

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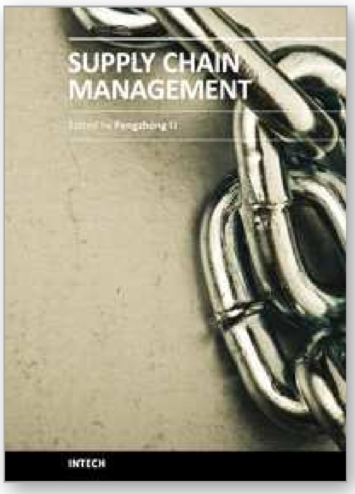


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The purpose of supply chain management is to make production system manage production process, improve customer satisfaction and reduce total work cost. With indubitable significance, supply chain management attracts extensive attention from businesses and academic scholars. Many important research findings and results had been achieved. Research work of supply chain management involves all activities and processes including planning, coordination, operation, control and optimization of the whole supply chain system. This book presents a collection of recent contributions of new methods and innovative ideas from the worldwide researchers. It is aimed at providing a helpful reference of new ideas, original results and practical experiences regarding this highly up-to-date field for researchers, scientists, engineers and students interested in supply chain management.