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Antecedents of Inventory Levels in the U.S. Manufacturing Industry

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Introduction

According to the U.S. Census Bureau report, American 2006 year-end total manufacturing inventories are worth $482 billion while total business inventories of $1.4 trillion, based on non-seasonally adjusted, current dollar figures. According to the 2005 Annual Survey of Manufactures, the U.S. manufacturing sector provides total value of shipments of $4.7 trillion and employs 13 million employees, including over 9 million production workers, and accounting for nearly 10% of the total U.S. employment. As the engine of the U.S. economy, manufacturing plays a significant role in driving supply chain efficiency through inventory investment. However, economists and business researchers have been intrigued by the "macro-micro paradox" of manufacturing inventory: destabilizing effect at the macroeconomic level while stabilizing effect at the firm level.

From a macroeconomic perspective, change in industry inventory directly contributes to GDP as the component of business investment, accounting for 0.3% of the total real GDP in 2006, 0.2% in 2005 and 0.4% in 2004, averaging less than one half of 1% of total real GDP for the past half century. However, inventory movement has been considered a dominant feature of business cycles. Empirical studies report that U.S. GDP variations can be explained by inventory variations and that the drop in inventory investment has accounted for over two-thirds of the drop in GDP during the average post war recession in the U.S. (Blinder and Macinni 1991;

Blinder et al. 1981). Decreases in inventory investment accounted for two-thirds or more of the shrinkage in GDP during three recessions, 1969-70, 1974-75, and 1979-80(Akhtar 1983). Quarterly movements in inventory investment over the postwar period have been, on average, more than one-third the size of quarterly variations in real GDP (Fitzgerald and Ransom 1998; McConnell et al. 1999). In contrast, from a firm's perspective, inventory is largely a stabilizing factor through smoothing production, buffering variable demand and boosting sales. Quite often, manufacturers procure more raw materials inventory due to quantity discounts or for speculative purposes because they expect the price of raw materials to go up in the near future. Given high uncertainty of global supply chains in the post-911 era, researchers suggest that holding excessive inventory may be one effective option under a firm's control to mitigate a catastrophic disruption in supply chains (Tomlin 2006).

Recent body of inventory research has made important contributions by tracking inventory changes at all three stages (raw materials, work-in-process and finished goods) in the U.S. manufacturing sector (Chen et al. 2005; Rajagopalan and Malhotra 2001). However, there is little empirical research which provides systematic examination of what factors may have impacted inventory levels. This current research adds to the literature through a systematic examination of variables suggested by prior research based on a panel of 184 five-digit NAICS industries over the period 2002-2004, collected from U.S. Economic Census and Annual Survey of Manufacturers. Estimating both simultaneous equations and fixed effects models for inventories at all three stages, we investigate how inflation, IT investment, imports and exports may have played a role in determining the levels of manufacturing inventories after controlling for the number of plants, sector growth and other industry and time specific effects. Results suggest that inventories at all three stages are positively associated with sector inflation rates, raw materials inventory is positively associated with imports, and that finished goods inventory is positively associated with exports. We also find some evidence that IT investment may lead to reduced inventory requirements.

Inventory Models and Manufacturing Inventory Research

Based on research methodology, empirical inventory research can be characterized into three major streams: macroeconomic view, firm perspective, and industry approach.

Table 1. Inventory Research Streams

Research Steam	Macroeconomic View	Firm Perspective	Industry Approach
Primary Interest	Inventory theory; economic cycles; economic policies	best practice; inventory efficiency	industry specific characteristics
Unit of Analysis	national aggregate	firm level	industry level
Primary Data	quarterly or monthly time series data	cross-sectional survey data	time series and cross sectional industry level data
Dependent Variable	inventory/sales ratios	inventory turnover or inventory days	inventory levels or normalized ratios
Literature	Blinder and Maccini (1991); Miron and Zeldes (1988); Blinder (1986); Bivin (1986); Akhtar (1983); Feldstein and Auerbach (1976)	Chen et al. (2005); Gaur et al. (2005); Zhu and Kramer (2002); Lieberman et al. (1996); Chang and Lee (1995); Huson and Nanda (1995)	Rajagopalan and Malhotra (2001); Boute et al. (2004)

Macroeconomic view

Economists have shown strong interest in the aggregate inventory behavior at the U.S. national level. Due to large impact of inventory variation on economic cycles, study of U.S. aggregate inventory is expected to provide insight and guidance for policy makers. Research on inventory has been strongly affected by the macroeconomic view for the period 1960-1980s.

Modern interest in inventory behavior may be traced to Lundberg (1937) and Metzler (1941) whose work demonstrated that inventory movement can produce business cycles in simple Keynesian models. Economists' interest in inventory behavior largely rests on which model explains best the variation of inventory investment. Why do firms hold inventories? Is there one generalizable theory which can explain motivations by firms in all situations? Among competing theories there are three preeminent models: the buffer-stock production-smoothing model, the stock adjustment model, and the (S, s) model.

