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정보기술, 기업 및 산업특성, 재고회전율 간의 관계에 대한 실증분석

(Investigating the Relationships Among Inventory Turnover Performance, IT, and Firm and Industry Characteristics)

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요 약 본 연구는 다음의 세 가지 목적을 갖는다. 첫째, 98개 미국기업의 11년(1999년에서 2009년)치 자료를 통하여 정보기술(IT) 관련 투자가 기업의 재고회전율에 미치는 영향을 분석한다. 둘째, 기업 및 산업의 특성이 재고회전율에 미치는 영향을 살펴본다. 구체적으로, 기업의 특성을 반영하기 위하여 수직결합도(vertical integration)와 성장옵션(growth option)을 고려하였고 기업이 속한 산업의 특성을 반영하기 위해 산업역동성(industry dynamism)과 산업집중도(industry concentration)를 선택하였다. 셋째, 분석 대상기업의 재고회전율에 대한 시계열적 추세를 검토한다. 본 연구의 주요 결과는 다음과 같다. 첫째, 정보기술 투자와 성장옵션은 재고회전율에 양의 영향을 주었다. 둘째, 수직결합도와 산업집중도는 재고회전율은 음의 영향을 주었다. 셋째, 재고회전율에 대한 산업역동성의 효과는 양의 값을 보였다. 마지막으로 분석기간 동안 재고회전율과 '조정된 재고회전율'로 표현된 재고생산성(inventory productivity)의 상승추세를 확인하였다.

핵심주제어 : 정보기술, 재고회전율, 수직결합도, 성장옵션, 산업역동성, 산업집중도

Abstract The objective of this study is three-fold: to investigate the relationship between information technology (IT) investment and inventory turnover, using 98 U.S. firms spanning eleven years (from 1999 to 2009); to analyze the correlation of inventory turnover with firm and industry characteristics, where vertical integration and growth options are chosen to reflect the features of the firm's internal characteristics, and industry dynamism and industry concentration are selected to represent the industry's competitive environment; and to examine time trends in inventory turnover. The significant findings include the following: (i) both IT investment and growth options have a positive impact on inventory turnover; (ii), but vertical integration and industry concentration have a negative impact on inventory turnover; (iii) the impact of industry dynamism on inventory turnover positive; and (iv) the time trends in inventory turnover and 'adjusted inventory turnover' have been increased during the sample period from 1999 to 2009.

Key Words : Information technology, Inventory turnover, Vertical integration, Growth options, Industry dynamism; Industry concentration

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1. Introduction

Recently, firms are paying close attention to inventory management in their operations processes since they have to satisfy customer demand, which has become increasingly complicated and diversified. Therefore, firms have been raising their inventory levels to improve the fill rate of customer demand. For example, as depicted in Fig. 1, the total business inventories show an increasing pattern over time (source: U.S. Department of Commerce: Census Bureau). Moreover, using the inventory data adopted in this paper, we also can observe the increasing trend of inventory over the period from 1999 to 2009 (Fig. 2). However, the increase of inventory is not only an opportunity but also a challenge for the firm because, although the inventory results in a high product availability to meet the customer demand, the cost related to it also increases accordingly. Thus, managing inventory is a very crucial aspect of operations management; and research on inventory management has been of importance to investigate the operational competence of the firm.

Inventory turnover, the ratio of the firm's cost of goods sold to its average inventory level, is designed to objectively evaluate the extent to which the firm effectively manages inventory and is commonly accepted to compare inventory management across firms. Some previous studies used inventory turnover as the metric for inventory performance. For instance, Kim et al. [37] considered an inventory turnover as the factor that may affect the post-M&A performance of the buyer, Hancerliogullari et al. [28] analyzed the impact of demand uncertainty on inventory turnover performance, and Lee et al. [42]

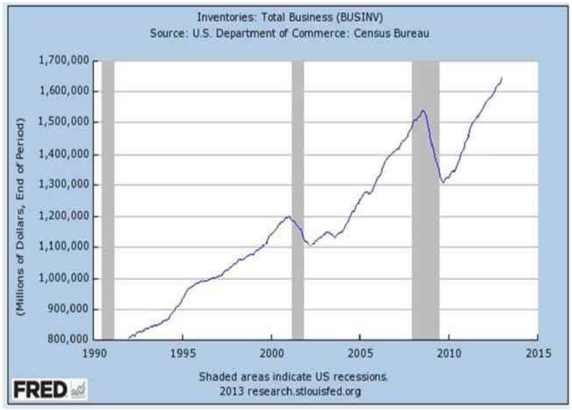

Fig. 1 Total U.S. business inventory over time

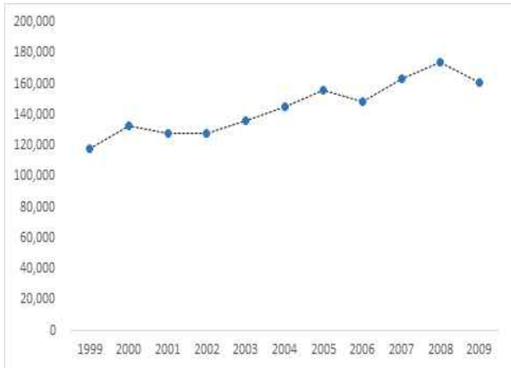

Fig. 2 Total inventories over time: from a data set used in this research

found that the firms in a more innovative industry are likely to improve their inventory turnover effectively. Moreover, Gaur et al. [23] compared the inventory turnover across U.S. retail companies; subsequently, Gaur and Kesavan [24] extended Gaur et al. [23] by analyzing the effects of firm size and sales growth rates on inventory turnover. This study extends Gaur et al. [23] and Gaur and Kesavan [24] by considering IT investment, firm characteristics, and industry characteristics as the driving forces that affect the firm's inventory turnover. Specifically, this study uses the IT investment data collected and published by InformationWeek 500, regards the vertical integration and growth options as the proxy for the firm characteristics, and

