An Exploratory Examination of the Direct and Indirect Effects of Industry Competition on Manufacturing Inventories

Chaodong Han*
Towson University, Towson, Maryland, USA

Tobin Porterfield
Towson University, Towson, Maryland, USA

Stella Tomasi
Towson University, Towson, Maryland, USA

Inventory theory has not clearly addressed the relationship between industry competition and inventory levels. Grounded in the classic Structure - Conduct – Performance (S-C-P) paradigm, this study builds a theory-based research model and uses regression models to test the direct and indirect effects of industry competition on manufacturing inventories at all three stages (i.e., raw materials, work-in-process and finished goods). Data is provided from U.S. Economic Census data on manufacturing industries collected for 1997, 2002 and 2007. Industry competition is operationalized as upstream industry competition, focal industry competition and downstream industry competition. Regression results suggest that industry competition has both direct and indirect effects on manufacturing inventories through several moderating inventory drivers. The results provide a bridge between an industry's competitive landscape (structure) and firm inventory strategy (conduct) and serves as a benchmark that manufacturing inventories at different stages may be associated with industry competition. This study improves our understanding of the relationship of industry competition and inventory decisions in a rich manufacturing setting.

* Corresponding Author. E-mail address: chan@towson.edu

I. INTRODUCTION

In the era of global supply chains, manufacturing firms face long lead times, vulnerable supply networks, and highly uncertain customer demand. These issues challenge global firms to balance inventory management with efficiency and responsiveness, calling for a nuanced lean-agile (so called "leagile") supply chain strategy (Galankashi and Helmi, 2016; Mason-Jones et al. 2000). A lean-agile strategy pairs lean manufacturing with level scheduling upstream from the decoupling point and the agile paradigm is adopted to meet market demand downstream from the decoupling point. The lean-agile strategy results in a lean raw material inventory and a responsive finished goods inventory. Furthermore, the firm's overall supply chain structure, which includes global sourcing and exports, upstream and downstream relationships, may also have profound implications to a company's inventory, which will eventually impact the firms' inbound and outbound strategy (Han et al. 2008; Nag et al., 2016). Forbes attributes the disappointing stock performance of Under Amour in 2017 its excess inventory resulting from the closure of a major retail store - Sports Authority (Danziger, 2017), which decreased competition in the downstream customer industry.

Empirical inventory research identifies several firm specific inventory drivers (micro level), including demand uncertainty, product variety, gross profit margin, and holding costs. However, there is a need for a macro view of inventory management which considers the impacts of competition and industry dynamics on inventory levels (Rumyantsev and Netessine, 2007). While extant literature has mostly been conducted at the product or firm level (a microscopic perspective), a macroscopic perspective at the industry level can be insightful. More importantly, upstream and downstream industry competition may have profound impacts on firm raw material and finished goods inventory strategy.

Given that "theory is ambiguous" in predicting the relationship between industry competition and inventory levels (Olivares and Cachon, 2009, p.1586), this study explores the direct effects of industry competition on inventory levels and further examines the moderating effects of industry competition on classic inventory drivers. This study is grounded in the Structure – Conduct – Performance (S-C-P) paradigm and enhances the understanding of the relationship between industry competition and inventory decisions in a manufacturing context.

The remainder of this paper is organized as follows: we first review relevant empirical inventory management literature and then discuss the S-C-P paradigm as the theoretical framework resulting in research hypotheses. In the subsequent estimation models section, regression models are estimated to test hypotheses. In the data section, the data collection process and variable measurements are discussed. The regression results are reported in the results section, followed by a discussion of the findings. The study concludes with implications for practice and future research.

II. LITERATURE REVIEW

Two research streams have been productive in the empirical inventory management literature: one strand is devoted to the investigation of factors for decision making in inventory management including lean inventory practice. The second focuses on the relationship between inventory management and financial performance. Since the current research aims to investigate how industry competition moderates the roles of classic inventory drivers, the literature review is focused on research which has identified inventory drivers based on empirical evidence.

Generally, empirical inventory management research suggests that inventory levels may be associated with several drivers including: demand uncertainty, cost of capital, gross profit margin, industry growth rate, product variety, IT investment, economies of scale, employee skills, and the adoption of advanced inventory management techniques.

Demand Uncertainty: Inventory levels can be used as a buffer during demand uncertainty. Economic literature states that manufacturing firms hold inventory to buffer against demand surges, or to smooth out production or to gain efficiencies through batch production (Blinder and Maccini, 1991). Rumyantsev and Netessine (2007) found evidence of a positive relationship between demand uncertainty and inventory levels.

Cost of Capital: The classic economic order quantity (EOQ) model suggests that the optimal inventory level decreases when inventory holding costs increase. Chen et al. (2005) and Rumyantsev and Netessine (2007) both report a negative relationship between the cost of capital and firm inventory levels.

Gross Profit Margin: In the newsvendor model, the underage cost (i.e., the opportunity cost of a stockout) is expressed by a product's gross profit margin. For products with high gross profit margins, firms may be less willing to lose sales, leading to increased service levels and hence increased inventory levels. This positive relationship is supported by studies using several contexts, including U.S. retailers (Gaur et al., 2005) and public firms in Organization for Economic Cooperation and Development (OECD) countries (Rumyantsev and Netessine, 2005).

Industry Growth Rate: Inventories at all stages move faster and deplete more quickly when the industry output growth rate increases quickly. In the presence of strong economic growth, inventory levels may become lower relative to sales than during slow growth or recessionary times. Industries that are fast growing may carry lower inventory levels with respect to sales than slow-growing industry sectors. Rajagopalan and Malhotra (2001) provided empirical evidence for the negative relationship between industry output growth rate and inventory levels.

Product Variety: Striving to improve product variety due to competitive pressure and customer requirements, manufacturing firms need to balance competitive and flexibility priorities by considering machine set-up times, production scheduling and inventory management (Da Silveira, 1998). Product variety is associated with higher unit cost of production due to the lack of economies of scale (Fisher and Ittner, 1999). Greater product variety also leads to increased complexity in the procurement of raw materials and inventory handling, resulting in longer lead times and higher inventory levels.

IT Investment: Firms adopt advanced information technologies to track point-of-sale data and inventory in real time. With increased inventory visibility and improved demand forecasting techniques, inventory ordering, storage and transportation are optimized which result in decreased overall inventory levels. IT applications and IT infrastructure significantly enhance a firm's dynamic capabilities and result in competitive advantage (Shah and Shin, 2007).

Economies of Scale: Economies of scale allow large firms to more efficiently manage inventory due to better utilization of labour and better use of distribution networks and transportation capacity (Gaur and Kesavan, 2009). For example, large firms may pool demand from various locations and products and resulting in reduced safety stocks.

Manufacturing Worker Skills and Best Practices in Inventory Management: Lieberman et al. (1999) found that low inventories are associated with employee training and problem-solving activities, as well as frequent communications with customers. It is expected that manufacturing industries with more skilled workers achieve better inventory performance. Technology-enabled practices, such as just-in-time (JIT) purchasing and manufacturing processes, may lead to better inventory performance. Sriparavastu and Gupta (1997) reported that manufacturing firms that implement JIT and total quality management (TQM) experienced substantial reductions in finished goods and work-in-process inventories.

TABLE 1. INVENTORY DRIVERS AND THEIR IMPACTS ON INVENTORY

Inventory Driver	Impacts	Research
Demand uncertainty	+	Eroglu & Hofer (2014); Rumyantsev & Netessine (2007); Blinder & Maccini (1991)
Cost of capital	-	Han, Dong & Drener (2013); Rumyantsev & Netessine (2007); Chen, Frank & Wu (2005)
Gross profit margin	+	Rumyantsev & Netessine (2007); Gaur, Fisher & Raman (2005)
Industry growth rate	-	Rajagopalan & Malhotra (2001)
Product variety	+	Cheng, Cantor, Dresner & Grimm (2012); Marvel & Peck (2008); Fisher & Ittner (1999)
IT investment	-	Shah & Shin (2007)
Economies of scale	-	Cheng, Cantor, Dresner & Grimm (2012); Gaur & Kesavan (2009); Rumyantsev & Netessine (2007a)
Worker skills (and best practices in inventory management)	-	Lieberman, Helper & Demeester (1999); Sriparavastu & Gupta (1997); Clark & Hammond (1997)

While previous literature reveals great insights into inventory drivers using different business and economic contexts, the current study identifies three areas of research gaps that need to be addressed:

(1) There is a lack of systematic investigations of all relevant inventory drivers in the manufacturing context. In fact, most of the existing literature has examined one or a few inventory drivers in a specific firm or retail context.

