

Submission ID: 025-1345

Industry Competition and Manufacturing Inventory: An Exploratory Study

Chaodong Han
College of Business and Economics
Towson University
Email: chan@towson.edu
Phone: 410-704-4658

Abstract

Theoretical models have been ambiguous on the relationship between industry competition and inventory holdings of manufacturing firms. Facing competition, on the one hand, firms may desire to hold more inventory to avoid losing sales to competitors; on the other hand, firms strive to improve inventory turns to control costs and stay competitive. Using U.S. Census data on manufacturing industries, this study explores the implications of industry competition on manufacturing inventory at all three stages (i.e., raw materials, work-in-process and finished goods inventories).

Keywords: Industry Competition, Manufacturing Inventory, Simultaneous Models

Production and Operations Management Society 23rd Annual Conference

Chicago, Illinois, USA

April 20-23, 2012

January 25, 2012

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Introduction

Inventory has been a double-edged sword for manufacturing firms. On one hand, as a buffer against disruption in raw material supply and the production process and surge in demand, inventory enables firms to level production and improve customer service levels. On the other hand, too much inventory leads to higher holding costs, which may eventually overwhelm the benefits; meanwhile, inventory may cover up problems and inefficiency existing in the business processes. In fact manufacturing firms have been striving to be as lean as possible.

From a focal firm's perspective, quantitative research has produced various models for determining the optimal inventory level and optimal inventory replenish policies under various scenarios, for example, with multiple supply sources (Song and Zipkin 2009), with replacement warranty (Huang, Kulkarni and Swaminathan 2008), under deterministic demand but stochastic supply disruptions (Parlar and Berkin 1991; Parlar and Perry 1995), with advance demand information and flexible delivery (Wang and Toktay 2008), with auctions and other sales channels (Huh and Janakiraman 2008), with financial risks (Berling and Rosling 2005), with transshipment (Wee and Dada 2005; Axsater and Sven 2003), with product returns (DeCroix and Zipkin 2005), under pooling (Benjaafar, Cooper and Kim, 2005), and with nonstationary demand and partial information (Treharne and Sox 2002).

However, those models have to make some simplistic assumptions on the external business environment facing the focal firm, including industry competition. Literature reveals that theoretical models have been ambiguous on predicting the relationship between industry competition and inventory holdings of manufacturing firms (Olivares

and Cachon (2009). Facing fierce competition, on the one hand, firms may desire to hold more inventory to avoid losing sales to competitors; on the other hand, firms strive to improve inventory turns to control costs and stay competitive. On the empirical research side, while inventory strategy has been well studied based on case studies and survey data, there is a lack of empirical research devoted to the examination of drivers of manufacturing inventory levels at all three stages based on large-scale datasets.

In this study, we set out to investigate how industry competition may have impacted inventory levels at all three stages, including raw material, work-in-process and finished goods inventories for manufacturing industries using an economy-wide panel data collected from U.S. Census of Bureau. We further explore the potential moderating effect of industry competition on other inventory drivers, including holding cost, product variety, plant capacity utilization, and economies of scale.

Our paper proceeds as follows: we review relevant literature on inventory model in general and on the relationship between competition and inventory in particular, followed by our research model. We then present regression models. We also describe plans for data collection and variable measurement. The paper is concluded with research contributions and managerial implications.

Inventory Models and Empirical Evidence

Economics literature reveals that manufacturing firms hold inventory due to the need to buffer against demand surges, or to smooth production and gain efficiencies in batch production (Blinder and Maccini 1991). The classic stock adjustment model suggests that facing surging labor, energy, or raw materials costs, firms cut production and draw upon inventories while firms build inventories when costs are low (Lovell 1961).

Lovell (1962) also noted that firms may lag adjustments to planned inventory levels in

the presence of demand uncertainties. Feldstein and Auerbach (1976) extended Lovell's model to a "target-adjustment" approach, and argued that it takes time for firms to change their target inventory levels because warehousing facilities, personnel, and knowledge lag behind in adjustment. Therefore, during adjustment periods, firms may carry excess inventory or realize inventory shortages.