Table 1 The variables considered in Gaur et al. [23], Gaur and Kesavan [24], and the present study

key variables	Gaur et. al.[23]	Gaur and Kesavan[24]	The present study
Inventory turnover	○	○	○
Gross Margin	○	○	○
Capital intensity	○	○	○
Sale Suprise	○	×	○
Sale Growth Rate	×	○	○
IT investment	×	×	○
Vertical integration	×	×	○
Growth options	×	×	○
Industry dynamism	×	×	○
Industry concentration	×	×	○

Note) ○: considered, ×: not considered

considers the industry dynamism and industry concentration as the variables reflecting industry characteristics. Considering the variables that have not bee considered in previous research, this study attempts to analyze the impacts of IT investment, firm characteristics, industry characteristics on inventory turnover and provide the implications for inventory management(See Table 1 for easy comparison between the variables considered in the previous two studies and the present paper).

One crucial issue to be addressed in this paper is the impact of IT upon inventory turnover. In general, there is a consensus that IT is a primary factor, playing a critical role in business success in a keenly competitive market.

Regarding the importance of IT, Jorgenson [34] stated that IT had produced a fundamental change in the U.S. economy, leading to a permanent improvement in growth prospects. Many managers have considered IT as a useful tool to augment outputs, do efficient organization-management, improve supply chain agility, reduce cycle times, achieve higher efficiency, and deliver products to customers promptly. Accordingly, much money has been invested in IT. For instance, Lin and Shao [43] have pointed out that the IT investments in 2001 for the United States and Japan were respectively $546,681 and $188,012 in millions of U.S. dollars (source: Digital Planet 2002: The Global Information Economy, published by the World Information Technology and Services Alliance [61]; and IT investment is expected to continue to increase through time. Similarly, the amount of IT investment in our data set also shows an increasing pattern (see Figure 2).

As mentioned above, both inventory and IT are accepted as highly influential factors in affecting the operational process of the firm. There exists substantial research examining the relationship between these two issues. Notably, most previous studies analyzed the influence of IT on inventory [2,22,49,56,59]. In contrast, the primary objective of this paper is to examine the direct relationship between IT investment and inventory turnover

Another research issue that concerns us in this paper is the relationship between firm characteristics and inventory turnover. In some previous studies, based on the resource-based view (RBV), firm characteristics (the firm's internal environments) have been considered the factors affecting the firm's performance [30]. However, the role of firm characteristics on the determination of inventory turnover has been unaddressed in the literature. Thus, we need to bridge the gap by analyzing how firm characteristics affect inventory turnover because the firm's internal factors may explain the inventory turnover across firms. As far as the firm characteristics are concerned, vertical integration (VI) and growth options (GO) are chosen to reflect the heterogeneity of firms in this paper.

Interestingly enough, VI and GO have been mainly examined in strategic management and finance, respectively. In the production and operations management field, however, these two characteristics have not been treated as critical variables, especially in the research related to inventory performance. To our best knowledge, this study is the first to analyze the relationship between firm characteristics and inventory turnover in the presence of IT.

A third research issue that interests us in this paper is the degree to which industry characteristics affect the firm's inventory turnover. There is a theoretical foundation known as industry organization (IO) on which the analysis of the effect of industry characteristics is based. The central assertion of IO is that the structural characteristics of industries primarily determine the firm's performance [30]. Specifically, the theory of IO scrutinizes the interaction among firm behavior, market structure, and economic performance [47]. The main theoretical framework is primarily based on the structure-conduct-performance (SCP) paradigm that industrial structure is assumed to shape the conduct of constituents which, in turn, affects the performance of firms and industries [55]. In other words, the structural feature of the industry inevitably restricts the behavior (i.e., the conduct or strategies) of the firms within the industry which, in turn, makes the firm and industry performance different [46]. Unfortunately, in production and operations management (POM) research, there is relatively little attention that has been paid to the impacts of the structural (or industry) characteristics upon inventory management, except for Olivares and Cachon [50] and Cachon and Olivares [6]. These two papers considered the U.S. automobile industry and analyzed how competition influences the inventory holding of dealers. Here, to bridge the gap, we consider industry concentration (IC) to reflect the competitive environment that the firm faces and industry dynamism (ID) to reflect the market uncertainty with which the firm is confronted. Using these two industry characteristics to measure the heterogeneity of industries, we analyze their effects on the firm's inventory turnover.

Finally, this paper retests the hypotheses suggested by Gaur and Kesavan [24] and computes time trends in inventory turnover suggested by Gaur et al. [23], based on a different set of data.

This paper is organized as follows. Section 2 provides a brief review of the relevant literature. Section 3 defines the variables needed in this study. We establish statistical hypotheses in Section 4, specify the research models in Section 5, and describe the data used in Section 6. Then, we present and discuss the empirical results in Section 7. Finally, we conclude with some managerial implications and extensions.

2. Literature Review

Inventory management has been considered a signaling role in evaluating the firm's operational competence [40]. Therefore, investigating the firm's inventory turnover performance has been a critical part of POM research. In particular, Gaur et al. [23] conducted an econometric analysis of the inventory turnover as a metric of inventory productivity in the U.S. retail sector. They developed an empirical model (i.e., a log-linear model) and found that inventory turnover has a high correlation with gross margin, capital intensity, and sales surprise. More precisely, they found that inventory turnover is negatively related to gross margin but positively related to capital intensity and sales surprise.