(2) The primary focus in the existing literature is finished goods inventory. However, the two other forms of inventories (raw materials and work-in-process inventories) are also important for the overall manufacturing process. Therefore, an understanding of the impact of inventory drivers on all three inventory types is critical for firms to develop an appropriate supply chain strategy.

(3) The implications of industry structural forces (e.g., competition) on inventory levels and their moderating effects

on inventory drivers have not been adequately studied in the existing literature. This study builds upon the extant models of all eight inventory drivers on all three inventory types and include industry competition to investigate how industry competition as a structural force directly impacts inventories and moderates the roles of the inventory drivers.

III. THEORETICAL FRAMEWORK AND RESEARCH HYPOTHESES

Rooted in industrial organization (IO) economics, the classic (S-C-P) paradigm posits that industry structures impact firm conducts, which in turn determines industry profitability and firm performance (Bain 1956; Mason 1949). In this context, structure refers to the characteristics of industries that determine the competitiveness of markets, including industry concentration, the number of firms in the industry, and barriers to entry and exit (Waldman and Jensen, 2001). Firms compete in a specific industry through various strategies and actions to maximize their own performance. Conduct thereby refers to these rivalrous strategies and actions, which are responses to the industry environment and dynamics. Ralston et al. (2015) observed that firms formulate a series of actions and strategies to gain competitive advantage and improve market and financial performance. In fact, firm actions may also include designing an appropriate inventory strategy (Ferrier et al., 1999). Therefore, raw materials inventory levels may be considered a strong indicator of inbound supply chain strategy while finished goods inventory levels indicative of outbound supply chain strategy (Golini and Kalchschmidt, 2011; Han et al., 2008). Performance includes a wide range of financial and operational indicators including industry average and firm specific profitability, operational efficiency and productivity.

To better understand industry competition from a focal manufacturer's complete supply chain perspective, this study examines industry competition, as a structural force, at three stages: (1) the competitive intensity of the supplier (upstream) industries, (2) the competitiveness of the focal industry in which a firm operates and (3) the competitiveness of the downstream industries which use finished goods produced by the focal manufacturer.

While economic literature suggests that firms in concentrated industries tend to accumulate high inventory levels to sustain collusion (Rotemberg and Saloner, 1989), the relationship between industry competition and inventory levels may be unclear. On the one hand, greater competition may lead to more-intense price competition and lower margins, suggesting that a lower service level (lower inventory level) is optimal. On the other hand, greater competition gives consumers more choices for where and what to purchase, which suggests that a higher service level (higher inventory level) is optimal to better retain demand. This study sets out to empirically examine the direct effects of industry competition on average inventory levels held in the focal industry and the moderating effects of industry competition on classic inventory drivers (Figure 1).

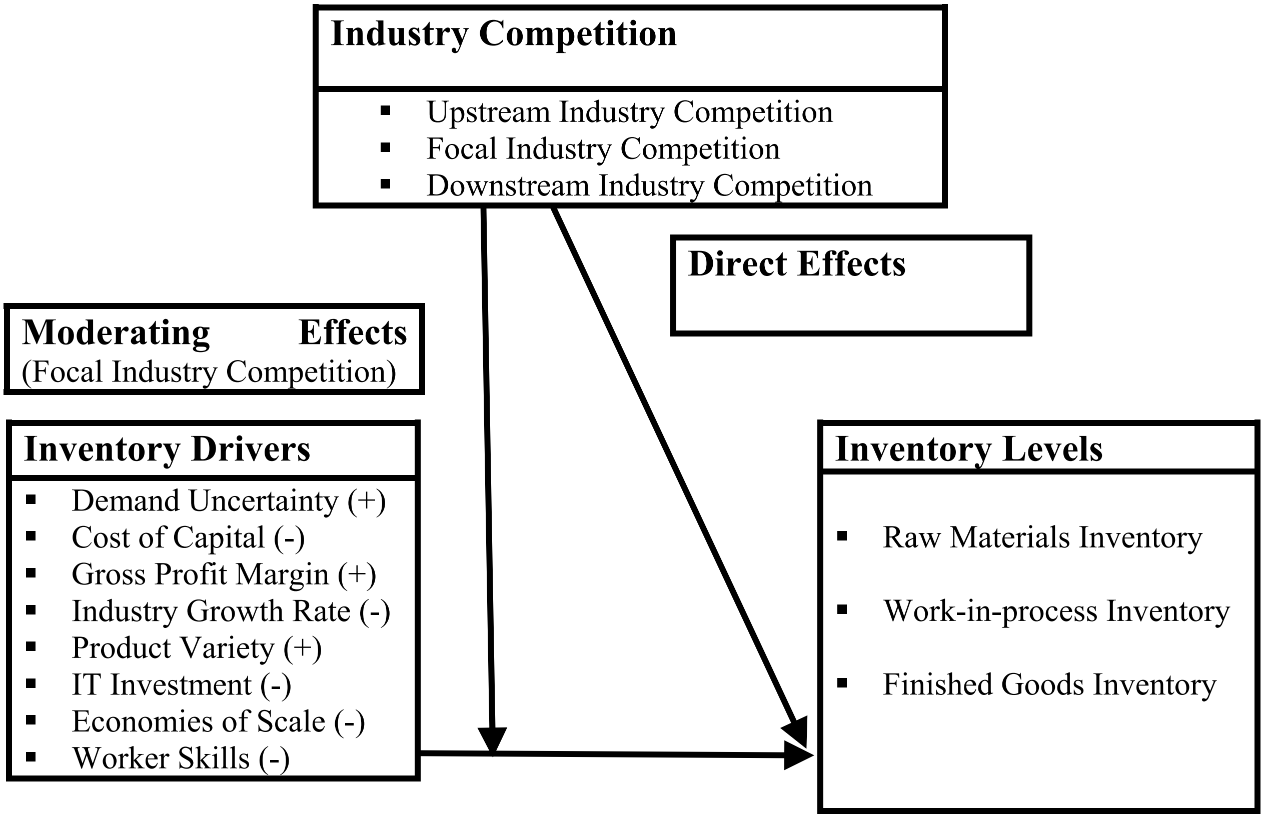

FIGURE 1. RESEARCH MODEL

In more concentrated and less competitive industries, manufacturing firms tend to have greater bargaining power over their suppliers and hence can push raw materials inventory back to their upstream suppliers through various supply contracts. For example, the U.S. computer manufacturing industry is moderately concentrated with five leading firms (i.e., HP, Dell, IBM, Apple and Oracle) accounting for approximately 80% of the market. As a result, larger player Dell sets its push-pull boundary very early in the supply chain where suppliers hold more inventory for frequent deliveries to Dell manufacturing plants (Collier and Evans, 2011, p.175). In contrast, facing intense competition in the same industry, manufacturers may have to compete for the supply due to a lack of bargaining power over suppliers and hence desire to hold more raw materials inventory to secure an undisrupted supply. We therefore hypothesize the direct effects of focal industry competition on raw materials inventory held in the focal industry as follows:

H1: *Focal industry competition is positively associated with raw materials inventory.*