The buffer-stock/production-smoothing model has been the dominant inventory theory which builds on the theoretical foundations of optimal production and inventory investment developed by Holt, Modigliani, Muth and Simon (1960). This model assumes that firms use inventory to smooth production schedule and build safety stock to meet stochastic demands. It predicts that manufacturing firms should have demonstrated smaller variation of production due to smoothing effect. However, stylized facts show that the variance of production exceeds the variance of shipments or sales in virtually all cases. Meanwhile, the buffer stock model predicts that inventory investment is negatively correlated with unanticipated components of sales due to buffer effect. But empirical studies have found the covariance between sales and inventory change is not negative (Blinder 1986). Miron and Zeldes (1988) claimed that inventories play little role in smoothing seasonal fluctuations because seasonal variation in production follows closely seasonal variation in sales.

An amendment to the buffer-stock production smoothing model is the stock adjustment model. Intuitively, when faced with surging labor, energy or raw material costs, firms can cut on production and draw upon inventories; when faced with low labor or raw material costs, firms can build inventories. Lovell (1961) first proposed the stock-adjustment model and Lovell (1962) verified a multi-sector buffer stock model, assuming that individual firms make delayed/lagged inventory adjustment to the planned/optimum level in the face of incomplete knowledge of future sales. In this model, firms adjust the stock of inventories when sales surprises occur and firms partially close the gap between current desired inventories and the previous level of the stock. But empirical studies based on this model show that inventory investment is not sensitive to changes in interest rates. Also, this model predicts a very slow inventory adjustment speed given that annual inventory change is only worth of a few days' production. One of Bivin (1986)'s criticisms of the stock adjustment model was that this model is based on reduced form specifications and fails to identify the means by which a change in interest rate causes a change in inventories.

With analysis of durable goods manufacturing data, Feldstein and Auerbach (1976) proposed a target-adjustment model to extend Lovell's model. They reported that inventories adjust completely within one quarter to the target level but this target level responds only slowly to changes in the fundamental determinants. For example, inventory targets depend on firms' warehousing facilities, personnel and knowledge which can adjust only slowly.

Finally, Blinder and Maccini (1991) suggested the (S, s) model which assumes a fixed cost plus a constant marginal cost. Under this strategy, firms optimally pick an inventory threshold value s, below which they will start to order or build inventory in a quantity large enough to restore inventories to some upper limit, S, also optimally predetermined.

Macroeconomic view has primarily focused on finished goods inventory. This aggregate approach examines short-term behavior of inventory and provides an important picture about inventory impact on macroeconomics. Given that finished goods inventory in manufacturing has demonstrated the least variation among all three components of inventory and that raw materials inventory has the biggest variation largely due to longer lead time or supply uncertainty, Blinder and Maccini (1991) criticized that researchers have barked up the wrong tree by paying too much attention to finished goods inventory in stead of other two components.

Firm perspective

Management oriented research on inventory seeks to provide best-in-class practices in inventory management and therefore focuses on how firms can maintain an optimal customer service level with minimized inventory through various inventory management systems and tools (e.g., EDI, JIT, EOQ, QR, etc.)

Chen et al. (2005) empirically investigated inventory performance of U.S. public manufacturers using a sample of over 7,000 manufacturing firms from the Compustat dataset for the period 1981-2000. They reported that the median inventory holding period decreased over years and overall inventory decreased at 2% annually on average. Work-in-process inventory declined by 6% per year, and raw material inventory decreased by 3% per year while finished goods inventory remained unchanged. Their research also tested a few macroeconomic factors which have sensible impact on inventories at three stages, such as interest rates, inflation rates, GDP growth and purchasing managers' optimism.

Sampling over 300 public retail firms, Gaur et al. (2005) empirically examined the correlation of inventory turnover with gross margin, capital intensity and sales surprise. Their time trend analysis showed that inventory turnover had declined in retailing for the 1987-2000 period. Extending this research, Gaur and Kesavan (2005) controlled firm size and sale growth rate in the econometric model and found that inventory turnover is positively associated with firm size, measured by one-year lagged sales. However, inventory turnover increases with size at a slower rate for large firms than for small firms, suggesting diminishing returns to scale. They also reported that inventory turnover increases with sales growth but decreases dramatically with sales contraction. Even though their findings may be limited to retailing industry, apparently the methodology has value for investigation of inventory performance in manufacturing industry.

Based on survey data on hundreds of N.A. automotive suppliers, Lieberman et al. (1996) empirically examined determinants of inventory levels in high-volume manufacturing and proposes that inventories at three stages are jointly determined by technological factors and managerial factors. They found that low inventories are associated with employee training and problem solving activities and frequent communication with customers. Also, inventory levels vary due to different setup times and throughput times caused by technological factors such as material used and technical processes applied which are unique to industry sectors.