Extending the work by Gaur et al. [23], Gaur and Kesavan [24] introduced firm size and sales growth rate as additional factors influencing inventory turnover and found that it increases with sales growth rate, but its rate of increase depends on firm size, and it responds differently to the sales contraction (or expansion) regions and is positively associated with firm size.

Using inventory holding periods, inventory-to-sales ratio, and inventory-to-assets ratio instead of using inventory turnover ratio, Chen et al. [11] examined the inventories of publicly traded American manufacturing companies between 1981 and 2000. They found that the average inventory reduction is about 2% per year, and firms with abnormally high inventories have abnormally poor long-term stock returns. Chen et al. [12], an extension to Chen et al. [11], investigated the U.S. retail and wholesale inventory performance from 1981 to 2004. During this period, the inventories of wholesalers decreased, while those of retailers started to decrease in the latter part of the 1990s. Whereas the study examined the inventory trend over a long period and connected inventory to financial performance, it did not consider the factors that may affect the inventory, which becomes an important issue to be pursued in this paper.

Eroglu and Hofer [19] introduced the Empirical Leanness Indicator (ELI) to evaluate the firm's inventory leanness relative to firms of comparable size. They revealed that the significance and shape of the inventory-performance relationship vary substantially across industries. Meanwhile, to assess inventory performance, Cannon [7] considered the percentage increase (or decrease) in inventory turnover from the previous year and concluded that while the improvement in inventory performance was associated with improvement in overall performance for some firms, it was associated with a reduction in overall performance for many other firms. However, Capkun et al. [9] found a significant positive correlation between inventory performance (the total and the discrete components of inventory) and financial performance (at both the gross and operating levels) for firms in manufacturing industries.

Nevertheless, the studies reviewed above ignored entirely the role played by IT in the high-tech era. In contrast, Shah and Shin [56] examined the direct impact of IT investment on inventory performance (as measured by the inventory-to-sales ratio), the relationship between IT investment and financial performance, and whether it is mediated by inventory performance. In their work, it was found that the direct effect of IT investment on financial performance is insignificant and inventory performance plays a significant mediating role in the manufacturing and retail sectors. However, they considered IT as the only variable affecting inventory performance. Instead, in this research, we consider not only IT but also firm and industry characteristics.

For the firm characteristics, we use GO and VI, as suggested by Dewan et al. [17] and Lin and Chiang [44]. The reason why these two variables are significant and chosen is that they reflect the boundaries of the firm (that is, the scale and scope of the firm). Regarding VI, Dewan et al. [17] argued that VI describes the extent to which successive activities in a value chain are conducted within the firm. More specifically, when a firm operates in a highly vertically integrated value chain, it takes advantage of the reduction in market transaction cost due to the hierarchy but undergoes two counteracting forces: increased internal coordination costs and operations costs [27]. For GO, Dewan et al. [17] pointed out that GO represents the future potential of the firm to grow in scale or scope. The activities such as new product introductions, capacity expansion, acquisitions of other firms, investments in the brand name, and basic research can be considered as examples of GO [17, 44]

Concerning industry characteristics, we choose IC and ID as the proxies of industry heterogeneity that the firm faces since these two variables are essential features of the industry-wide competitive environment. First, IC measures the extent to which industry output (or sales) is produced (or sold) by a few firms and is commonly used as an inverse proxy for industry competitiveness, namely, the degree to which industry revenue is concentrated within a few large firms [47]. Second, ID refers to the change that is difficult to predict [16, 36]. In particular, ID can be regarded as the mirror of the uncertainty of consumer demand because ID is measured by using total industry sales. Specifically, in this paper, a four-firm concentration index is adopted for IC; and ID is measured as the deviation of industry sales from a trend line obtained from a simple regression.

3. Definitions of the Variable

Following Gaur et al. [23] and Gaur and Kesavan [24], we let S_{it} and CGS_{it} denote the sales and the cost of goods for firm i in year t, respectively. The firm i's fixed assets, which consist of plant, property, and equipment, are denoted by FA_{itq} at the end of quarter q in year t. Inv_{itq}denotes the inventory of firm i at the end of quarter q in year t. Then, we define the variables needed in this study as follows.

-Inventory turnover(I):

$$I_{it} = \frac{CGS_{it}}{\frac{1}{4}\sum_{q=1}^{4} Inv_{itq}}$$

-Gross margin(GM)

$$GM_{it} = \frac{S_{it} - CGS_{it}}{S_{it}}$$

-Capital intensity(CI)

$$CI_{it} = \frac{\sum_{q=1}^{4} FA_{itq}}{\sum_{q=1}^{4} Inv_{itq} + \sum_{q=1}^{4} FA_{itq}}$$

-Sale growth rate(SG)

$$SG_{it} = \frac{S_{it}}{S_{it-1}}$$

For the measurement of VI and GO, we follow Dewan et al. [17] and Cao et al. [8]. Let VAD_{it}, TA_{it}, and TCE_{it} denote the value added[2)], total assets, and total common equity of firm i in year t, respectively. Finally, let

2) To measure the value added for each firm, we follow Imrohoroglu and Tuzel [33]: the value added is computed as sales minus materials cost. Accurately, materials cost is measured as total expenses minus labor expense, where the total expense is calculated by subtracting operating income before depreciation and amortization (OIBDA) from sales and labor expense is computed by multiplying the number of employees by the average wage from the average wages data of the Social Security Administration.

CSO_{it} and ASP_{it} denote common share outstanding and annual average stock price, respectively. Using these notations, we define VI and GO of firm i in year t as follows.

