Analysis of Relationship between Lean Inventory and Firm Performance: Evidence from the Stock Exchange of Thailand

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Abstract

Lean inventory strategy and just-in-time philosophy have been widely adopted by organisations worldwide. However, prior studies which examine relationships between inventory leanness and firm's financial performance have yielded, at best, mixed results. In addition, these studies often focus on advanced economies. Relatively little is understood how inventory leanness is associated with firm performance in emerging economies, where logistics systems and information and communication technology are less developed. Therefore, in this paper, relationship between inventory leanness and firm performance is analysed by using data of companies listed on the Stock Exchange of Thailand. Panel regression with fixed effects is employed to investigate the relationship between inventory leanness and accounting returns. Associations between inventory leanness and stock returns are also examined using portfolio construction method. Empirical findings indicate that relationships between inventory leanness and accounting returns vary across industries. Further analysis into stock returns shows no statistically significant difference in returns between low and high inventory leanness portfolios.

Keywords: Inventory Management, Lean Inventory, Financial Performance, Factor Pricing Model

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การวิเคราะห์ความสัมพันธ์ระหว่างระดับสินค้าคงเหลือแบบลีนกับผลการดำเนินงานขององค์กร: หลักฐานจากตลาดหลักทรัพย์แห่งประเทศไทย

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บทคัดย่อ

กลยุทธ์สินค้าคงเหลือแบบลีนและปรัชญาการผลิตแบบทันเวลาได้มีการนำมาปฏิบัติในองค์กรทั่วโลก แต่อย่างไรก็ตาม งานวิจัยในอดีตที่ศึกษาความสัมพันธ์ระหว่างระดับความลีนของสินค้าคงเหลือกับผลการดำเนินงานด้านการเงินขององค์กรยังคงให้ผลการศึกษาที่แตกต่างกัน นอกจากนี้ การศึกษาส่วนใหญ่มุ่งเน้นกลุ่มประเทศที่มีการพัฒนาทางเศรษฐกิจในระดับสูง ความเข้าใจเกี่ยวกับความสัมพันธ์ระหว่างระดับความลีนของสินค้าคงเหลือกับผลการดำเนินงานขององค์กรในกลุ่มประเทศเศรษฐกิจเกิดใหม่ยังไม่เป็นที่เข้าใจเท่าที่ควร ในกลุ่มประเทศเศรษฐกิจเกิดใหม่เหล่านี้ ระบบโลจิสติกส์และระบบเทคโนโลยีสารสนเทศและการสื่อสารได้รับการพัฒนาน้อยกว่าในกลุ่มประเทศที่มีการพัฒนาทางเศรษฐกิจในระดับสูง จึงอาจทำให้ผลกระทบของการบริหารสินค้าคงเหลือแบบลีนต่อผลการดำเนินงานขององค์กรแตกต่างจากในกลุ่มประเทศที่มีการพัฒนาทางเศรษฐกิจในระดับสูง ดังนั้น บทความวิจัยนี้จึงศึกษาความสัมพันธ์ระหว่างระดับความลีนของสินค้าคงเหลือกับผลการดำเนินงานขององค์กร โดยใช้ข้อมูลจากบริษัทจดทะเบียนในตลาดหลักทรัพย์แห่งประเทศไทย งานวิจัยนี้ใช้การวิเคราะห์ความถดถอยอิทธิพลคงที่ในการวิเคราะห์ความสัมพันธ์ระหว่างระดับความลีนของสินค้าคงเหลือกับผลตอบแทนทางการบัญชี สำหรับการวิเคราะห์ความสัมพันธ์ระหว่างระดับความลีนของสินค้าคงเหลือกับผลตอบแทนของหุ้นใช้วิธีการจัดกลุ่มหลักทรัพย์ ผลการศึกษาพบว่าความสัมพันธ์ระหว่างระดับความลีนของสินค้าคงเหลือกับผลตอบแทนทางการบัญชีมีความแตกต่างกันระหว่างอุตสาหกรรม สำหรับการวิเคราะห์ผลตอบแทนของหุ้นพบว่าไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างกลุ่มหลักทรัพย์ที่มีระดับความลีนของสินค้าคงเหลือในระดับต่ำกับกลุ่มที่มีระดับความลีนของสินค้าคงเหลือในระดับสูง

คำสำคัญ: การบริหารสินค้าคงเหลือ สินค้าคงเหลือแบบลีน ผลการดำเนินงานด้านการเงิน แบบจำลองปัจจัยราคา

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1. Introduction

Since 1980s, inventory reduction has received increasing interest from managers. It is perceived as one of the important means for firms to reduce costs. From lean and just-in-time (JIT) principles, inventories are seen as one form of waste that should be minimised (Womack, Jones and Roos, 1990). Several innovations, including Material Requirements Planning (MRP), process innovations, and advanced information technology, have helped support inventory reduction.