In contrast, management research has focused on a combination of technological factors and managerial factors in accounting for firm inventory decisions. For example, based on surveys of hundreds of North American automotive suppliers, Lieberman et al. (1996) found that low inventories are associated with employee training and problem solving activities, as well as frequent communications with customers. As well, inventory levels varied due to technological factors, such as the quantities of materials used and the technical processes applied and factors that are unique to industry sectors. Technology-enabled practices, such as just-in-time (JIT) purchasing and manufacturing processes, may lead to better inventory performance (i.e., lower levels combined with better customer service) than do non-JIT firms (Huson and Nanda 1995; Chang and Lee 1995; Billesbach and Hayen 1994). Clark and Hammond (1997) showed that vendor-managed inventory (VMI) improves retailer inventory turns, while McCarthy and Golicic (2002) reported that the adoption of collaborative planning, forecasting, and replenishment (CPFR) leads to optimized inventory levels and associated costs. Shah and Shin (2007) reported that IT investment is positively associated with inventory performance.

A growing number of systematic studies on inventory drivers have appeared in the operations and supply chain management literature.

Based on U.S. two-digit SIC-code manufacturing industry data over the period 1961-1994, Rajagopalan and Malhotra (2001) regressed inventory ratios on time trend and industry growth rates and found that raw material and work-in-process inventories decreased in a majority of U.S. manufacturing sectors while finished goods inventories did not decrease in more than half the sectors.

Chen, Frank and Wu (2005) investigated inventory levels in days of supply for over 7,000 public U.S. manufacturing firms between 1981 and 2000 and found a declining trend of median overall inventory holding at a reduction rate of 2 percent per year over this period. However, finished goods inventoried remained steady while work-in-process inventories declined 6 percent annually.

In a retailer context, Gaur, Fisher and Raman (2005) built an empirical model accounting for retailer inventory turnover based on three factors: sales surprise, measured as a ratio of current sales and expected sales, gross margin, and capital intensity. The study reported that inventory turnover is negatively associated with sales surprise and capital intensity while positively associated with gross margin. In a similar retail context but with additional data, Gaur and Kesavan (2007) confirmed findings reported by Gaur, Fisher and Raman (2005) and further examined the effects of firm size and sales growth on inventory turnover. Gaur and Kesavan (2007) reported strong evidence of diminishing returns with respect to firm size and also found that inventory turns faster with increasing sales growth rate and the rate of increase varies with firm size and the direction of sales growth.

In a supply chain, the demand variability increases from downstream distributors and retailers to upstream manufacturers, the bullwhip effect, likely caused by amplified information asymmetry up the supply chain (Lee, Padmanabhan and Whang 1997a and

1997b). However, using industry sector-level data collected from U.S. Census Bureau and the U.S. Bureau of Economic Analysis, Cachon, Randall and Schmidt (2007) documented that while the bullwhip effect exists within wholesale industries, manufacturing industries do not have substantially greater demand variability than retail industries.

Using quarterly data over 1992-2002 for 722 public firms in 8 industry sectors, oil and gas, electronics, wholesale, retail, machinery, hardware, food, and chemicals, Rumyantsev and Netessine (2007a) studied what may have accounted for inventory ratio, measured by inventory over cost of goods sold using a set of variables, including fixed assets, gross profit margin, demand uncertainty, cost of capital and sales surprise.

Cachon and Olivares (2010) investigated the drivers of finished vehicle inventory in the U.S. automobile industry and reported that the number of dealerships in a car maker's distribution network and its production flexibility accounted for most difference in finished-goods inventory between Toyota and its U.S. competitors: Chrysler, Ford, and General Motors.

Based on three-digit NAICS industry data collected from U.S. Annual Survey of Manufactures over 2002-2005, Han, Dresner and Windle (2008) studied how global sourcing and exports may have affected U.S. raw material and finished goods inventories and documented that increase in import ratios and export ratios may lead to a proportional increase in raw material and finished goods inventory, respectively.

Competition and Inventory

While economics literature suggests that firms in concentrated industries tend to pile up a high level of inventories to sustain collusion (Rotemberg and Saloner, 1989), there

appears to a paucity of relevant literature on the role of competition in driving inventory decisions, particularly in empirical management research. Olivares and Cachon (2009) may be among the first empirical studies in the operations literature to report a positive relationship between competition and inventory levels. In the context of General Motor's dealerships, Olivares and Cachon (2009) studied how competition may have affected the inventory holdings of dealerships in isolated local markets. Based on inventory and sales data collected from over 200 GM dealerships over a six-month period, this study estimated the impact of the number and type of local competitive GM dealerships on inventory holdings at the dealerships and found that dealerships tend to hold more inventory facing increasing demand due to the entry or exit of a competitor, a sales effect clearly predicted by inventory theories. More interestingly, this study also found a strong, non-linear and positive service-level effect caused by the entry or exit of a competitor and reported that dealers hold more inventory when facing additional competition.