-Vertical integration(VI)

$$VI_{it} = \frac{VAD_{it}}{S_{it}}$$

-Growth options(GO)

$$GO_{it} = \frac{TA_{it} - TCE_{it} + ASP_{it} + CSO_{it}}{TA_{it}}$$

Next, we move to the two industry characteristics variables, namely, IC and ID. Following previous studies, we compute these two variables for industry d to which firm i belongs as follows

-Industry dynamism (ID)

$$ID_{idt} = \frac{SD_{id}}{\frac{1}{m}\sum_{j=1}^{m} IS_{ijdt}}$$

where IS_{ijdt} is the sales of firm j in industry d to which firm i belongs in year t (m is the total number of firms in industry d to which firm i belongs in year t) and SD_{id} is the standard error of a simple regression over time. In other words, ID is measured by regressing total industry sales on time and dividing the resulting standard error of the regression by the average industry sales [16, 36, 47]

-Industry concentration(IC)

$$IC_{idt} = \sum_{j=1}^{4} s_{ijdt}$$

where s_{ijdt} is the market share of j^{th} firm in industry d to which firm i belongs in year t. The largest four firms are selected according to the amount of sales in each and every year. This variable is usually referred to as the four-firm concentration ratio, which measures the total market share of the four largest firms in an industry [5, 10, 47]

4. Hypotheses[3]

4.1 The effect of IT investment on inventory turnover

It has been argued that IT can enable firms to configure business processes and control resources more efficiently and effectively. For example, the IT device such as electronic data interchange (EDI) and point-of-sale (POS) can make the firm figure out the behavior of end-consumer promptly, thereby increasing the visibility of the relevant information [35, 41]. This advance usually results in the efficient allocation of the firm's internal resource [51, 54] and the effective coordination of the firm's external resource [9]. Also, Radio Frequency Identification (RFID) technology can improve product traceability and visibility across the supply chain[13, 39] and is widely known as a promising solution for inventory inaccuracies[20]. Therefore, the IT-driven capability to acquire information concerning the behavior of consumer and process the firm's resource can reduce inventory levels [48, 56].

Moreover, the Economic Report of the President [18] pointed out, "technologies that improve the dissemination of information enable companies to reach more promptly to market and to economize on inventories (by

3) When developing some hypotheses(H2a, H2b, H3a, H3b, H5a, H5b), we consider the positive and negative impacts of key variables on inventory turnover by referring to Gaur and Kesavanl [24] that suggested both directions on inventory turnover

sharing the point-of-sales date, for example).” Greenspan [25], the former Federal Reserve Chairman, also stated, “the remarkable surge in the availability of real-time information in recent years has sharply reduced the degree of uncertainty confronting business management,” Therefore, it can be said that IT enables firms to remove the substantial inventory deemed unnecessary [56].

On the other hand, many previous empirical studies have shown a positive relationship between IT and sale (or performance) [3, 10, 14, 15, 21, 32]

Thus, building on the finding of previous studies, we can hypothesize H1 as follows:

H1: IT investment has a positive impact on inventory turnover.

4.2 The effect of VI on inventory turnover

VI describes the extent to which the following processing activities are continued in a single organization [17]. To be specific, the shorter the production line and the fewer continuous processes are operated by one firm, the lower the degree of VI. Thus, the firm with less VI is likely to have fewer inventories and a higher inventory turnover ratio than the more vertically integrated firm. In this regard, Wan and Sanders[60] have empirically found that vertical integration has a positive impact on inventory levels, which leads to a negative relationship with inventory turnover.

However, the opposite outcome may occur, too. The firm with less VI may be unable to control an external problem, and there is a possibility that the demand of customers would not be satisfied due to the external problem. Consider an example. When the firm subcontracts parts of the production process to a third party, it may not produce the finished product if the third party has difficulty in producing the intermediate good. In this situation, the customer’s demand would not be met, and the sales of the firm would be decreased, leading to a lower inventory turnover ratio. Given that the effect of VI on inventory turnover may be positive or negative, the relationship between inventory turnover and VI can be one way or the other. Following this argument, we can hypothesize

H2a: VI has a positive impact on inventory turnover.

H2b: VI has a negative impact on inventory turnover.

4.3 The effect of GO on inventory turnover

GO represents the future potential of the firm to grow in scale or scope [15]. Activities such as basic research, new product introduction, acquisition of other firms, etc. are some examples of GO at the firm level [44]. A well-known characteristic of the higher GO is that the firm is likely to reinvest its earnings in branding and research and development (R&D) to survive in the market. Generally speaking, R&D research may bring new and good quality products into the market[26], and a good brand name is likely to be connected with increased demand and sales[57]. In other words, the higher GO the firm has, the more investment in brand and R&D it is likely to undertake, and the higher sales it can expect. Given this argument, it can be expected that the firm with higher GO will have a higher inventory turnover. However, the other side of the coin could appear if the firm excessively increases inventory to meet the increased demand. That is, in cases where the firm has surplus inventory due to an inaccurate demand forecast, there is a possibility that it will have a lower inventory turnover. Therefore, similar to the above two hypotheses of VI, we test the following hypotheses.

H3a: GO has a positive impact on inventory turnover.
H3b: GO has a negative impact on inventory turnover.

4.4 The effect of ID on inventory turnover

As mentioned earlier, ID mirrors market (or demand) uncertainty. Thus, it can be agreed that the relationship between inventory turnover and ID is referred to as the relationship between inventory turnover and market uncertainty. Many classical inventory models lead to the well-known conclusion that inventory increases with demand uncertainty, i.e., the firm buffers inventories against demand uncertainty; and the empirical evidence supports this conclusion [53]. Some previous empirical work also found that uncertainty hurts the firm's performance [4, 10, 31]. Hence, it may be inferred that the market uncertainty negatively affects sales. In line with the existing inventory theory and empirical evidence, it is expected that higher ID (or demand uncertainty) leads to higher inventory and lower sales, thereby decreasing inventory turnover. Similarly, Hancerliogullari et al. [28] found that demand uncertainty has a native relationship with the inventory turnover. These arguments lead to the fourth hypothesis.