To investigate the long-term benefits of adopting JIT on firm inventory performance, Billesbach and Hayen (1994) conducted non-parametric study by tracking a cohort of 28 public manufacturing firms, comparing average pre-JIT performance in late 1970s with average after-JIT performance in late 1980s. Inventory performance is measured in four different ways, such as inventory turnover, inventory/total asset ratio, sales/inventory ratio, and inventory total. They reported that all performance indicators except for inventory total have significantly improved.

Beyond Billesbach and Hayen's simple comparison, Chang and Lee (1995) incorporated a paired control group, resulting in 44 pairs of public firms (JIT firms vs. non-JIT firms), and tracked firm performances of each pair at year ends of 1984 and 1990 using the Compustat database. They found that JIT firms have significantly bigger improvement in terms of inventory turnover over the period even though not on other measures. Their study provides more confidence about the impact of JIT on inventory turnover. This finding is not alone. Using a sample of 55 firms from different manufacturing SIC codes, Huson and Nanda (1995) verified that adoption of JIT has significant impact on firm inventory turnover.

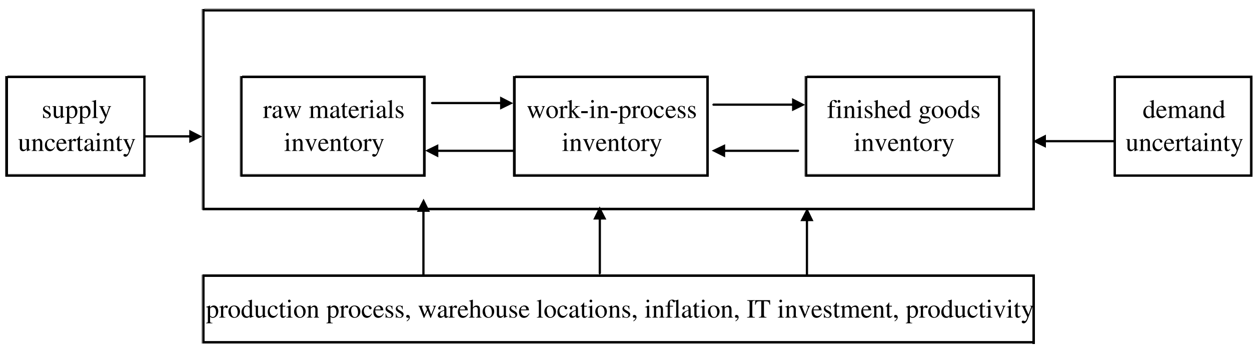
Industry approach

There has been a micro-macro paradox for inventory behavior in that inventory, supposed to be a stabilizing factor at firm level, becomes a destabilizing factor at the macroeconomic level. A middle ground approach is needed to bridge this gap and establish a dialogue between macroeconomic view and firm specific perspective. Industry level analysis may be considered such an effort.

Rajagopalan and Malhotra (2001) were among the first researchers to comprehensively examine inventory trends for a three-decade period for the whole manufacturing sector and at all three stages of inventories. The unit of analysis was the two-digit SIC manufacturing industry sectors. The actual time horizon for the dataset spanned from 1961 to 1994. Their research provided a full picture of inventory trends in each of the 20 industry sectors and an overall trend for all sectors combined. They observed a significant decreasing trend for total U.S. manufacturing inventory ratios (e.g., actual inventory levels normalized by cost of raw materials and value added) at all three stages during 1961-1994, but a mixed picture for inventory breakdowns or for particular industry sectors. While raw materials and work-in-process inventory ratios showed a decreasing trend in a majority of sectors, finished goods inventory ratio did not show a decreasing trend for most of the sectors. Another interest finding was that work-in-process inventory ratios showed a greater rate of improvement than raw materials and finished goods inventory ratios. Meanwhile, their research tests the anecdotal evidence that inventory ratios in the post-JIT-adoption era have been improved compared to the pre-JIT adoption era using 1980 as the cut off year but does not find strong support. This industry approach was adopted to examine the evolution of inventory performance of the Belgian manufacturing sector for the period 1979-2000 (Boute et al. 2004).

Research Framework

Figure 1 Manufacturing Inventory Factors



According to the literature, inventory is used as cushion against uncertainty from supply and demand and as a decoupling mechanism to smooth production. Demand uncertainty and supply uncertainty are reflected in traditional inventory models through variability of demand and supply lead time. In this current research, we capture the impact of global supply chains. We believe that the intensity of global involvement has a big impact on firm's raw materials or finished goods inventory positions. Meanwhile, firm internal factors such as production process, warehouse locations, IT investments, and worker productivity affect a firm's inventory decision. Inventories at three stages may constrain each other. Of course, some other unobserved factors will have an impact as well, such as cost of capital, product variety. In this current research, data of cost of capital and product variety for the five-digit industry is not available.