Caro and Martínez-de-Albéniz (2010) extended the competitive newsvendor model to examine the benefits of quick response under competition. In this study, two retailers compete based on inventory availability because stockout at one retailer results in lost sales with the customer shopping at the other retailer. Two retailers have different supply chain strategies and inventory reordering capabilities: one retailer pursues a traditional build-to-stock strategy and has a lower ordering cost but the products need to be produced at the beginning of the selling season; the other retailer adopts a quick response strategy and hence has a higher ordering cost but is able to replenish stocks whenever additional demand becomes clear. The research reported that quick response is more beneficial when facing higher demand uncertainty or less responsive competitor and that asymmetric competition can benefit both competitors.

Lin and Parlaktürk (2011) studied how the profitability to the manufacturer, the retailers and the entire channel varies with quick response ability, demand variability and consideration of competition. The study is set up so that a manufacturer supplies a product with a single selling season to two competing retailers who place initial orders for the product ahead of the selling season. With quick response, a retailer is able to place replenishment orders when demand information is updated; however, the manufacturer is able to charge a higher unit price for replenishment order through quick response. The research finds that optimal profitability may depend on the manufacturer's pricing decision, retailer's ordering strategy, and quick response ability.

Based on a product-level dataset collected from Best Buy and Circuit City, Ren, Hu, Hu and Hausman (2011) studied how retailer stores manage product variety based on the nature of competition and the actual distance between competitive stores. The study found that a store generally maintains higher product variety, measured by the number of stock-keeping units, in the presence of a competitor's store in a common local market. However, when one store is located within one mile of the other competitive store, so called "collocation", collocated rival stores tend to be less overlapping in product range.

Research Model

Inventory literature has indicated that inventory is positively associated with gross profit margin, and negatively associated with inventory holding costs, industry growth rate, plant capacity utilization, and industry average plant size.

Gross Profit Margin

In typical inventory models, gross profit margin is used to capture the opportunity cost of a stockout. As gross profit margins are high, firms may be less willing to lose sales, leading to increased service levels and inventory levels. Therefore, it is expected that inventory level is positively associated with gross profit margin. Roumiantsev and Netessine (2007a) and Gaur, et al. (2005) provided logic from an analytical perspective. In fact, Gaur, et al. (2005) provided empirical evidence from U.S. retailers, while Roumiantsev and Netessine (2007b) provided empirical evidence from public firms in Organization for Economic Cooperation and Development (OECD) countries.

Industry Growth Rate

Inventories at all stages move faster and deplete more quickly when the industry output grows fast (Rajagopalan and Malhotra, 2001). Generally speaking, in the presence of a strong economic growth, inventory levels would become lower relative to sales than during slow growth or recessionary times. Industries that are fast growing may carry less inventory with respect to sales than slow-growing industry sectors. Rajagopalan and Malhotra (2001) and Han, Dresner and Windle (2008) provided empirical evidence for the negative association between industry output growth and inventory based industry sector data.

Product Variety

First of all, product variety is associated with higher unit cost of production due to the lack of economies of scale (Fisher and Ittner 1999). Product variety also leads to the complexity of raw material procurement and inventory handling, resulting in a longer lead time. Product variety is also associated with longer set-up and processing time during the production process. Therefore, with a broader product line or greater product variety, manufacturing firms are expected to have higher inventory than those with

narrower product line or smaller product variety, *ceteris paribus*. Marvel and Peck (2008) showed that maintaining a greater product variety may be conflicting with containing inventory costs.