H4: ID has a negative impact on inventory turnover.

4.5 The effect of IC on inventory turnover

It should be noted that the relationship between inventory turnover and IC can be considered as the relationship between inventory turnover and competition since IC is used as an inverse proxy for competition. Concerning this issue, Olivares and Cachon [50] investigated how the competition is related to inventory. They found that competition increases inventory in the auto industry and also validated that higher competition leads a dealer to hold higher inventory in order to provide a higher service level. Thus, it is expected that higher competition results in lower inventory turnover. However, the opposite direction may be possible while considering the impact of competition on sales. This is because within the framework of economics theory competition may push the firm to cut prices [58], which, in turn, increase demand (or sales)[1] and, subsequently, increase inventory turnover. Therefore, it can be argued that the relationship between competition and inventory turnover is ambiguous. Based on these arguments, we formulate the following hypotheses:

H5a: IC has a positive impact on inventory turnover.
H5b: IC has a negative impact on inventory turnover.

5. Model Specifications

To test the hypotheses, we construct the log-linear regression models as follows. First, the basic model (Model 1) is specified as

$$\ln I_{it} = F_i + C_t + \beta_{GM} \ln GM_{it} + \beta_{CI} \ln CI_{it} + \beta_{SG} \ln SG_{it} + \epsilon_{it} \qquad (1)$$

where F_t is the time-invariant firm-specific fixed effect for firm i; C_t is the year-specific fixed effect for t; and β_{GM}, β_{CI}, and β_{SG} are the unknown coefficients of $\ln GM_{it}$, $\ln CI_{it}$, and $\ln SG_{it}$, respectively. Based on Model 1, we can retest the hypotheses of Gaur et al. [23] and Gaur and Kesavan [24].

Second, more importantly, adding the variables of IT(IT investment), VI, GO, ID, and IC to Model 1, we arrive at Model 2 given by

$$\begin{aligned}\ln I_{it} &= F_i + C_t + \beta_{GM}\ln GM_{it} + \beta_{CI}\ln CI_{it} \\ &+ \beta_{SG}\ln SG_{it} + \beta_{IT}\ln IT_{it} + \beta_{VI}\ln VI_{it} \\ &+ \beta_{GO}\ln GO_{it} + \beta_{ID}\ln ID_{idt} + \beta_{IC}\ln IC_{idt} + \epsilon_{it}\end{aligned} \quad (2)$$

where F_t and C_t remain as defined in Model 1; and β_{IT}, β_{GO}, β_{VI}, β_{ID}, and β_{IC} are the unknown coefficients of $\ln IT_{it}$, $\ln VI_{it}$, $\ln GO_{it}$, $\ln ID_{idt}$, and $\ln IC_{idt}$, respectively. Employing Model 2, we can test our proposed hypotheses.

In Models 1-2, ϵ_{it} is assumed to be the random error distributed according to $N(0, \sigma^2)$ The firm-specific dummy variable (F_i) is employed to approximately capture time-invariant and firm-specific effect. As pointed out by Gaur et al. [23], inventory turnover may be highly correlated with the factors that are omitted in the data set used, including managerial efficiency, marketing, location strategy, accounting policy, and so on. These factors can cause the unknown parameters to be overestimated or underestimated [29]. Hence, we need to control such potential effects by using the firm-specific dummy variable to achieve a better model fit.

Similarly, the year-specific dummy variable (C_t) is presented to control for the changes taking place as time goes by, such as changes in economic conditions, interest rates, prices, etc [23]. Capturing these effects, we can compare the inventory turnover over the years considered. Moreover, by observing the coefficient of C_t, we can measure the time-trend of the inventory turnover after controlling for GM, CI, SG, IT, VI, GO, ID, and IC.

6. Data Description

The data set used for this study is comprised of the firm-level panel data on 98 U.S. firms, covering the period from 1999 to 2009. The firms were selected due to the availability of the data on IT capital and the data needed to measure firm characteristics. Most firms that were selected belong to manufacturing, wholesale trade, and retail trade industries in which the inventory plays a significant role. The data were collected from two sources. For IT investment data, we used Information Week (IW) 500.

Specifically, the IW 500 defines the IT capital variable as being composed of IT budget figures, including capital, and operating expenses for infrastructure (including telecom, networking, and hardware), allocations (maintenance, development, and packages), Internet-based costs, recruitment, IT services and outsourcing, and training [45]. The remaining data were obtained from Compustat. Precisely, the industry characteristics for manufacturing firms were measured based on the 4-digit code of 2007 NAICS. The 3-digit code of 2007 NAICS was used to compute the industry characteristics for wholesale and retail firms.

The final data set containing 1,078 observations across 98 firms and all the data on the relevant variable were adjusted to the

Table 2 Summary Statistics of the Variables

	mean	standard deviation	max	min
Inventory turnover	7.14570	7.27757	84.79394	0.68647
Gross margin	0.35671	0.18532	0.92414	0.00971
Capital intensity	0.73043	0.18853	0.97385	0.08111
Sale growth rate	0.96716	0.19149	2.60711	0.26117
IT investment*	368.4	556.1	3684.3	1.4
Vertical integrationI	0.28177	0.11295	0.74018	-0.19219
Growth Option	2.27441	5.27846	139.01662	0.44652
Industry dynamism	142.72467	765.55914	5522.57235	0.00761
Industry concentration	0.61350	0.22770	1.03505	0.01292

*reported in million dollars

2000 U.S. dollar value. Table 2 presents summary statistics of the variables.

7. Results and Discussion

7.1 Basic results and analysis

Table 3 reports estimates for Models 1-2. In particular, observing the coefficient estimates for Model 1, we can retest the hypotheses suggested by Gaur et al. [23] and Gaur and Kesavan [24].