In the US, slogans such as ‘zero inventory’ and ‘inventory is evil’ were often used during the late 1970s and 1980s. A number of empirical studies have also shown a trend of inventory reduction over time. For example, Rajagopalan and Malhotra (2001) examined manufacturing inventories at an industry level and found a decrease in manufacturing inventories between 1961 and 1994. The decrease was particularly larger in the post-1980 period. Similarly, Chen, Frank and Wu (2005) showed that American manufacturing companies reduced their inventory holding period by an average of 2 percent per year between 1981 and 2000. In wholesale sector, Chen, Frank and Wu (2007) also found a downward trend in days of inventory during the period between 1981 and 2004. As for retail sector, Chen et al. (2007) found that inventory days started to decline in around 1995, while Gaur, Fisher and Raman (2005) found a declining inventory turnover during the 1987-2000 period. In other countries, such as Australia, Canada, Spain and other European countries, lean operations have also been widely adopted (Callen, Fader and Krinsky 2000; Cagliano, Caniato and Spina 2006; Olhager and Prajogo, 2012; González-Benito, da Rocha and Queiruga, 2010)

Despite the popularity of lean inventory principle and evidence of inventory reduction over the last several decades, whether leanness of inventory is associated with superior financial performance is still questionable. Empirical studies which examine relationship between inventory performance and financial performance have yielded, at best, mixed results (Chen et al., 2005, 2007; Swamidass, 2007; Cannon, 2008; Koumanakos, 2008; Capkun, Hameri and Weiss, 2009; Eroglu and Hofer, 2011; Isaksson and Seifert, 2014).

Existing studies have also yielded inconclusive results with regard to functional form of the relationship between inventory leanness and firm performance. While Capkun et al. (2009) found a linear relationship between inventory and financial performance, others found an inverted U-shape relationship between inventory level and financial performance (Eroglu and Hofer, 2011; Isaksson and Seifert, 2014).

With mixed evidence on relationship between inventory leanness and financial performance, this study examines relationship between inventory leanness and financial performance at firm level, using empirical data from Thai companies listed on the Stock Exchange of Thailand (SET). The effect of inventory leanness on financial performance is investigated on an industry-by-industry basis. In addition, instead of assuming a certain form of relationship between inventory leanness and performance, the functional form of the relationship is explored. Following Eroglu and Hofer (2011), the study uses Empirical Leanness Indicator (ELI) as a measure of inventory leanness. ELI is a superior measure to absolute level of inventory and inventory turnover, as it takes into account economies of scale and estimates firm's inventory leanness relative to industry-specific norms. The study extends Eroglu and Hofer (2011) by examining not only relationship between inventory leanness and accounting returns but also association between inventory level and stock returns. By extending to examine such relationship, it can help enhance our understanding how lean inventory management is viewed and valued from an investor perspective.

To our best knowledge, this study is the first to employ empirical archival method to examine relationship between inventory leanness and financial performance using Thai data. Most of the existing studies focus on US data. Lean management has been implemented in various industries in Thailand (Rahman, Laosirihongthong and Sohal, 2010; Lila, 2012; Laohavichien and Wanarat, 2013; Punnakitikasem, Buavaraporn and Chen, 2013; Sureerattanan, Napompech and Panjakhajornsak, 2014). In Thailand, logistics and transportation systems are not as well developed as those in the US. In addition, information and communication technology is less advanced in Thailand. These factors may have an impact on effectiveness of lean inventory management. Studies investigating performance consequences of lean implementation in Thailand tend to focus on operational performance (Rahman et al., 2010; Laohavichien and Wanarat, 2013). Financial performance is left unexplored.

The rest of the paper is organised as follows. Section 2 reviews relevant literature and Section 3 sets out research questions. Section 4 defines variables which are of interest of the study and explains data collection and analysis procedures. Results of the empirical analysis are presented and discussed in section 5. Section 6 concludes the paper. Limitations and suggestions for future research are also discussed.