Average Plant Size

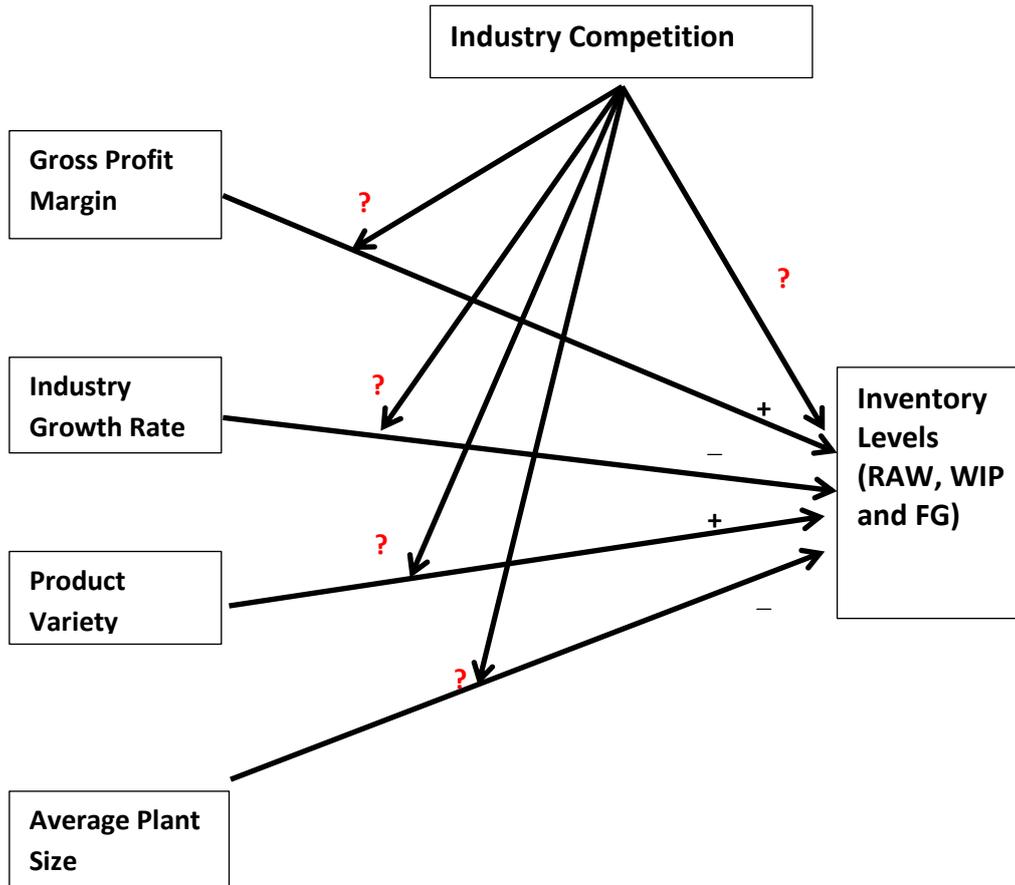
Industry average plant size is used to measure the effect of economies of scale.

Large plants may have more efficient inventory management due to better utilization of labor, and better use of distribution networks and transportation capacity (Gaur and Kesavan 2005; Roumiantsev and Netessine 2007a). Gaur and Kesavan (2005) reported a positive but nonlinear correlation between inventory turnover and firm size.

Industry Competition

As Olivares and Cachon (2009) noted, inventory theories have been ambiguous in predicting the relationship between competition and inventory level. On one hand, competition drives down the profit margin, which may put enormous pressure on the firm to control inventory costs, resulting in a downward pressure on inventory levels. On the other hand, loss of sales and goodwill may have a greater negative impact on a manufacturing firm in a more competitive environment. There is a lack of research in the literature regarding which force will dominate. More importantly, industry competition may further affect the effects of industry drivers.

In this study, therefore, we explore the main effect of industry competition on inventory and the moderating effect of industry competition on other inventory drivers, including gross profit margin, industry growth rate, product variety and average plant size. Our research model is presented below.



Regression Model

Given the interrelation between three components of inventory, we estimate simultaneous equation models in a panel setting as follows, whereas i denotes industry and t denotes time period.