First of all, from Table 3, we find that the estimated coefficients of $\ln GM_{it}$ and $\ln CI_{it}$ are respectively -0.70056 and 0.50723 and are statistically significant at the 1% level. Thus, we infer that inventory turnover is negatively correlated with gross margin and positively correlated with capital intensity. These results are consistent with the findings of Gaur et al. [23] and Gaur and Kesavan [24]. However, we observe from the same table that the estimated coefficient of $\ln SG_{it}$ is -0.360401 and significant at the 1% level, suggesting that inventory turnover is negatively correlated with the sales growth rate. This result contradicts the finding of Gaur and Kesavan [24] in that they found that inventory turnover is positively correlated with the sales growth rate. Our finding can be explained by the possibility of excessive inventory. An increase in the sales growth rate means that the firm needs to increase the number of inventories to meet the increased sales. In this situation, if the firm inappropriately retains excessive inventory, the inventory turnover ratio will decrease as a result of the sales growth. The scenario seems to be a reasonable explanation because the same empirical evidence is found from Models 2, 5, and 6.

Second, observing the results from Model 2 reported in Table 3, we find that the impact of IT investment on inventory turnover is significantly positive. Notably, the coefficient of $\ln IT_{it}$ is 0.17404 and significant at the 1% level. This result entails that IT investment has a positive impact on inventory turnover, thereby supporting hypothesis H1. Since we adopt a log-linear model, an estimated coefficient gives the elasticity of inventory turnover concerning its corresponding

Table 3 Results for Models 1 and 2

Inventory turnover	Model 1	Model 2
$\ln GM_{it}$	-0.70056**	-0.43861**
$\ln CI_{it}$	0.50723**	0.95537**
$\ln SG_{it}$	-0.36041**	-0.31693**
$\ln IT_{it}$		0.17404**
$\ln VI_{it}$		-0.21883**
$\ln GO_{it}$		0.11821**
$\ln ID_{idt}$		0.09236**
$\ln IC_{idt}$		-0.11628**
R-square	0.9853	0.9886

Notes: **p < 0.01, * p < 0.05

independent variable. Thus, a 1% increase in IT investment is associated with an increase of 0.17404% in inventory turnover, holding the other independent variables unchanged.

Third, to test the hypotheses related to the firm characteristics studied, we have to examine the signs and significance of the estimated coefficients of $\ln VI_{it}$ and $\ln GO_{it}$ for Model 2 again shown in Table 3. It can be readily observed that, while the impact of VI on inventory turnover is significantly negative, the impact of GO is significantly positive. In particular, the estimates of the coefficients of $\ln VI_{it}$ and $\ln GO_{it}$ are -0.21883 and 0.11821, significant at the 1% level. Thus, inventory turnover is negatively correlated with VI but positively correlated with GO. These findings support H2b and H3a, meaning that H2a and H3b are rejected. Furthermore, the estimated coefficients suggest that other things being equal, an 1% increase in VI would result in a 0.21883% decrease in inventory turnover, whereas a 1% increase in GO would lead to a 0.11821% increase in inventory turnover.

Table 4 A summary of the conclusions of the hypothesis tests

Hypothesis	Conclusion
H1	Supported
H2a	Not Supported
H2b	Supported
H3a	Supported
H3b	Not Supported
H4	Not Supported
H5a	Not Supported
H5b	Supported

Fourth, again observing the sign and significance of the coefficient estimates of $\ln ID_{idt}$ for Model 2 reported in Table 3, we find that the impact of ID on inventory turnover is significantly positive (specifically, the coefficient estimate of $\ln ID_{idt}$ is 0.09236 and significant at the 1% level). In other words, this finding leads us to the conclusion that inventory turnover is positively correlated with ID, thereby rejecting H4; and a 1% increase in ID is associated with a 0.09236 % increase in inventory turnover, holding the other independent variables constant.

Fifth, it can also be observed from Table 3 that the impact of IC on inventory turnover is significantly negative. Therefore, we can support H5b. As shown in Table 3, the coefficient of $\ln IC_{idt}$ for Model 2 is -0.11629 at the 1% level. This result leads us to know that a 1% increase in IC would result in a 0.11629% decrease in inventory turnover, as other independent variable being unchanged.

Our hypothesis test results are shown in Table 4.

7.2 Time trends in inventory productivity

An important question arising in inventory management is: Has there been a decrease in overall U.S. manufacturing and retail sector inventories during the past decades? To answer this question, Rajagopalan and Malhotra [52] studied trends in materials, work-in-process, and finished-goods inventory ratios[4] during the period from 1961 to 1994 to determine whether a significant decrease was observed in these ratios, and concluded that total manufacturing inventory ratio decreased from 1961 to 1994 at all three stages: material, work-in-process, and finished goods. Similarly, Gaur et al. [23] investigated time trends in inventory productivity as measured by "unadjusted" overall time trend of inventory turnover and "adjusted" overall time trend of inventory turnover, and found that both have declined in retailing during the 1987-2000 period. In line with these two studies, we analyze time trends in inventory productivity, using a different dataset.