Given the intense rivalry in the focal industry, manufacturers in the focal industry do not have much bargaining power over downstream customers and hence may have to hold more finished goods inventory to avoid stockouts and losing sales to competitors. It is no surprise that manufacturing firms in a more competitive focal industry are under greater pressure to accommodate their downstream customers by holding more finished goods inventory through arrangements like vendor management inventory (VMI) and quick response (QR). In contrast, in less competitive and more concentrated industries, manufacturing firms have more bargaining power over customers who are competing for limited supply and hence may be able to push finished goods inventory forward to their downstream distributors. Olivares and Cachon (2009) found that dealerships tend to hold more inventory facing increasing demand due to the entry or exit of a competitor and that dealers hold more inventory when facing additional competition. Therefore, we hypothesize the direct effects of focal industry competition on finished goods inventory held in the focal industry as follows:

H2: *Focal industry competition is positively associated with finished goods inventory.*

Notably, competitive pressure may have confounding effects on a firm's internal operations, which in turn directly affects work-in-process inventory. On one hand, under intense competition, firms strive to be lean by minimizing inventory, including work-in-process inventory; on the other hand, firms are fully aware that too little inventory may increase the risk of supply chain disruptions. Eroglu and Hofer (2011) suggest that manufacturing firms may be pursuing an optimal inventory level and the leanness of inventory varies dramatically across the 54 U.S. manufacturing industries in their study due to industry-specific inventory management characteristics. However, given that focal industry competition has immediate pressure on firm operations while the supply chain risk may be mitigated by other measures in the near future, we believe that the downward pressure of competition on inventory levels may be greater than the upward pressure caused by supply chain risk consideration and therefore hypothesize the net effects of focal industry competition on work-in-process inventories as follows:

H3: *Focal industry competition is negatively associated with work-in-process inventory.*

Research suggests that inbound supply chain factors, including procurement lead times and lead time variations, buyer-supplier relationships, and other factors may affect raw materials inventory (Oke and Szwejczewski, 2005). The intensity of rivalry in the upstream supplier industry may force suppliers to provide better service, including shorter and less variable lead times, which reduces supply uncertainty and lowers raw materials inventory. Therefore, facing a more competitive supplier industry, manufacturing firms in the focal industry have more bargaining power and hence can push raw materials inventory back to upstream suppliers through more favorable supply arrangements, resulting in lower inventory levels. Given that raw materials inventory most likely responds to the inbound (upstream) supply chain, we propose the direct effects of upstream industry competition on raw materials inventory as follows:

H4: *Upstream industry competition is negatively associated with raw materials inventory.*

Research also suggests that outbound supply chain factors, such as variation of market demand and reliability of the distribution network, affect the level of finished goods inventory held in the focal manufacturing industry (Oke and Szwejczewski, 2005). Manufacturing firms in the focal industry may also serve as suppliers to provide finished goods inventory as components for manufacturers in the downstream industries. If downstream industries are highly concentrated and less competitive, leading firms in the downstream industries have more bargaining power and hence may be able to push inventories back to their suppliers, which are the manufacturing firms in the focal industry from the perspective of this research. In contrast, if the downstream industries are highly competitive, manufacturing firms in the focal industry are facing a fragmented customer base and may be able to push more finished goods inventory to their downstream firms. Manufacturing firms in the downstream industries may hold more inventory to ensure a stable supply of raw materials. Cachon and Olivares (2010) examined the drivers of finished vehicle inventory levels 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 the greatest difference in finished goods inventory levels. Given that finished goods inventory most likely responds to the outbound (downstream) supply chain, we propose the direct effect of downstream supply chain competition on finished goods inventory held in the focal industry as follows:

H5: *Downstream industry competition is negatively associated with finished goods inventory.*

At the mid-stage of manufacturing inventories, work-in-process inventory connects both inbound and outbound supply chains and is reflective of a firm's internal operations. Suppliers may affect work-in-process inventory levels through the supply of raw materials inventory while downstream distributors and customers may affect work-in-process inventory levels through the demand for finished goods inventory. Facing intense competition in both upstream and downstream industries, focal firms have less incentive to maintain high levels of raw materials and finished goods inventories, which subsequently leads to lower demand for work-in-process inventory. Therefore, we hypothesize the direct effects of both upstream and downstream industry competition on work-in-process inventory held in the focal industry as follows:

H6a: *Upstream industry competition is negatively associated with work-in-process inventory.*
H6b: *Downstream industry competition is negatively associated with work-in-process inventory.*

The S-C-P paradigm suggests that successful firms take rivalrous actions and develop strategies to respond to their external environment. The most critical structural force - industry competition has a profound effect on firm strategies, including product variety, IT investment, employee training, and the adoption of advanced inventory management techniques. Competition may also interact with demand uncertainty to create a more dynamic external environment. Eroglu and Hofer (2014) defined environmental dynamism as a combination of technological innovation, demand uncertainty and competitive intensity and reported that the relationship between inventory leanness and firm performance is enhanced when innovative intensity and demand uncertainty increase and the relationship is weakened when industry competitive intensity increases. Since focal industry competition changes the extent that classic inventory drivers may affect inventory held in the focal industry, we hypothesize the moderating effects of focal industry competition on each of the eight inventory drivers as follows:

H7a: *The positive effect of demand uncertainty on inventory becomes stronger when focal industry competition increases.*

H7b: *The negative effect of cost of capital on inventory becomes stronger when focal industry competition increases.*
H7c: *The positive effect of gross profit margin on inventory becomes stronger when focal industry competition increases.*
H7d: *The negative effect of industry growth rate on inventory becomes stronger when focal industry competition increases.*
H7e: *The positive effect of product variety on inventory becomes stronger when focal industry competition increases.*
H7f: *The negative effect of IT investment on inventory becomes stronger when focal industry competition increases.*
H7g: *The negative effect of economies of scale on inventory becomes stronger when focal industry competition increases.*
H7h: *The negative effect of manufacturing worker skills on inventory becomes stronger when focal industry competition increases.*

IV. ESTIMATION MODELS

4.1 The Baseline Models

We start with a baseline model where eight classic inventory drivers are all included as independent variables. We estimate three baseline inventory models (raw materials, finished goods and work-in-process inventories) using the same set of explanatory variables, respectively.

Equation 1: *Raw Materials Inventory = f (Demand Uncertainty, Cost of Capital, Gross Profit Margin, Industry Growth Rate, Product Variety, IT Investment, Economies of Scale, Manufacturing Worker Skills)*

Equation 2: *Finished Goods Inventory = f (Demand Uncertainty, Cost of Capital, Gross Profit Margin, Industry Growth Rate, Product Variety, IT Investment, Economies of Scale, Manufacturing Worker Skills)*

Equation 3: *Work-in-Process Inventory = f (Demand Uncertainty, Cost of Capital, Gross Profit Margin, Industry Growth Rate, Product Variety, IT Investment, Economies of Scale, Manufacturing Worker Skills)*

4.2 The Augmented Models

Building upon the baseline models, we then introduce competition variables together with eight inventory drivers to test the direct effects of industry competition on inventory and explore the moderating effects of focal industry competition by including interaction terms with each of the eight inventory drivers.

Since we hypothesize that focal industry competition may affect inventories at all three stages, we include focal industry competition as an independent variable in all three augmented inventory models to test the direct effects of focal industry competition on raw materials inventory, finished goods inventory and work-in-process inventory, respectively (**H1, H2 and H3**). Furthermore, raw materials inventory held in the focal industry is also hypothesized to be negatively associated with upstream industry competition (**H4**) and finished goods inventory held in the focal industry is hypothesized to be negatively associated with downstream industry competition (**H5**), respectively. Therefore, upstream industry competition is also included in the raw materials inventory model and downstream industry competition is also included in the finished goods inventory model. Meanwhile, both upstream and downstream industry competition are included in the work-in-process inventory model because work-in-process inventory is hypothesized to be negatively associated with both upstream competition (**H6a**) and downstream industry competition (**H6b**).

To further test the moderating effects of focal industry competition on the role of the eight inventory drivers, we include the interaction terms of focal industry competition with the eight inventory drivers in each of the three augmented inventory models. By so doing, we test **Hypotheses 7a-7h** regarding the moderating effects of focal industry competition in three different settings.