2. Literature Review

In recent decades, lean philosophy has gained widespread adoption. It has been implemented not only in manufacturing companies but also in other sectors (Poksinska, 2010; Punnakitikasem et al., 2013; Myerson, 2014). Lean philosophy involves a set of practices to minimise waste and improve performance. Among the waste to minimise is inventory. It is argued that by carrying inventories, capital is tied up. In addition, the identification of defects in the operations process becomes more difficult, as inventories act as buffers covering these unsolved problems. With increasing popularity of lean philosophy, lean inventory management has often been regard as, or sometimes even become synonymous with, good inventory management (Cooper and Maskell, 2008). JIT production and JIT purchasing have been promoted to help reduce inventory levels.

Since the 1990s, research examining performance consequences of lean or JIT implementation has emerged, particularly in the areas of operations management and accounting. Previous research has found that, in general, lean or JIT adoption has led to an improvement in operational performance, including inventory performance metrics. However, results with regard to financial performance have been mixed. Literature which has examined relationship between lean adoption and inventory leanness and firm performance can be broadly classified into three streams. The first stream investigates lean or JIT adoption and performance consequences using mail survey questionnaire. The second stream of literature also examines relationship between lean or JIT adoption and performance but using public announcements to identify lean or JIT firms and Compustat database to measure financial performance. For the third stream of literature, relationship between inventory level, a presumed outcome of lean implementation and performance is analysed. Empirical archival method is used. The current paper follows the third stream of the literature. However, broader literature examining lean or JIT adoption directly is also reviewed.

2.1 Survey-based studies on lean or JIT adoption and performance consequences

This stream of literature adopts a survey questionnaire approach to identify whether lean or JIT has been adopted. These studies typically incorporate multiple lean practices such as total productive maintenance, JIT and total quality control (White, 1993; Cua, McKone and Schroeder, 2001; Fullerton, McWatters and Fawson, 2003; Shah and Ward, 2003; Fullerton, Kennedy and Widener, 2014) although some place an emphasis on JIT specifically (Norris, Swanson and Chu, 1994; Fullerton and McWatters, 2001). With respect to level of analysis, some studies focus on firm level while some place an emphasis on plant level. Performance examined include operational and financial performance. Majority of literature examining lean and inventory management practices and performance consequences in Thailand falls into this category. Summary of this stream of literature is provided in Table 1.

Most of the survey-based studies on lean or JIT implementation, including those conducted in Thailand, show positive impact on performance. However, these studies have often tended to rely on self-evaluated performance (Callen et al., 2000 and Fullerton et al., 2003 are among few exceptions). The use of self-assessed performance could lead to a biased result, as management of the firms which decided to adopt lean or JIT are more inclined to have a positive attitude towards lean or JIT and its benefits, therefore, reporting positive results. In addition, many of these studies examine the issues in manufacturing sector in general without controlling for industry. Effectiveness of lean or JIT may vary across industries due to differences in product, production, technology, supply and demand characteristics (Eroglu and Hofer, 2011). Controlling for industry factors could help enhance our understanding of how lean or JIT affects performance.

Table 1 Survey-based studies on lean or JIT adoption and performance

	Sample/Data Source	Independent Variable(s)	Dependent Variable(s)	Results
White (1993)	1,035 US JIT manufacturing firms	-	Overall benefit, change in throughput time	Most respondents reported overall net benefit from JIT implementation. Decreases in throughput time varied for firms using different manufacturing process.
Norris et al. (1994)	48 US plant managers operating under JIT	-	Plant performance (Inventory management, process control, information flow and human factors, quality control)	Most respondents reported improvement in inventory management process control, information flow and quality control. However, for human factors, most respondents reported positive impact on worker motivation, job satisfaction and teamwork but not union relations, absenteeism and labour turnover.
Callen et al. (2000)	100 Canadian manufacturing plants	TQM, JIT	Plant performance (Production improvement, inventory utilisation, profitability, cost structure)	JIT plants have higher plant productivity in inventory usage, improved quality of processes, lower variable and total costs (but not fixed costs), and higher operating profit.

Table 1 Survey-based studies on lean or JIT adoption and performance (cont.)