Table 5 shows the time trend of inventory turnover based on Models 1 and 2. Observing the estimated coefficients of C_t, we canexamine the inventory productivity over time. Notably, the results for Model 1 show the time trend after controlling for gross margin, capital intensity, and sales growth rate. The results for Model 2 provide the time trend after adjusting for the correlation with IT investment, VI, GO, ID, and IC, in addition to the variables considered in Model 1. Table 3 demonstrates that, even though the estimates of time-specific fixed effect (C_t) decrease across models in years 2001, 2003, 2007, and 2008 as compared to the previous year, they show an overall increasing trend. Fig. 3 and

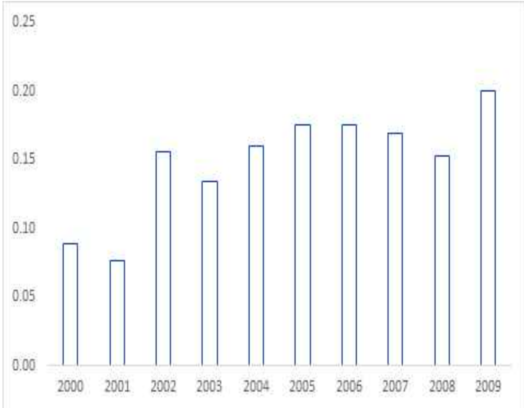

Fig. 3 Histogram for time-specific effect(C_t) for Model

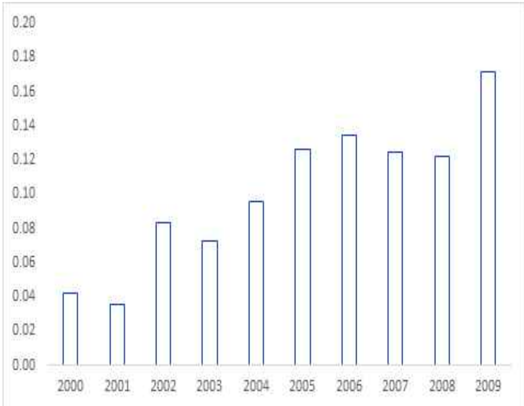

Fig. 4 Histogram for time-specific effect(C_t) for Model2

Fig. 4 support this observation.

As suggested by Gaur et al. [23], to observe the "unadjusted" overall time trend of inventory turnover, we consider the following two models (Models 3 and 4):

$$I_{it} = F_i + \beta_t t + \epsilon_{it} \quad (3)$$

and

$$\ln I_{it} = F_i + \beta_t t + \epsilon_{it} \quad (4)$$

where F_i is the time-invariant and firm-specific fixed effect for firm i; β_t is the coefficient of the time variable; and ϵ_{it} is the error term being assumed to be according to

4) ****Rajagopalan and Malhotra [52] defined three types of inventory ratios as follows: (i) materials-and-supplies inventory/material cost (ii) work-in-process inventory, and (iii) finished-goods inventory/(material cost + value added). Therefore, it should be careful to compare the results of this study with those of Rajagopalan and Malhotra [49] because we adopt inventory turnover ratio (=cost of goods sold/inventory) for the proxy of inventory performance.

Table 5 Estimates of Time-specific Fixed effect

Year	Model 1	Model 2
1999	·	·
2000	0.08890**	0.04233
2001	**0.07628***	**0.03565**
2002	0.15569**	0.08298**
2003	**0.13380****	**0.07251***
2004	0.15956**	0.09595*
2005	0.17581**	0.12665**
2006	0.17589**	0.13471**
2007	**0.16888****	**0.12448***
2008	**0.15233****	**0.12222****
2009	0.19999**	0.17160**

Notes: **p < 0.01, * p < 0.05; and Bold means smaller value than previous year

N(0, σ^2). Models 3 and 4 are employed to estimate a linear time trend and an exponential time trend, respectively. Table 6 gives the estimates obtained. Notably, inventory turnovers have increased significantly with time because the estimated coefficients of the time variable in Models 3 and 4 are 0.08298 and 0.01858, and are significant at the 1% level. Moreover, to investigate the "adjusted" overall time trend of inventory turnover, we replace the year-specific fixed effect (C_t) of Models 1 and 2 by the time variable (t) (Models 5 and 6) as given by

$$\ln I_{it} = F_i + \beta_t t + \beta_{GM} \ln GM_{it} + \beta_{CI} \ln CI_{it} + \beta_{SG} \ln SG_{it} + \epsilon_{it} \quad (5)$$

and

$$\ln I_{it} = F_i + \beta_t t + \beta_{GM} \ln GM_{it} + \beta_{CI} \ln CI_{it} + \beta_{SG} \ln SG_{it} + \beta_{IT} \ln IT_{it} + \beta_{VI} \ln VI_{it} + \beta_{GO} \ln GO_{it} + \beta_{ID} \ln ID_{idt} + \beta_{IC} \ln IC_{idt} + \epsilon_{it} \quad (6)$$

These two models measure the "adjusted" time trend after controlling for the explanatory variables adopted in Models 1 and 2. The estimates of Models 5 and 6 are included in

Table 6 Estimates of time variable

Variable	Model 3	Model 4
t	0.08298**	0.01858**
R－square	0.9466	0.9791

Notes: **p < 0.01, * p < 0.05

Table 7, where we can observe that the estimated coefficients of the time variable for both Models 5 and 6 are positive (0.01588 and 0.01618) and significant at p<0.01. Therefore, the "adjusted" time-trend of inventory turnover also reveals an increasing pattern.

In summary, our data have confirmed that the overall trend of inventory turnover displays an increasing pattern. Our finding is inconsistent with Gaur et al. [23] in that they found a decreasing trend in inventory productivity. Also, it is partially consistent with Rajagopalan and Malhotra [52] because their results are mixed in that finished-goods inventories in some industry sectors are featured by a decreasing trend (namely, an increasing trend of inventory productivity) and in a few others by an increasing trend (namely, a decreasing trend of inventory productivity).