The augmented models are specified as follows:

Equation 4: *Raw Materials Inventory = f (Eight Inventory Drivers, Focal Industry Competition, Upstream Industry Competition, Focal Industry Competition X Each of the Eight Inventory Drivers)*

Specifically, Equation 4 tests the direct effects of focal industry competition (**H1**) and upstream industry competition (**H4**) on raw materials inventory and the moderating effects of focal industry competition on the role of the eight inventory drivers on raw materials inventory (**Hypotheses 7a -7h**).

Equation 5: *Finished Goods Inventory = f (Eight Inventory Drivers, Focal Industry Competition, Downstream Industry Competition, Focal Industry Competition X Each of the Eight Inventory Drivers)*

Specifically, Equation 5 tests the direct effects of focal industry competition (**H2**) and downstream industry competition (**H5**) on finished goods inventory and the moderating effects of focal industry competition on the role of the eight inventory drivers on finished goods inventory (**Hypotheses 7a-7h**).

Equation 6: *Work-in-Process Inventory = f (Eight Inventory Drivers, Upstream Industry Competition, Focal Industry Competition, Downstream Industry Competition, Focal Industry Competition X Each of the Eight Inventory Drivers)*

Specifically, Equation 6 tests the effects of focal industry competition (**H3**), upstream competition and downstream competition (**H6**) on work-in-process inventory, and the moderating effects of focal industry competition on the role of the eight inventory drivers on work-in-process inventory (**Hypotheses 7a-7h**).

V. DATA COLLECTION AND VARIABLE MEASUREMENT

This study uses inventory and operational data on manufacturing industries from the U.S. Economic Census for the Census years 1997, 2002 and 2007. The unit of observation in this research is the most detailed six-digit North American Industry Classification System (NAICS) industry. For example, automobile manufacturing is coded as 336111 while light truck and utility vehicle manufacturing is coded as 336112. Initially, there are 473 six-digit manufacturing industries reported for each Census year. However, due to the U.S. Census Bureau's intentional withholding of certain information to avoid disclosures of firm specific information, 25 industries are excluded from final analysis, resulting in a dataset of 1,344 firm-year observations (448 industries over three years). Note that the U.S. Census Bureau also reports the number of manufacturing firms in each industry and calculates the industry concentration ratios measured by the Herfindahl Hirschman Index (HHI).

5.1 Measurement of Dependent Variables

Following Rajagopalan and Malhotra (2001), inventory levels for each stage are operationalized by inventory in days of supply assuming a 365-day year as follows:

Raw Materials Inventory $_{it}$ =

$$365 * \frac{Raw\ Material\ Inventory_{it}}{Total\ Cost\ of\ Materials_{it}}$$

Finished Goods Inventory $_{it}$ =

$$365 * \frac{Finished\ Goods\ Inventory_{it}}{Total\ Cost\ of\ Materials + Value\ Added_{it}}$$

Work-in-Process Inventory $_{it}$ =

$$365 * \frac{WIP\ Inventory_{it}}{Total\ Cost\ of\ Materials + 0.5 * Value\ Added_{it}}$$

5.2 Measurement of Focal Industry Competition

HHI is a market share weighted concentration ratio. When normalized, HHI ranges from zero to one, with zero indicating the lowest level of concentration, which is perfect competition. An HHI of one indicates a monopoly market which is least competitive. Therefore, HHI is itself an inverse measure of competition. To derive a direct measure of competition from HHI, we follow Colla et al. (2010) to use an intuitive measure: ‘‘1-HHI’’, which also ranges from 0 to 1, with 0 indicating monopoly and 1 indicating perfect competition.

5.3 Measurement of Upstream Industry and Downstream Industry Competition

Competition for upstream supplier industries and downstream user industries is based on the Materials Consumed by Kind report published by the U.S. Census Bureau. Since manufacturers in the focal industry may source various raw materials from multiple suppliers in multiple upstream industries, we calculate an average competition level of all supplier industries as *Upstream Industry Competition* for a specific focal industry. The average is weighted by the percentage of the cost of materials supplied to the focal industry by each supplier industry. Similarly, firms in the focal industry may supply finished products to multiple downstream user industries. We calculate an average competition level of all user industries as *Downstream Industry Competition* for a specific focal industry. The average is weighted by the percentage of the cost of materials consumed by each downstream industry.

5.4 Measurement of Classic Inventory Drivers

Data on *Demand Uncertainty* are collected from the Purchasing Manager’s Index (PMI) published by the Institute for Supply Management. To reflect the changing pattern of demand facing U.S. manufacturing, the monthly standard deviation of the Manufacturing New Orders Index is used as a measure of demand variation for the year. An index greater than 50 indicates an increase in demand while an index less than 50 indicates a decrease in demand. Data on industry *Cost of Capital* are collected from the financial datasets compiled by Aswath Damodaran at New York University, who tracks and publishes annual data on the cost of capital by industry sector, weighted by the cost of equities and debts. The weighted cost of capital for manufacturing industries are estimated based on industry sectors, which are equivalent to the 3-digit NAICS industries.

The measure of *Gross Profit Margin* is rather straightforward, which is

$$\frac{Total\ Value\ of\ Shipments_{it} - Total\ Cost\ of\ Materials_{it}}{Total\ Value\ of\ Shipments_{it}}$$

Industry Growth Rate is measured on an annual basis, which is calculated as

$$\frac{Total\ Value\ of\ Shipments_{it} - Total\ Value\ of\ Shipments_{it-1}}{Total\ Value\ of\ Shipments_{it-1}}$$

Data on industry total value of shipments for non-Census years (1996, 2001 and 2006) are used to calculate the annual industry growth rate for the Census years 1997, 2002 and 2007, respectively. Data from the U.S. Annual Survey of Manufactures (ASM) us used, which is conducted annually except during Census years. Note that the 1996 Annual Survey of Manufactures used the Standard Industry Classification (SIC) codes rather than NAICS. We therefore derive the NAICS-based industry output using the Concordance Table provided by the U.S. Census Bureau.

Product Variety is the relative index of the extent an industry manufactures multiple product lines. According to Han et al. (2012) and Brush and Karnani (1996), product specialization can be operationalized as the dollar value of the primary product line divided by the dollar value of the total industry output. The U.S Economic Census reports primary ratios that reflect the extent to which the primary product line accounts for the total value of industry output. Product variety is derived by subtracting the primary ratio from 1.

IT Investment reflects the expenditures on computer hardware, software, data processing and computing services. *IT Investment* is normalized by using the total value of shipments following Shah and Shin (2007). Average plant size, measured by total output per plant, is used to assess *Economies of Scale*, calculated as

$$\frac{Industry\ Total\ Value\ of\ Shipments_{it}}{Number\ of\ Firms_{it}}$$

Note that for comparison purpose over 1997-2007, industry total value of shipments are deflated to 1997 U.S. dollars using the industry specific Producer Price Index (PPI) published by the U.S. Bureau of Labor Statistics. Given the lack of other available sources, *Manufacturing Worker Skills* is proxied by using the average hourly wage rate for each manufacturing industry. The Consumer Price Index (CPI) published by U.S. Bureau of Labor Statistics is used to obtain real wages in 1997 U.S. dollars.

VI. Descriptive Statistics and Regression Results

Industry characteristics and descriptive statistics are reported in Table 2. According to the dataset, inventory in days of supply averaged over 35 days for raw materials inventory, nearly 15 days for work-in-process inventory, and approximately 19 days for finished goods inventory across all industry sectors over this period. The competition index is generally high: averaging 0.92 for focal industry competition, 0.95 for upstream industry competition and 0.91 for downstream industry competition. Note that the minimum competition index is 0.51 for focal industry, 0.53 for upstream industry and 0.54 for downstream industry, which is largely equivalent to the competition level for a duopoly industry in which two dominant players evenly split the market.