Hypotheses Development

Inflation rate

High inflation means that prices will appreciate at a fast face for goods and services of the same quantity and quality. Inflation may be caused by too much money and demand chasing a limited supply. Therefore, to manufacturing firms, high inflation makes it desirable to buy raw materials earlier and hold them for later use because the price will go up soon. Producer price index (PPI) measures the price received by a producer, which includes subsidization, profits, and taxes and may cause the amount received by the producer to differ from what the consumer paid. Producer price inflation reflects the pressure being put on producers by the costs of raw materials. This could be "passed on" as consumer inflation, or it could be absorbed by profits, or offset by increasing productivity. Chen et al. (2005) applied producer price index (PPI) as inflation rates and finds that inflation is associated with an increase in the holdings of raw materials. Our second hypothesis is:

H1: inventory levels at all three stages are positively associated with inflation rates.

IT investment

IT investment includes investment in IT infrastructure, e.g., PC, LAN, Internet, and related personnel training. With more complex supply chain management systems in place, firms also make large investments in IT-enabled practices such as JIT, VMI, TQM, Lean Manufacturing, etc. Investments in information technologies have helped firms to cut back on the volume of inventories that they hold as a precaution against glitches in their supply chain or as a hedge against unexpected increases in aggregate demand (Ferguson 2001).

Buffer inventory seems to be an unavoidable price to prevent stockout for extended supply chains and in fact it amplifies up the stages of the supply chain. This phenomenon, so called "bullwhip effect," may be caused by poor quality of information exchange between pairs of suppliers and manufacturers. Milgrom and Roberts (1988) suggested information may be a substitute for inventory. Zhu and Kramer (2002) argued that by establishing electronic information linkages, the average inventory turnover rate should increase and the inventory stock decreases along the supply chain. Based on a sample of 98 manufacturing and retailing firms, they Zhu and Kramer found that the interaction between ecommerce capability and IT intensity has a positive impact on firm inventory turnovers, even though IT intensity alone does not have an expected positive effect. Huson and Nanda (1995) reported that adoption of JIT is positively associated with inventory turnover.

A sample of prominent research claiming that IT has positive impact includes Brynjolfsson and Hitt (1996), Mukhopadhyay et al. (1997), Bharawaj(2002) and Santhanam and Hartono (2003). However, there is also ample empirical literature arguing that IT has no impact on firm efficiency and market performance, as shown by the IT productivity paradox. Power (1998) investigated technology investment activities of a large number of firms based on Longitudinal Research Database but does not find the sensible link between IT investment and productivity. Martinsons and Martinsons (2002) claimed that IT investments have no benign effect on economic productivity. Pinsonneault and Rivard (1998) once offered explanations why empirical research has failed to provide support of IT impact: mismeasurement of IT as input or productivity as an output and organizational context is ignored.

Since anecdotal evidence suggests that IT investment should improve inventory performance, we hypothesize:

H2: Inventory levels at all three stages are negatively associated with IT investment.

Imports

As known, safety stock is a linear function of predetermined customer service level and standard deviation of demand during lead time (safety stock $= k\sigma$, where k = desired customer service level and σ =standard deviation of demand during lead time). One popular empirical formula is $\sigma = \sqrt{\overline{L}\sigma_D{}^2 + \sigma_L{}^2 D^2}$, where $\overline{L}$ = average lead time, σ_L = standard deviation of lead time, D=average demand, σ_D = standard deviation of demand, and assuming the demand and lead time distribution are independent (Tersine 1994). For firms with higher levels of imports, we expect their σ is higher because these firms are facing longer lead time and higher standard deviation of lead time due to many uncontrollable factors across borders. Meanwhile, when average lead time becomes longer, the demand during lead time may become more volatile, contributing to a higher σ for preparing safety stocks. Since data on lead time and demand during lead time are not directly available, the level of imports of raw materials is used as a proxy. Here we assume that the more imports a firm has, the more volatile the lead time will become. Anecdotal evidence shows that firms tend to hold excessive raw materials inventory as safety stock if they rely on international suppliers for certain components and raw materials. Rajagopalan and Malhotra (2001) suggested that increasing imports might have positive impact on raw materials inventory. Here we hypothesize that:

H3: the level of raw materials inventory is positively associated with the level of imports.