To explain the increasing trend of inventory productivity over time, Rajagopalan and Malhotra [52] offered these conjectures: strategies such as MRP, JIT, quick response, cycle time reduction, and inventory management software may have been practiced more readily and implemented more effectively in individual firms and industries, resulting in differences in improvement across industry sectors. The increasing trend of inventory productivity found in this study may also be explained by these conjectures. Furthermore, given the result regarding the impact of IT investment on inventory turnover obtained in this study, these conjectures seem to be powerful instruments to improve inventory productivity. However, for now, the conclusive evidence is still lacking because it remains unclear as to what relationships exist among IT, management software, production strategy, and the overall trend in inventory productivity.

On the other hand, observing the results shown in Table 7, it can be concluded that the estimated coefficients of Models 5 and 6 are consistent with those of Models 1 and 2.

Table 7 Results for Models 5 and 6

Inventory turnover	Model 5	Model 6
t	0.01588**	0.01618**
$\ln GM_{it}$	-0.71962**	-0.43762**
$\ln CI_{it}$	0.56246**	0.98096**
$\ln SG_{it}$	-0.37807**	-0.32077**
$\ln IT_{it}$		0.17248**
$\ln VI_{it}$		-0.21634**
$\ln GO_{it}$		0.11808**
$\ln ID_{idt}$		0.10698**
$\ln IC_{idt}$		-0.11818**
R-square	0.9851	0.9886

Notes: **p < 0.01, * p < 0.05

8. Concluding Remarks and Extensions

The need to research inventory management has been emphasized in order to discover the operational competence of the firm. Numerous previous studies have been devoted to analyzing inventory productivity [6, 7, 9, 11, 12, 19, 20 23, 24, 28, 37, 56, 60]. Because of the necessity, we undertook an empirical investigation in this study, using firm-level data on U.S. 98 firms and examined inventory productivity by employing an inventory turnover ratio. In particular, we investigated the relationship of inventory turnover ratio with IT investment, vertical integration, growth options, industry dynamism, and industry concentration. Besides, we retested the correlation of inventory turnover ratio with gross margin, capital intensity, and sales growth rate as found by Gaur et al. [23] and Gaur and Kesavan [24], and analyzed the time trends in two types of inventory productivity referred to as unadjusted inventory turnover and adjusted inventory turnover.

We have found that inventory turnover ratio is positively correlated with IT investment and growth options and negatively correlated with vertical integration and industry dynamism. However, contrary to our expectation, the relationship (negative or positive) between inventory turnover ratio and industry concentration is not confirmed by our data. Furthermore, we have discovered an upward time trend of inventory productivity over the period from 1999 to 2009.

On the other hand, this study has made the academic contribution to the literature by incorporating the new variables into the econometric models which Gaur et al. [23] and Gaur and Kesavan [24] suggested and then analyzing the impacts of them on inventory turnover. Specifically, as critical variables, this study used IT investment, vertical integration, growth options, industry dynamism, and industry concentration, which did not consider in the previous two studies.

Moreover, given the empirical results obtained, we can derive several managerial implications.

Firstly, since IT investment has a positive impact on inventory turnover was found, there is a high possibility that the active investment in IT leads to the improvement in inventory turnover. Secondly, to improve inventory turnover, it would be more useful for the high vertically integrated firm to appropriately lower the degree of vertical integration because the impact of vertical integration on inventory turnover is negative. Thirdly, again for the improvement in inventory turnover, it is vital to increase the potentiality of firms by the investment in R&D, new product development, and so on, because growth options have a positive effect on inventory turnover. Lastly, given that the impact of industry concentration on the inventory turnover is negative, decision-makers would be better to focus more on price policy than inventory holding levels to improve inventory turnover. This is because our result regarding the industry concentration indicates that the impact of competition on sales dominates the impact of competition on inventory holding levels at determining inventory turnover.

This study can be extended in at least four ways. In one way, employing a mediation model, we can extend this paper to an interesting one enabling us to scrutinize the collective impact of IT, firm characteristics, and industry characteristics on inventory productivity. As suggested by Chari et al. [10], considering the interaction terms of IT investment and each characteristic, we can examine the impact of IT on inventory turnover according to the degree of each characteristic; and we also can find the joint effects of IT investment, firm characteristics, and industry characteristics upon inventory productivity.

In another way, in line with previous studies devoted to exploring direct performance effects of IT investment and inventory turnover, this study can be extended to examine the effects of IT investment and inventory turnover on profitability measured by Tobin's q, ROA, ROE, and so on. Furthermore, by introducing interaction terms of IT investment and inventory turnover, we can uncover the effect of IT investment on profitability according to the degree of inventory turnover (conversely stated, the effect of inventory turnover according to the size of IT investment, see Lin and Shao [43] and Kim et al. [38]).

In a third way, based on our result regarding the relationship between inventory turnover and industry dynamism, we can attempt to examine the impact of market uncertainty on inventory turnover from the new perspective. As pointed out in Section 7, industry dynamism is positively related to inventory turnover, which is contrary to both our expectation and the findings of many previous studies that inventory holding level increases with demand uncertainty. To explain this uncertain outcome, it may be an excellent candidate to consider the effect of market uncertainty on sales in affecting inventory turnover. From this, we may be able to expand the discussion on the effect of industry dynamism (or market uncertainty) in terms of inventory management.

In a last way, collecting and using the updated dataset, we will be able to analyze the recent trends of key variables in determining the inventory turnover. As we have seen, the data used in this study are somewhat outdated, and this is a significant limitation of this study. In particular, it is urgent to update IT-related data, especially as IT-related technologies change faster than other variables. Therefore, it is imperative to use an updated dataset, which contains the firms' latest activities in inventory management.

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