TABLE 2. DESCRIPTIVE STATISTICS OF ALL VARIABLES

Variable	Meaning/Unit	Mean	Median	Min	Max	Std. Dev.
Raw Materials Inventory	Days	35.36	31.90	1.70	344.80	20.17
Work-in-Process Inventory	Days	14.66	10.40	0.10	187.90	16.88
Finished Goods Inventory	Days	18.53	16.00	0.30	138.40	12.88
Focal Industry Competition	Percentage Index (0-1)	0.92	0.94	0.51	0.99	0.07
Upstream Industry Competition	Percentage Index (0-1)	0.95	0.96	0.53	0.99	0.05
Downstream Industry Competition	Percentage Index (0-1)	0.91	0.93	0.54	0.99	0.07
Demand Uncertainty	Standard Deviation of Monthly New Orders Index	3.62	3.67	2.15	4.96	1.15
Cost of Capital	Percentage	0.08	0.08	0.06	0.13	0.02
Gross Profit Margin	Percentage (0-1)	0.50	0.51	0.11	0.88	0.12
Industry Growth Rate	Percentage	0.02	0.02	-0.66	2.93	0.20
Product Variety	Percentage Index (0-1)	0.11	0.06	0.01	0.99	0.19
IT Investment	Percentage (0-1)	0.004	0.002	0.00001	0.07	0.0056
Economies of Scale (Avg. Plant Size)	$Million (1997 Dollars)	30.32	11.71	0.37	2,115	100.32
Worker Skills (Hourly Wage)	$ (1997 Dollars)	14.07	13.66	5.90	31.75	3.76

To be able to interpret both direct and moderating effects appropriately, we follow Aiken and West (1991) to mean center the variables. In this case, the coefficient of an independent variable can be interpreted as the direct effect of this variable on the dependent variable when all other independent variables are at the mean values. Pairwise correlation

coefficients of mean-centered variables stay within the normal range. The diagnostic test for multicollinearity finds that the variance inflation factor (VIF) scores range from 1.17 to 4.57 with a mean VIF of 1.87. These low VIF scores support that multicolinearity is not a concern in this dataset.
Given the structure of this panel dataset with both time series and cross-sectional observations, generalized least squares (GLS) models are estimated by accounting for industry-wise heteroskedasticity, cross-industry correlations and common autocorrelation within industry over time. Regression results are presented in Table 3.

TABLE 3. ESTIMATION RESULTS FOR THE BASELINE INVENTORY MODELS

	Equation 1	**Equation 2**	**Equation 3**
DV	***Raw Materials Inventory***	***Finished Goods Inventory***	***Work-in-Process Inventory***
Constant	16.15*** (4.99)	7.96*** (3.03)	14.63*** (0.16)
Demand Uncertainty	0.93*** (0.30)	0.47** (0.19)	-1.21*** (0.20)
Cost of Capital	-99.35*** (30.91)	-39.02** (20.23)	-48.14*** (20.71)
Gross Profit Margin	53.52*** (7.12)	-14.43*** (4.66)	22.64*** (4.77)
Industry Growth Rate	-2.88** (1.46)	-3.96*** (0.96)	-4.48** (0.98)
Product Variety	2.46** (1.15)	2.87** (1.26)	4.03*** (1.29)
IT Investment	-35.16 (58.40)	-24.02 (38.23)	-117.79*** (39.14)
Economies of Scale	-0.026** (0.013)	-0.0034 (0.0054)	-0.02** (0.009)
Worker Skills	-0.25 (0.31)	-0.23 (0.16)	0.64*** (0.20)
No. of observations	1,344	1,344	1,344
No. of Industries	448	448	448
Common AR (1) Coefficient	0.21	0.19	0.26
Wald Chi-square	946.26	1089.60	1150.12
Prob > Chi-square	0.0000	0.0000	0.0000

(Note: two-tailed; ***, ** and * denote significance levels at 1%, 5% and 10%, respectively)

TABLE 4. ESTIMATION RESULTS FOR AUGMENTED INVENTORY MODELS

	Equation 1	Equation 2	Equation 3
DV	***Raw Materials Inventory***	***Finished Goods Inventory***	***Work-in-Process Inventory***
Constant	19.37*** (5.18)	8.69*** (3.08)	14.65*** (0.17)
Focal Industry Competition	46.01** (22.35)	42.98** (21.29)	-19.76** (7.78)
Upstream Industry Competition	-19.39*** (5.21)		-15.86 (12.31)
Downstream Industry Competition		-4.19*** (1.65)	11.51 (9.05)
Demand Uncertainty	7.37* (4.15)	2.26** (.95)	-2.68*** (0.08)
Cost of Capital	-86.24*** (22.15)	-54.77** (20.36)	-85.86 (48.77)
Gross Profit Margin	68.40*** (21.79)	-28.84 (40.21)	23.43*** (4.05)
Industry Growth Rate	-27.41** (12.43)	-2.51*** (0.37)	-70.57*** (11.52)
Product Variety	35.43** (16.04)	2.56* (1.03)	-.14 (0.90)
IT Investment	-57.67 (48.52)	-46.21 (27.38)	56.34 (49.28)
Economies of Scale	-0.12*** (0.04)	-0.05*** (0.002)	-0.03*** (0.005)
Worker Skills	-2.69** (1.03)	-1.79*** (0.16)	2.12* (1.30)
Focal Industry Competition x Demand Uncertainty	6.81*** (2.47)	2.52** (1.13)	1.89 (2.95)
Focal Industry Competition x Cost of Capital	-686.97*** (229.14)	343.81 (267.69)	128.88 (135.72)
Focal Industry Competition x Gross Profit Margin	136.65 *** (36.56)	-8.91 (19.03)	56.47* (28.52)
Focal Industry Competition x Industry Growth Rate	-27.44 (19.06)	-17.28** (7.63)	-72.67*** (12.59)
Focal Industry Competition x Product Variety	42.89* (24.59)	23.69*** (8.64)	13.55 (16.24)
Focal Industry Competition x IT Investment	-1117.08 (916.82)	-437.18 (603.12)	-636.85 (478.13)
Focal Industry Competition x Economies of Scale	-0.18 (0.14)	-0.14 (.58)	0.09 (0.06)
Focal Industry Competition x Worker Skills	-3.10** (1.39)	-1.79** (0.68)	-1.84 (1.52)
No. of observations	1,344	1,344	1,344
No. of industries	448	448	448
Common AR (1) Coefficient	0.25	0.23	0.28
Wald Chi-square	1155.87	1210.23	1468.96
Prob > Chi-square	0.0000	0.0000	0.0000

(Note: two-tailed; ***, ** and * denote significance levels at 1%, 5% and 10%, respectively)

According to Table 3, all three baseline models are highly significant as suggested by the Chi-square statistics. The signs of the coefficients for five inventory drivers, including *Cost of Capital* (negative), *Industry Growth Rate* (negative), *Product Variety* (positive), *Economies of Scale* (negative), and *IT Investment* (negative) are in line with empirical inventory literature across all three inventory models, indicating a degree of normality and soundness of the model specifications.

For the augmented inventory models, competition variables and the interaction terms between focal industry competition and inventory drivers are included. Regression results are reported in Table 4.