Exports

Due to high international transportation and shipping/processing costs, industries with active exporting activities tend to hold higher finished goods inventories to facilitate ocean transportation through containers in batches. To explain increasing trend of inventory in certain sectors in the Belgian manufacturing industry, Bonte et al. (2004) suggested that export orientation leads to less frequent deliveries and higher finished goods inventories. Using firm level data, Bonte et al. (2006) further reported that high finished goods inventory is generally associated with high export ratios (defined as percentage of orders destined for export). So we hypothesize that

H4: the level of finished goods inventory is positively associated with the level of exports.

Control variables

Number of plants

Larger industries may have more manufacturing plants and more warehouse locations. In this current research, we control industry size by including in the regression model the number of plants each industry has. Inventory modeling on centralization suggests that if there are n warehouses/plants in a decentralized system, the system inventory will be $\sqrt{n}$ multiple of inventory required in the case of a centralized system. Therefore, it is reasonable to predict that the more plants an industry has, the more system inventory this industry has.

Sector real growth

It is likely that the changes of inventory levels may be associated with sector growth. As argued by Rajagopalan and Malhotra (2001), inventories at all stages move faster and deplete more quickly when sector output grows fast. However, they did not find a consistent impact of sector growth on inventories, so our current research will use it as a control variable without a priori prediction.

Durable-goods sector

Inventory behaviors vary maybe due to the different natures of products produced or different production processes. As shown in Table 1, there are ten durable goods sectors, including metal, machinery, computer and electronics, electrical equipment, transportation equipment, furniture, minerals, wood product, and others. Also, eleven non-durable goods sectors include food, beverage, textile, apparel, leather, paper, printing, petroleum, and plastics. Overall, durable goods industries tend to hold more finished goods inventory than non-durable goods industries. For example, the transportation equipment sector (e.g., aerospace) has extremely large work-in-process inventory. However, one exception is that the apparel manufacturing sector has a large position of finished goods inventory relative to its total product shipments because of long production cycle, short sales season and large varieties.

Table 2 Durable and Non-Durable Goods Manufacturing

NAICS Code	Meaning of 2003 NAICS code	Durable or Non-Durable Goods
311	Food mfg	Non-Durable Goods
312	Beverage & tobacco product mfg	Non-Durable Goods
313	Textile mills	Non-Durable Goods
314	Textile product mills	Non-Durable Goods
315	Apparel mfg	Non-Durable Goods
316	Leather & allied product mfg	Non-Durable Goods
321	Wood product mfg	Durable Goods
322	Paper mfg	Non-Durable Goods
323	Printing & related support activities	Non-Durable Goods
324	Petroleum & coal products mfg	Non-Durable Goods
325	Chemical mfg	Non-Durable Goods
326	Plastics & rubber products mfg	Non-Durable Goods
327	Nonmetallic mineral product mfg	Durable Goods
331	Primary metal mfg	Durable Goods
332	Fabricated metal product mfg	Durable Goods
333	Machinery mfg	Durable Goods
334	Computer & electronic product mfg	Durable Goods
335	Electrical equipment, appliance, & component mfg	Durable Goods
336	Transportation equipment mfg	Durable Goods
337	Furniture & related product mfg	Durable Goods
339	Miscellaneous mfg	Durable Goods

Methodology

Data Collection

Basic data are collected from the 2002 Economic Census and Annual Survey of Manufacturers (ASM), a yearly economic survey conducted by the U.S. Census Bureau. The unit of analysis in this research is the five-digit NAICS industry, a level comparable among US, Canada and Mexico. The NAICS codes are classified primarily based on technology and process used in manufacturing. Even though industry could further be broken down to a six-digit level in the United States, due to the U.S. census reporting rule of protecting company confidential information, some information may be not available at very detailed levels and only available at higher aggregate levels. Balancing detail with availability of information, the 5-digit level industry is preferred over the 6-digit level industry. The ASM data are complemented by export and import data from US international trade statistics, and Producer Price Index (PPI) from Department of Labor.

Current research draws upon a panel of 184 industries spanning a three-year period from 2002 to 2004, the most recent years with available comparable data. This period is chosen due to two major considerations: (1) 2002 was an economic census year. For manufacturing, the 2002 economic census added quite a few new dimensions of our research interest compared to the 1997 economic census. Also, the 2003-2004 ASM data followed the 2002 census format and contained comparable columns. (2) Prior research has investigated aggregate industry inventory behavior using time-series data up to the year of 2000 (e.g., Rajagopalan 2001).