$$\begin{aligned}
 \text{Raw Material Inventory}_{it} = & \alpha_0 + \alpha_1 \text{Industry Competition}_{it} + \alpha_2 \text{Gross Profit Margin}_{it} + \\
 & \alpha_3 \text{Industry Growth Rate}_{it} + \alpha_4 \text{Product Variety}_{it} + \alpha_5 \text{Average Plant Size}_{it} + \alpha_6 \text{Industry} \\
 & \text{Competition}_{it} \times \text{Gross Profit Margin}_{it} + \alpha_7 \text{Industry Competition}_{it} \times \text{Industry Growth} \\
 & \text{Rate}_{it} + \alpha_8 \text{Industry Competition}_{it} \times \text{Product Variety}_{it} + \alpha_9 \text{Industry Competition}_{it} \times \\
 & \text{Average Plant Size}_{it} + \epsilon_1 \quad (1)
 \end{aligned}$$

$$\begin{aligned}
 \text{Work in Process Inventory}_{it} = & \beta_0 + \beta_1 \text{Industry Competition}_{it} + \beta_2 \text{Gross Profit} \\
 & \text{Margin}_{it} + \beta_3 \text{Industry Growth Rate}_{it} + \beta_4 \text{Product Variety}_{it} + \beta_5 \text{Average Plant Size}_{it} +
 \end{aligned}$$

$$\beta_6 \text{Industry Competition}_{it} \times \text{Gross Profit Margin}_{it} + \beta_7 \text{Industry Competition}_{it} \times \text{Industry Growth Rate}_{it} + \beta_8 \text{Industry Competition}_{it} \times \text{Product Variety}_{it} + \beta_9 \text{Industry Competition}_{it} \times \text{Average Plant Size}_{it} + \epsilon_2 \quad (2)$$

$$\text{Finished Goods Inventory}_{it} = \gamma_0 + \gamma_1 \text{Industry Competition}_{it} + \gamma_2 \text{Gross Profit Margin}_{it} + \gamma_3 \text{Industry Growth Rate}_{it} + \gamma_4 \text{Product Variety}_{it} + \gamma_5 \text{Average Plant Size}_{it} + \gamma_6 \text{Industry Competition}_{it} \times \text{Gross Profit Margin}_{it} + \gamma_7 \text{Industry Competition}_{it} \times \text{Industry Growth Rate}_{it} + \gamma_8 \text{Industry Competition}_{it} \times \text{Product Variety}_{it} + \gamma_9 \text{Industry Competition}_{it} \times \text{Average Plant Size}_{it} + \epsilon_3 \quad (3)$$

Data Collection and Variable Measurement

We plan to collect data from U.S. Census of Manufactures. The unit of observation is six-digit North American Industry Classification System (NAICS) industry. Variables will be measured as follows:

$$RAW_{it} = 365 * \frac{\text{Raw Material Inventory}_{it}}{\text{Total Cost of Materials}_{it}}$$

$$WIP_{it} = 365 * \frac{\text{WIP Inventory}_{it}}{\text{Total Cost of Materials} + 0.5 * \text{Value Added}_{it}}$$

$$FG_{it} = 365 * \frac{\text{Finished Goods Inventory}_{it}}{\text{Total Cost of Materials} + \text{Value Added}_{it}}$$

$$\text{Industry Growth Rate}_{it} = \frac{\text{Industry Output}_{it} - \text{Industry Output}_{it-1}}{\text{Industry Output}_{it-1}}$$

$$\text{Gross Profit Margin}_{it} = \frac{\text{Industry Output}_{it} - \text{Total Cost of Materials}_{it}}{\text{Industry Output}_{it}}$$

$$\text{Product Variety}_{it} = 1 - \text{specialization ratio}$$

$$\text{Average Plant Size}_{it} = \frac{\text{Industry Output}_{it}}{\text{Number of Plants}_{it}}$$

Research Contributions and Managerial Implications

This study is the first empirical effort to investigate the relationship between industry competition and inventory levels based on a large scale archival dataset. Our focus is to explore the main effect of industry competition on inventory levels and the moderating effects of industry competition on the role of other industry characteristics, including gross profit margin, industry growth rate, product variety, and average plant size in driving inventory levels. Given that theories have been ambiguous in predicting the relationship between competition and inventory levels, this study will improve our understanding of the relationship in a rich empirical setting and hence fill in the gap in supply chain strategy theories. We investigate drivers of inventory at all three stages and results may be able to show that competition and other drivers may have different effects on raw material, work-in-process or finished goods inventory. The findings will make a meaningful contribution to the current inventory literature.

Managers have been trained to perform industry competitiveness analysis to understand the business environment facing their firms. However, the link between industry competition and firm inventory decisions has not been included in the conventional decision making frameworks (e.g., Porter's Five Forces model or SWOT analysis). Our findings may provide a bridge between industry competitive landscape and firm inventory strategy and may further serve as a benchmark that inventory at different stages may be associated with industry competition to different degrees.

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