According to Table 4, all three augmented inventory models are highly significant according to the Wald Chi-square statistics. The coefficients for all eight inventory drivers are comparable to findings shown in the baseline models. The majority of the inventory drivers show significant effects on certain forms of inventory as predicted in the literature, which provides support for the model specifications. For example, *Demand Uncertainty* is positively associated with raw materials inventory (coefficient of 7.37 and significant at 10%) and finished goods inventory (coefficient of 2.26 and significant at 5%). *Cost of Capital* has negative coefficients for all three inventory models; however, the coefficients are significant only in the raw materials inventory (-86.24, significant at 1%) and in the finished goods inventory model (-54.77, significant at 5%), but not significant in the work-in-process inventory model, this finding is worth further investigation. The effects of *Gross Profit Margin* are mixed. Its coefficients are highly significant for both raw materials inventory (136.65) and for work-in-process inventory (23.43); in contrast, the coefficient is not significant for finished goods inventory. *Industry Growth Rate* is negatively associated with inventory at all three stages, showing a coefficient of -27.41 (significant at 5%) for raw materials inventory, a coefficient of -2.51 (significant at 1%) for finished goods inventory, and a coefficient of -70.57 (significant at 1%) for work-in-process inventory. *Product Variety* is significantly and positively associated with raw materials inventory (35.43, significant at 5%) and finished goods inventory (2.56, significant at 10%), but not significant with work-in-process inventory. The coefficient of *Economies of Scale* is -0.12 (significant at 1%) for raw materials inventory, -0.05 (significant at 1%) for finished goods inventory, and -0.03 (significant at 1%) for work-in-process inventory, indicating that the inventory reduction effect of *Economies of Scale* exists for inventory at all three stages. *Worker Skills* is negatively associated with raw materials inventory (-2.69, significant at 5%) and finished goods inventory (-1.79, significant at 1%).

Focal Industry Competition in the raw materials inventory model has a positive coefficient (46.01, significant at 5%), indicating that on average manufacturing firms in more competitive industries tend to hold more raw materials inventory. This provides strong support for **Hypothesis 1** that focal industry competition is positively associated with raw materials inventory. In the finished goods inventory model, *Focal Industry Competition* also has a positive coefficient (42.98, significant at 5%), indicating that on average manufacturing firms in more competitive industries tend to hold more finished goods inventory. This supports **Hypothesis 2** that focal industry competition is positively associated with finished goods inventory. In contrast, in the work-in-process inventory model, the coefficient of *Focal Industry Competition* is negative (-19.76, significant at 5%), which suggests that on average manufacturers in more competitive industries tend to hold less work-in-process inventory. This supports **Hypothesis 3** that focal industry competition is negatively associated with work-in-process inventory.

Upstream Industry Competition has a negative coefficient (-19.39, significant at 1%) in the raw materials inventory model, suggesting that manufacturers tend to hold less raw materials inventory when their suppliers are in more competitive industries. This supports **Hypothesis 4** that upstream industry competition is negatively associated with raw materials inventory. *Downstream Industry Competition* has a negative coefficient (-4.19, significant at 1%) in the finished goods inventory model, indicating that manufacturers tend to hold less finished goods inventory when their downstream industries are more competitive. This supports **Hypothesis 5** that downstream industry competition is negatively associated with finished goods inventory.

Note that in the work-in-process inventory model, the coefficient for *Upstream Industry Competition* is not significant despite a negative sign, indicating that upstream competition may not directly affect a firm's work-in-process inventory. Therefore, **Hypothesis 6a** that upstream competition is negatively associated with work-in-process inventory is not supported. The coefficient for *Downstream Industry Competition* is not significant despite a positive sign, indicating that downstream competition may not directly affect a firm's work-in-process inventory. Therefore, no support is found for **Hypothesis 6b** that downstream competition is negatively associated with work-in-process inventory.

Table 4 further shows mixed results regarding the moderating effects of focal industry competition on several inventory drivers. For example, the coefficient for the interaction term *Focal Industry Competition X Demand Uncertainty* is positive and statistically significant in both the raw materials inventory model (6.81, significant at 1%) and the finished goods inventory model (2.52, significant at 5%), indicating that the positive effect of demand uncertainty on inventory may be enhanced when the competitive intensity in the focal industry increases. This finding provides support for **Hypothesis 7a** that the positive effect of demand uncertainty on inventory becomes stronger when focal industry competition increases. However, the coefficient of this interaction term is not significant in the work-in-process inventory model; therefore, **Hypothesis 7a** is partially supported.

The coefficient for *Focal Industry Competition X Cost of Capital* is negative and statistically significant in the raw materials inventory model (-686.97, significant at 1%), indicating that the negative effect of cost of capital on raw materials inventory increases as the competition level increases. However, this coefficient is not significant either in the finished goods inventory model nor in the work-in-process inventory model. Therefore, we only find partial support for **Hypothesis 7b.**

The coefficients for *Focal Industry Competition X Gross Profit Margin* are positive for the raw materials inventory model (136.65, significant at 1%) and the work-in-process inventory model (56.47, significant at 10%), indicating that the positive effect of gross profit margin on inventory increases when focal industry competition increases. However, a negative despite insignificant coefficient appears for the finished goods inventory model. While we find partial support for **Hypothesis 7c** that focal industry competition moderates the effect of gross profit margin, it is interesting that the sign for finished goods inventory differs from those for raw materials inventory and work-in-process inventory, which warrants further examination.

The coefficients for *Focal Industry Competition X Industry Growth Rate* are negative and statistically significant for both the finished goods inventory model (-17.28, significant at 5%) and the work-in-process inventory model (-72.67, significant at 1%), indicating that the reduction effects of industry growth rate can be enhanced when focal industry competition increases. However, this moderating effect is not significant for the raw materials inventory model. Therefore, we find partial support for **Hypothesis 7d** that the negative effect of industry growth rate on inventory becomes stronger when focal industry competition increases.

The coefficients for the interaction term *Focal Industry Competition X Product Variety* are positive and statistically significant for the raw materials inventory model (42.89, marginally significant at 10%) and for the finished goods inventory model (23.69, significant at 1%), indicating the increasing effect of product variety on inventory is further enhanced when focal industry competition increases. However, the coefficient is not significant despite a positive sign in the work-in-process inventory model. Therefore, **Hypothesis 7e** that the positive effect of product variety on inventory becomes stronger when focal industry competition increases is only partially supported.

The coefficients for *Focal Industry Competition X IT Investment* are not statistically significant in any of the three inventory models, indicating a lack of a moderating effect of competition on IT investment. Therefore, **Hypothesis 7f** that the negative effect of IT investment on inventory becomes stronger when focal industry competition increases is not supported. This finding is not surprising given that the main effect of IT investment on inventory is not clear. The coefficients for *Focal Industry Competition X Economies of Scale* are not significant across all three inventory models, indicating that economies of scale in inventory management do not change with the focal industry competition. Therefore, no support is found for **Hypothesis 7g** that the negative effect of economies of scale on inventory becomes stronger when focal industry competition increases. The lack of support could be caused by the use of average plant size as a measure to capture economies of scale. Lastly, the coefficients for *Worker Skills* are all negative but only significant in the raw materials inventory model (-3.10, significant at 5%) and in the finished goods inventory model (-1.79, significant at 5%), not significant in the work-in-process inventory model. This finding provides partial support for **Hypothesis 7h** that the negative effect of manufacturing worker skills on inventory becomes stronger when focal industry competition increases. It is interesting to note that the moderating effect does not apply to the work-in-process inventory.

The testing results of all hypotheses are summarized in Table 5 as follows:

TABLE 5. RESULTS OF HYPOTHESIS TESTING

H#	Hypothesis	Result
Direct Effects of Industry Competition on Inventory		
H1	Focal industry competition is positively associated with raw materials inventory	Strong support
H2	Focal industry competition is positively associated with finished goods inventory	Support
H3	Focal industry competition is negatively associated with work-in-process inventory	Strong support
H4	Upstream industry competition is negatively associated with raw materials inventory	Strong support
H5	Downstream industry competition is negatively associated with finished goods inventory	Strong support
H6a	Upstream industry competition is negatively associated with work-in-process inventory	No support
H6b	Downstream industry competition is negatively associated with work-in-process inventory	No support
Moderating Effects of Industry Competition through Inventory Drivers		
H7a	The positive effect of demand uncertainty on inventory becomes stronger when focal industry competition increases	Partial support
H7b	The negative effect of cost of capital on inventory becomes stronger when focal industry competition increases	Partial support
H7c	The positive effect of gross profit margin on inventory becomes stronger when focal industry competition increases	Partial support
H7d	The negative effect of industry growth rate on inventory becomes stronger when focal industry competition increases	Partial support
H7e	The positive effect of product variety on inventory becomes stronger when focal industry competition increases	Partial support
H7f	The negative effect of IT investment on inventory becomes stronger when focal industry competition increases	No support
H7g	The negative effect of economies of scale on inventory becomes stronger when focal industry competition increases	No support
H7h	The negative effect of manufacturing worker skills on inventory becomes stronger when focal industry competition increases	Partial support