Seemingly unrelated regression (SUR) model

Since inventories at all three stages may be related, we simultaneously estimate those three inventory equations, using an ordinary least square (OLS) estimation for each equation.

$$Y_{it} = \beta_o + \sum_{i=1}^{K} X_{itk} \cdot \beta_k + \varepsilon_{it}, \;\; where\ i = 1, ..., N(number\ of\ industries);$$

$$t = number\ of\ time\ periods;\;\; k = number\ of\ regressors;$$

$$\varepsilon_{it} = a\ classic\ error\ term\ with\ zero\ mean\ and\ a\ homoscedastic\ covariance.$$

Specifically, we measure the following three equations simultaneously:

$$Log(RAW) = \beta_{10} + \beta_{11} Log(Imports) + \beta_{12} Log(IT) + \beta_{13} Inflation + \beta_{14} SectorGrowth + \beta_{15} Log(Plants) + \beta_{16} DurableDummy + \varepsilon_1$$

$$Log(WIP) = \beta_{10} + \beta_{21} Productivity + \beta_{22} Log(IT) + \beta_{23} Inflation + \beta_{24} SectorGrowth + \beta_{25} Log(Plants) + \beta_{26} DurableDummy + \varepsilon_2$$

$$Log(FG) = \beta_{30} + \beta_{31} Log(Exports) + \beta_{32} Log(IT) + \beta_{34} Inflation + \beta_{35} Log(Plants) + \beta_{36} DurableDummy + e_3$$

Fixed effects model

Unobserved industry specific characteristics, including observable but not captured characteristics due to lack of relevant data and many other unobservable heterogeneous characteristics, may account for a big portion of the inventory variation. Make-to-order industries tend to hold less raw materials inventory and finished goods inventory due to the use of JIT, e.g., Dell Computers, while make-to-stock industries tend to hold more inventories. Product varieties and the number of firms in each industry also affect inventory levels. Besides internal operations efficiency, external relationships with upstream suppliers and downstream customers may have a big impact on firm inventory levels. Depending on where they are located in a particular supply chain, some industries may have to hold more of a particular type of inventory. Considering the nature of our dataset being cross-sectional and time series, we propose to consider industry fixed effects in our estimation model to capture many unobserved industry specifics which usually are a source of the heterogeneity problem. Below is general model:

$y_{it} = x_{it}'\beta + \alpha_i + \gamma_t + \varepsilon_{it}$, where i = number of groups, t = number of periods,

x_{it} = a set of independent variables, β = a set of coefficients,

a_i =industry fixed effects, γ_t= time fixed effects,

ε_{it} = standard error term with zero mean and normal distribution.

Three equations are estimated separately as specified below:

Raw materials inventory:

$$Log(RAW) = \beta_{10} + \beta_{11}Log(Imports) + \beta_{12}Log(IT) + \beta_{13}Inflation + \beta_{14}SectorGrowth + \beta_{15}Log(Plants)$$

$$+\sum Industry\ Fixed\ Effects + \sum Time\ Fixed\ Effects + \varepsilon_1 \qquad (1)$$

Work-in-process inventory:

$$Log(WIP) = \beta_{21}Productivity + \beta_{22}Log(IT) + \beta_{23}Inflation + \beta_{24}SectorGrowth + \beta_{25}Log(Plants)$$

$$+\sum Industry\ Fixed\ Effects + \sum Time\ Fixed\ Effects + \varepsilon_2 \qquad (2)$$

Finished goods inventory:

$$Log(FG) = \beta_{31}Log(Exports) + \beta_{32}Log(IT) + \beta_{33}Inflation + \beta_{34}SectorGrowth + \beta_{35}Log(Plants)$$

$$+\sum Industry\ Fixed\ Effects + \sum Time\ Fixed\ Effects + \varepsilon_3 \qquad (3)$$

Operationalizations of Variables

The dependent variables in the current model are raw materials, work-in-process and finished goods inventory levels. Average annual inventories are calculated as the arithmetic means of the beginning-of-year and the end-of-year levels, adjusted to 2002 constant dollars. The values of the dependent variables are estimated as the natural logarithms of their respective inventory levels. IT investments, imports of raw materials, and exports of finished goods are all taken from the Census of Manufacturers and are adjusted to 2002 constant dollars. Sector inflation levels are calculated based on the annualized producer price index for each sector over the period 2001-2004. Sector growth rates are formulated in real terms, calculated from annual total product shipments for each sector over the period 2001-2004. Productivity is measured by the ratio of value added over production worker wages. The number of plants in each industry is collected from County Business Pattern 2002-2004. If the industry is classified as a durable goods industry, coded as 1.