VII. DISCUSSION OF REGRESSION RESULTS AND FINDINGS

First, not all inventory drivers show the same effect on all three types of manufacturing inventory. Some insights and explanations are discussed here, which may be of value to inventory management professionals and researchers. (1) *Demand Uncertainty* is positively associated with raw materials inventory and finished goods inventory but appears to be negatively associated with work-in-process inventory. Facing variable demand, firms need more safety stock to buffer demand surges and need to secure enough raw materials to build up production in case of a demand surge, resulting in more raw materials and finished goods inventory. When demand is uncertain, however, firms are more likely to pursue flexibility through advanced supply chain practices, including the use of common components and a postponement strategy, resulting in less work-in-process inventory. Therefore, the results suggest that manufacturers facing highly uncertain demand may strive to improve internal operational efficiency and reduce work-in-process inventory to offset the upward pressure on both raw materials and finished goods inventories. (2) *Gross Profit Margin* is positively associated with raw materials inventory and work-in-process inventory but negatively associated with finished goods inventory. Existing research has consistently reported a positive relationship between gross profit margin and total inventory since gross profit margin represents the cost of lost sales to competitors. The negative coefficient for finished goods inventory may suggest that products with high gross profit margins also incur high holding costs and opportunity costs. This result not consistent with extant literature which suggests that firms may be willing to move products with high margins faster, resulting in greater inventory turns and lower inventory in days of supply. (3) *Product Variety* is positively associated with raw materials and finished goods inventory but shows no significant association with work-in-process inventory. It is reasonable that firms with a broader product line need to procure more raw materials inventory and prepare for more finished goods inventory due to the greater variety of products produced and potentially more complex and specialized manufacturing processes. The lack of association between *Product Variety* and work-in-process inventory is not intuitive and warrants further investigation. (4) As a proxy measure for manufacturing worker skills, *Worker Hourly Wage* is positively associated with work-in-process inventory, which is opposite of findings regarding raw materials and finished goods inventory. This anomaly may be attributed to the fact that some highly paid industries, such as aerospace manufacturing and ship building, have extremely long periods of maintaining work-in-process inventory while almost minimum finished goods inventory due to build-to-order. (5) Note that *IT Investment* is not significant in any inventory model, which may be accounted for by the fact that IT investment remains a negligible portion of a firm's total output. Based on the dataset, on average IT Investment is 0.4% of total industry output.

Second, regression results interestingly show that the effects of industry competition on inventory levels are not consistent and may vary with the stage of inventory: positive impact of focal industry competition on both raw materials and finished goods inventories but negative impact on work-in-process inventory. (1) Facing high competition in the focal industry, firms may be more concerned with losing sales to competitors than controlling inventory costs; therefore, firms may be more willing to build up their finished goods inventory to improve their customer service level. Meanwhile, high competition means that many manufacturers compete for the same raw materials, which puts enormous pressure on maintaining a stable supply of raw materials to avoid a potential shut-down of manufacturing lines. One of the effective solutions under a firm's control is to hold more inventory for certain critical raw materials. Therefore, we expect that *Focal Industry Competition* is positively associated with both raw materials inventory and finished goods inventory. In contrast, work-in-process inventory is largely within a firm's control. Facing competition, firms need to control their operating costs to stay competitive. To offset rising costs due to increasing raw materials and finished goods inventory, firms may be under greater pressure to reduce work-in-process inventory through more efficient manufacturing processes. (2) *Upstream Industry Competition* and *Downstream Industry Competition* are negatively associated with raw materials inventory and finished goods inventory, respectively but show no association with work-in-process inventory. It is understandable that when the upstream supplier industry is competitive, firms in the focal industry may be able to hold less raw materials inventory. In this situation, manufacturing firms may enjoy more bargaining power over the suppliers in negotiating favorable arrangements for raw materials supply, including shifting more raw materials inventory from their own books to the suppliers'. In the same spirit, when the downstream industry is competitive, manufacturing firms in the focal industry may be able to move out finished goods inventory faster since downstream users are competing for those finished products as their inputs of production and hence are willing to hold more raw materials inventory in their own hands. Due to a lack of bargaining power, users in a competitive downstream industry may have to hold more raw materials inventory on their own books as well. While raw materials inventory is closely linked with inbound or upstream supply chain, finished goods inventory is tied to the outbound or downstream supply chain, work-in-process inventory may be more affected by a firm's internal operations, possibly accounting for the lack of impact of upstream competition and downstream competition on work-in-process inventory.

VIII. CONTRIBUTIONS, LIMITATIONS AND FUTURE RESEARCH STEPS

This study is the first empirical effort to investigate the relationship between industry competition and inventory levels based on a large scale archival dataset of all U.S. manufacturing industries over three Census periods. Our focus is to explore the direct effects of industry competition, in terms of focal industry competition, upstream industry competition and downstream competition, on inventory levels and the moderating effects of focal industry competition on the roles of eight classic inventory drivers. Given that literature provides no clear prediction about the relationship between competition and inventory levels, this study improves our understanding of the relationship in a rich empirical setting. This study is also among the first research efforts to investigate inventory drivers at all three inventory stages and results indicate that competition and other drivers have varying effects depending on the stage of the manufacturing processes. Our findings, based on industry level analysis have practical implications for firms competing in a global supply chain context. All firms operate in a specific industry and hence need to adapt to the overall industry environment. Industries vary due to their unique structures and the dynamics of supplier power, buyer power, barriers of entry, substitutes, and rivalry. Firm strategies related to inventory types (i.e., raw material, work-in process and finished goods inventories) reflect their internal operations and vertical relationships with upstream suppliers and downstream customers.

Supply chain managers have been trained to perform industry competitiveness analysis to understand the market forces and business environment facing their firms. However, the link between industry competition and firm inventory decisions has not been highlighted in the conventional decision-making frameworks. Our findings may provide a bridge between industry competitive landscape (structure) and firm inventory strategy (conduct) and may further serve as a benchmark that manufacturing inventories at different stages may be associated with industry competition to different degrees. For example, raw material inventory level may be adjusted based on the level of upstream industry competition and finished goods inventory level may be adjusted based on the level of downstream industry competition. Lean work-in-process inventory through efficient internal operations may be used to offset upward pressures from both upstream and downstream industry structural forces.

Our research is subject to a number of limitations and hence we call for future research efforts to improve our understanding. First, since accurate industry concentration ratios are only reported in the U.S. Economic Census, which is always five years apart, we only have three temporal observations for each industry over 1997, 2002 and 2007. Manufacturing industries may have experienced significant changes during the interim periods. Future research may estimate concentration ratios annually based on published data and hence utilize annual data collected from the U.S. Annual Survey of Manufactures to improve our results. Second, this study has only considered the moderating effects of focal industry competition on inventory levels. Despite that focal industry competition holds more weight when firms make inventory decisions, from an end-to-end supply chain perspective, upstream and downstream competition may also moderate the inventory drivers. Therefore, future research on upstream and downstream competition may provide a full picture of the roles of industry competition in driving inventory decisions along the supply chain. Third, while the scope of this research is to provide a macroscopic view of inventory behavior, mangers should be cautioned when applying our findings to firm level inventory decisions. We acknowledge that individual firms may depend on their own unique resources and capabilities to cope with their competitive business environment and that inventory decisions are made at the product level within a firm. Obviously, future research with firm-level data can be very useful in examining firm inventory behaviors. Fourth, since our unit of observation is the six-digit NAICS industry, competition facing individual firms may need to be defined more narrowly due to geographic focus or more broadly if a broader product category is considered. Future research may use data at other aggregate levels to further test our findings. Fifth, inventory theory supports that supply uncertainty is another major inventory driver. Unfortunately, this study is not able to include this important variable due to data limitation. Future research is encouraged to include both supply and demand uncertainties in studies to reflect a more complete picture of supply chain uncertainty. Lastly, our current study is limited to a dataset spanning only three Census years. When the 2017 U.S. Economic Census data are released in late 2019 and become publicly available, an expanded dataset spanning the entire 20-year period (1997-2017) would be very helpful and powerful for inventory research at the industry level.