Summary Statistics

Table 3 Variable Means and Standard Deviations

		2002		2003		2004		all years	
variables	**unit**	**mean**	**std**	**mean**	**std**	**mean**	**std**	**mean**	**std**
raw inventory	000' $	788,280	976,222	752,594	911,361	733,180	884,562	758,018	923,452
wip inventory	000' $	631,987	2,112,315	611,670	2,044,401	578,598	1,869,342	607,418	2,007,760
fg inventory	000' $	834,938	967,780	802,795	953,846	777,925	982,936	805,219	966,783
exports	000' $	3,382,127	7,479,511	3,428,441	7,485,607	3,713,783	7,879,514	3,508,117	7,604,757
imports	000' $	5,347,991	11,843,093	5,557,459	11,906,368	6,194,320	12,774,651	5,699,923	12,165,325
IT	000' $	42,704	70,632	41,952	82,725	33,093	62,687	39,250	72,485
product shipment	000' $	21,275,129	29,916,355	21,286,844	31,541,656	21,765,539	33,136,781	21,442,504	31,502,498
sector growth	%	-6.50%	17.82%	-1.12%	18.60%	-2.95%	6.84%	-3.52%	15.52%
inflation	%	1.03%	3.27%	2.27%	4.01%	3.95%	6.57%	2.42%	4.97%
plant	count	1,871	3,498	1,858	3,425	1,843	3,388	1,857	3,431
employees	count	78,226	94,220	76,804	92,184	75,119	90,712	76,716	92,224
productivity	index	117	133	120	132	137	168	125	145

Table 3 shows that average inventories at three stages decreased annually from 2002 to 2004 while average product shipments were stable over this period. Average exports and imports increased slightly from 2002 to 2004. Notably, IT investments actually decreased by 23% from 2002 to 2004. One possible explanation is that computers of the same functionalities are getting cheaper. Even though the average number of plants was stable over this period, the average employment decreased annually maybe due to a nationwide economic recession following the terrorist attack in 2001. With decreasing employment, it is no surprise that productivity index measured by value added over production wages were increasing during the same period. Also, note that the average sector growth was negative, which is consistent with the national economic trend of recession during this period. The average inflation rate increased significantly from 2002 to 2003 due to a very low level (1.03%) in 2002 and stabilized over 2004.

Table 4 Correlation Table

		1	2	3	4	5	6	7	8	9	10
1	sectorgrowth	1.00									
2	inflation	0.07	1.00								
3	productivity	0.06	0.12	1.00							
4	log(plants)	0.06	-0.11	-0.29	1.00						
5	log(IT)	0.02	-0.06	0.04	0.56	1.00					
6	log(imports)	0.03	-0.02	0.09	0.07	0.21	1.00				
7	log(exports)	0.04	-0.01	0.13	0.06	0.23	0.99	1.00			
8	log(raw inventory)	0.06	0.04	0.17	0.51	0.62	0.37	0.39	1.00		
9	log(wip inventory)	-0.02	0.03	0.04	0.46	0.54	0.36	0.37	0.77	1.00	
10	log(fg inventory)	0.06	0.04	0.13	0.45	0.58	0.34	0.36	0.83	0.73	1.00

Overall, independent variables show very low correlations with two exceptions. Log (IT) and log(plants) is correlated at .56. log(imports) and log(exports) are correlated at .99. This result is not surprising because average imports and exports move in the same direction. However, this high correlation does not cause a problem for current research because they do not appear in the same model. Log(imports) is a factor for raw materials inventory while log(exports) only appears in the finished goods inventory equation as hypothesized.

Regression Results

Table 5 Results of SUR Model

	Equation 1		**Equation 2**		**Equation 3**	
Dependent Variable	Log(RAW Inventory)		Log (WIP Inventory)		Log (FG Inventory)	
Independent Variables	coefficient	t-value	coefficient	t-value	coefficient	t-value
log(plant)	0.2011	6.36***	0.3232	6.23***	0.2149	6.20***
log(IT)	0.2792	11.68***	0.3054	8.13***	0.2608	9.89***
DurableGoods	0.1919	2.90****	0.8205	7.79***	-0.1985	-2.74***
inflation	2.0918	3.26***	1.8397	1.98*	2.0284	2.89**
SectorGrowth	0.1737	0.85	-0.3853	-1.21	0.0875	0.39
log(imports)	0.0470	8.32***				
productivity			0.0018	4.82***		
log(exports)					0.0507	7.97***
R-square	0.5128		0.4103		0.4362	
adjusted R-square	0.5074		0.4038		0.4300	
number of observations	552		552		552	

two-sided tests, *** significant at 0.1%, ** significant at 1%, * significant at 5%

The SUR model imposes correlation among the error terms of the three equations. All three years of observation are pooled together. For each equation, an OLS regression imposes a common intercept for each industry sector. For equation 1, results show that raw materials inventory level is: positively associated with inflation (β=2.0918, t=3.26), supporting H1; positively associated with imports(β=0.0470, t=8.32), supporting H3. The signs for plant and durable goods are positive and significant, as expected. For equation 2, results show that raw materials inventory level is: positively associated with inflation (β =2.0918, t=3.26), supporting H1. Durable good dummy is positive and significant, as expected. For equation 3, results show that finished goods inventory is: positively associated with inflation (β =2.0284, t=2.89), supporting H1; positively associated with exports (β =0.0507, t=7.97), supporting H4. However, the sign for IT is positive across all three equations, indicating H2 is not supported. Sector growth is shown to be not significant across all three equations.