REFERENCES

Aiken, L. S. and West, S. G., *Multiple Regression: Testing and Interpreting Interactions*, Newbury Park, Sage, 1991.

Bain, J. S., *Barriers to New Competition. Cambridge*, Harvard University Press, MA, 1956.

Blinder, A. S. and Maccini, L. J., "The Resurgence of Inventory Research: What Have We Learned?" *Journal of Economic Surveys,* 5 (4), 1991, 291-328.

Brush, T. and Karnani, A., "Impact of Plant Size and Focus on Productivity: An Empirical Study," *Management Science*, 42 (7), 1996, 1065-1081.

Cachon, G. P. and Olivares, M., "Drivers of Finished-Goods Inventory in the U.S. Automobile Industry," *Management Science*, 56 (1), 2010, 202-216.

Chen, H., Frank, M. and Wu, O. Q., "What Actually Happened to the Inventories of American Companies between 1981 and 2000?" *Management Science*, 51 (7), 2005, 1015-1031.

Cheng, L. C., Cantor, D. E., Dresner, M. and Grimm, C. M., "The Impact of Contract Manufacturing on Inventory Performance: An Examination of U.S. Manufacturing Industries," *Decision Sciences*, 43 (5), 2012, 889-928.

Clark, T. and Hammond, H. J., "Reengineering Channel Reordering Processes To Improve Total Supply-chain Performance." *Production Operations Management*, 6 (1), 1997, 248-265.

Colla, C. H., Escarce, J. J., Buntin, M. B. and Sood, N., "Effects of Competition on the Cost and Quality of Inpatient Rehabilitation Care under Prospective Payment," *Health Services Research,* 45 (6), 2010, 1981–2006.

Collier, D. A. and Evans, J. R., *OM 3* (3rd Edition), Cengage Learning, Boston, MA, 2011.

Da Silveira, G., "A Framework for the Management of Product Variety," *International Journal of Operations & Production Management,* 18 (3), 1998, 271-285.

Danziger, P. N., "Winning the Sports Retail Race: Under Armour and Nike Hit the Wall," *Forbes*, November 1, 2017. https://www.forbes.com/sites/pamdanziger/ 2017/11/01/winning-the-sports-retail-race-under-armour-and-nike-hit-the-wall/#4fc4658f1a96 (accessed June 16, 2018).

Eroglu, C. and Hofer, C., "Lean, Leaner, Too Lean? The Inventory-Performance Link Revisited," *Journal of Operations Management*, 32 (4), 2011, 356-369.

Eroglu, C. and Hofer, C., "The Effect of Environmental Dynamism on Returns to Inventory," *Journal of Operations Management*, 29 (6), 2014, 347-356.

Ferrier, W. J., Smith, K. G. and Grimm, C. M., "The Role of Competitive Action in Market Share Erosion and Industry Dethronement: A Study of Industry Leaders and Challengers," *Academy of Management Journal*, 42 (4), 1999, 372-388.

Fisher, M. L. and Ittner, C. D., "The Impact of Product Variety on Automobile Assembly Operations: Empirical Evidence and Simulation Analysis," *Management Science*, 45 (6), 1999, 771-786.

Galankashi, M. R. and Helmi, S. A., "Assessment of Hybrid Lean-Agile (Leagile) Supply Chain Strategies." *Journal of Manufacturing Technology Management*, 27 (4), 2016, 470-482.

Gaur, V., Fisher M. L. and Raman, A., "An Econometric Analysis of Inventory Turnover Performance in Retail

Services," *Management Science*, 52 (2), 2005, 181-194.

Gaur, V. and Kesavan, S., The Effects of Firm Size and Sales Growth Rate on Inventory Turnover Performance in U.S. Retail Services, in Agrawal, N. and Smith, S. (eds.), *Retail Supply Chain Management*, Kluwer Publishers, Norwell, MA, 2009, 25-52.

Golini, R. and Kalchschmidt, M., "Moderating the Impact of Global Sourcing on Inventories through Supply Chain Management," *International Journal of Production Economics,* 133, 2011, 86-94.

Han, C., Dresner, M., Windle, R. J., "Impact of Global Sourcing and Exports on US Manufacturing Inventories", *International Journal of Physical Distribution & Logistics Management*, 38 (6), 2008, 475-494.

Han, C., Porterfield, T. and Li, X., "Impact of Industry Competition on Contract Manufacturing: An Empirical Study of U.S. Manufacturers," *International Journal of Production Economics*, 138 (1), 2012, 159-169.

Lieberman, M., Helper, S. and Demeester, L., "The Empirical Determinants of Inventory Levels in High-Volume Manufacturing," *Production and Operations Management,* 8 (1), 1999, 44-55.

Mason-Jones, R., Naylor, B., Towill, D. R.,"Engineering the Leagile Supply Chain", *International Journal of Agile Management Systems*, 2 (1), 2000, 54-61.

Mason, E. S., "The Current State of the Monopoly Problem in the United States." *Harvard Law Review*, 62, 1949, 1265-85.

Marvel, H. P. and Peck, J., "Inventory Turnover and Product Variety." *The Jorunal of Law and Economics*, 51 (3), 2008, 461-478

Nag, B., Han, C. and Yao, D., "Mapping Supply Chain Strategy – An Industry Analysis", *Journal of Manufacturing Technology Management*, 25 (3), 2014, 351-370.

Olivares, M. and Cachon, G. P., "Competing Retailers and Inventory: An Empirical Investigation of General Motors' Dealerships in Isolated U.S. Markets," *Management Science,* 55 (9), 2009, 1586-1604.

Oke, A. and Szwejczewski, M., "The Relationship between UK Manufacturers' Inventory Levels and Supply, Internal and Market Factors," *International Journal of Production Economics*, 93-94, 2005, 151-160.

Rajagopalan, S. and Malhotra, A., "Have Inventories Declined in the U.S.: An Empirical Study," *Manufacturing & Service Operations Management*, 3 (1), 2001, 14-24.

Ralston, P. M., Blackhurst, J., Cantor, D. E. and Crum, M. R., "A Structure - Conduct - Performance Perspective of How Strategic Supply Chain Integration Affects Firm Performance." *Journal of Supply Chain Management*, 51 (2), 2015, 47-64.

Rumyantsev, S. and Netessine, S., "What Can Be Learned from Classic InventoryModels? A Cross-Industry Exploratory Investigation. *Manufacturing & Service Operations Management,* 9 (4), 2007, 409-429.

Rumyantsev, S. and Netessine, S., "Should Inventory Policy Be Lean or esponsive? Evidence for US Public Companies?" 2005, http://knowledge.wharton.upenn.edu/papers/1307.pdf (Accessed July 28, 2016).

Rotemberg, J. J. and Saloner, G., "The Cyclical Behavior of Strategic Inventories," *Quarterly Journal of Economics,* 104 (1), 1989, 73-97.

Shah, R. and Shin, H., "Relationships among Information Technology, Inventory and Profitability: An Investigation of Level Invariance Using Sector Level Data," *Journal of Operations Management,* 25 (4), 2007,768-784.

Sriparavastu, L., and Gupta, T., "An Empirical Study of Just-In-Time and Total Quality Management Principles Implementation in Manufacturing Firms in the USA," *International Journal of Operations & Production Management*, 17 (12), 1997, 1215-1232.

Waldman, D. E, and Jensen, E. J., *Industrial Organization: Theory and Practice* (2nd), Addison Wesley Longman, 2001.