Table 6 Results of Two-way Fixed Effects Model

Dependent Variable	**Equation 1** Log(RAW Inventory)		**Equation 2** Log (WIP Inventory)		**Equation 3** Log (FG Inventory)	
Independent Variables	coefficient	t-value	coefficient	t-value	coefficient	t-value
log(plant)	0.2856	12.77***	0.2102	1.87	0.2037	2.04*
log(IT)	-0.0032	-0.77	-0.0072	-1.25	-0.0133	-2.61**
inflation	0.6565	5.39***	0.0206	0.12	0.5819	3.86***
SectorGrowth	0.0165	0.60	0.0619	1.59	0.0447	1.30
log(imports)	-0.0022	-0.05				
productivity			0.0006	3.86***		
log(exports)					0.1686	2.55**
R-square	0.9956		0.9956		0.9933	
F	215		287		165	
number of observations	552		552		552	

two-sided tests, *** significant at 0.1%, ** significant at 1%, * significant at 5%;
industry and time fixed effects are not reported here.

The two-way fixed effects model assumes that unobserved industry fixed effects and time effects may affect inventory levels. The results show that raw materials inventory (equation 1) is positively associated with inflation (β =0.6565, t=5.39), supporting H1. Meanwhile, the number of plants (β =0.2856, t=12.77) has an expected, positive sign. For work-in-process inventory (equation 2), the productivity index has a positive and significant sign, but not expected. For equation 3, finished goods inventory is positively associated with inflation (β=0.5819, t=3.86), supporting H1; positively associated with exports (β=0.1686, t=2.55), supporting H4; negatively associated with IT investments (β=-0.0133, t=-2.61), supporting H2. As a control variable, sector growth is not found to be significant across all the three equations. Note that, durable goods dummy is not included in the model since this dummy variable does not vary over time, infeasible to estimate a two-way fixed-effects model.

Conclusion

In conclusion, H1 is supported by five out of six equations through different model specifications, suggesting inflation has a strong positive impact on inventory levels. H2 is partially supported based on the fixed effects model results, suggesting that IT investments may not have a direct impact on inventory levels. H3 is partially supported by the SUR model, suggesting the relationship between average imports and average raw materials inventory may be plausible. H4 is strongly supported by both SUR and fixed effects models, indicating that the level of exports has a strong positive impact on the level of finished goods inventory. The significance levels of control variables confirm that inventory levels are positively impacted by the number of plants and on average durable goods industries have higher inventories than non-durable goods industries.

Discussion of Results

A few noises in the regression results need discussion and further investigation. The significant, positive signs of IT investments across all three equations in the SUR model are surprising. After checking the correlation table, we exclude multicollinearity as a cause. Also, the fixed effects model only partially finds a positive, negative sign for the finished goods inventory, even though negative signs are discovered for the raw materials and work-in-process inventories as well. This may be due to the lagged effect of IT investment or imprecise measurement of IT. In the census data, IT is expressed in monetary terms, other aspects of infrastructure such as number of IT staff, LAN, networks, etc. are not captured. Even though, the sign is consistently positive, the magnitude of the coefficients of inflation varies dramatically across two different model specifications. The sign for imports in the raw materials inventory equation for the fixed effects model is close to zero without any significance. This suggests that after controlling for industry fixed effects, the level of imports has no impact on the level of raw materials inventory. We expect that sector growth, which reflects the growth of demand, has a negative impact on the inventory levels, but equations across both model specifications do not show the expected effect.

Contributions, Limitations and Further Research

Even though there is rich literature on inventory models in general and on the status of U.S. manufacturing inventory in particular, there is little empirical research on the factors which may have impacts on inventory levels all different stages. Manufacturing remains the source of technology innovation and a very important employer in certain geographic areas. Due to high costs of inventories, manufacturing has been devoted to improving operational efficiency through lean production and JIT procurement and fulfillment. However, manufacturing effort to cut inventories may be constrained by internal operations as well as global supply and demand uncertainties. This paper is believed to be among the first papers to systematically examine the antecedents of the manufacturing inventories at all three stages, using secondary data collected from the U.S. census. Results from this research should enable management to make better inventory investment decisions by considering a full set of factors, such as inflation and global operations.

Of course, there are limitations to our study. According to our proposed framework, manufacturing inventory decision making is constrained by supply uncertainty, demand variation and internal operational characteristics. Obviously, this paper has not considered some of those important factors, such as cost of capital and product variety due to unavailability of information about such variables. Another limitation is that some of the results reported here are sensitive to model specifications. It should be noted that the magnitude of the coefficients of independent variables may be only applicable to the manufacturing inventory for the period under study. Future research should collect measures of capital costs and product variety across industries and further test the robustness of results from different model specifications.

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