	Sample/Data Source	Independent Variable(s)	Dependent Variable(s)	Results
Cua et al. (2001)	163 manufacturing firms in various countries	TQM, JIT, TPM	Plant performance (weighted sum of 4 measures – quality, cost, delivery and flexibility)	Different configurations of practices have impact on different dimensions of performance. Simultaneous implementation of TQM, JIT and TPM resulted in higher performance.
Fullerton and McWatters (2001)	91 US (self-classified) JIT firms	Degree of JIT implementation	Self-reported performance on the following areas: quality improvements, time-based responses, employee flexibility, accounting simplification, firm profitability and inventory reduction	Managers adopting JIT have experienced substantial benefits in all the measured areas.
Shah and Ward (2003)	1,575 US manufacturing plants	Lean practices	Plant operational performance, including manufacturing cycle time, scrap and rework costs, labour productivity, unit manufacturing costs, first pass yield and customer lead time	Lean bundles are associated with higher performance.

Table 1 Survey-based studies on lean or JIT adoption and performance (cont.)

	Sample/Data Source	Independent Variable(s)	Dependent Variable(s)	Results
Rahman et al . (2010)	187 Thai manufacturing firms	JIT, waste minimisation, flow management	Self-assessed operational performance relative to industry (Quick delivery, unit cost, productivity, customer satisfaction)	All three lean constructs are significantly associated with operational performance.
Laohavichien and Wanarat (2013)	119 Thai manufacturing firms	Lean practices	Organisational performance (Lead time, inventory turnover, product rejection/return, sales, cost reduction, meeting customers' requirement) Innovation performance (Process innovation, product and service innovation)	Lean practices have positive impact on organisational performance and innovation performance. Innovation performance also has positive impact on organisational performance.

Table 1 Survey-based studies on lean or JIT adoption and performance (cont.)

	Sample/Data Source	Independent Variable(s)	Dependent Variable(s)	Results
Fullerton et al. (2014)	244 US manufacturing firms	Extent of lean implementation	Self-assessed improvements of operational perfomance over three years (scrap and rework, setup times, queue times, machine downtime, lot sizes and cycle time) Self-assessed financial performance (changes in net sales, ROA, profitability and market share over three years)	Lean manufacturing practices indirectly affect operational performance through lean management accounting practices.
Sureerattanan et al. (2014)	540 managers of Thai automotive parts manufacturers	Lean Leadership	Quality, timeliness, efficiency	Leadership has a positive impact on lean manufacturing practices and firm performance. Lean manufacturing also positively influences firm performance.

2.2 Studies on lean or JIT adoption and performance using literature search

The second stream of literature addresses limitations of the first stream by using objective data to identify lean or JIT adoption and evaluate its performance consequences. The authors searched public announcements to identify whether firms have adopted lean or JIT. Financial performance data was drawn from Compustat. Huson and Nanda (1995) searched for JIT adoption announcements from public sources. Questionnaires were then mailed to JIT firms to enquire the adoption date. Huson and Nanda (1995) found that JIT adoption led to an increase in inventory turnover and a significant reduction in labour per sales dolloar. JIT adoption also led to an increase in earnings per share although unit costs increased and operating margins decreased. The increase in earnings per share was due to a reduction in interest expenses and other financing costs necessary to service the investment in inventories. As for Balakrishnan, Linsmeier and Venkatachalam (1996) and Kinney and Wempe (2002), JIT firms were matched with non-JIT firms, and performance of the two groups were compared. While Kinney and Wempe (2002) found that JIT firms showed an improvement in financial performance, Balakrishnan et al. (1996) did not find significant differences in ROA between JIT and their matched non-JIT firms. Findings from Balakrishnan et al. (1996) also indicated that firms with diffused customer base exhibited a superior ROA to firms with high degree of customer concentration. Summary of this stream of literature is shown in Table 2.

Findings from this stream of literature confirm those of the first stream of literature that JIT firms outperform non-JIT firms with respect to inventory utilisation. However, this stream of literature suggests inconclusive results regarding financial performance. One plausible reason for mixed results is the use of dichotomous variable (i.e. JIT and non-JIT firms) with no consideration regarding the nature of JIT practices and the extent to which JIT has been implemented (Eroglu and Hofer, 2011). Different firm size could also be another plausible reason explaining inconsistent findings between Balakrishnan et al. (1996) and Kinney and Wempe (2002). Large proportion of Balakrishnan et al. (1996) samples are small firms, and findings from Kinney and Wempe (2002) suggest that very small JIT firms achieved no significant ROA improvement compared to their control firms. Moreover, many studies in this stream do not consider impact of industry which may affect the effectiveness of JIT adoption.

Table 2 Studies on lean or JIT adoption and firm performance, using secondary data

	Sample/Data Source	Independent Variable(s)	Dependent Variable(s)	Results
Huson and Nanda (1995)	55 JIT adopters (From public announcements search followed by mail questionnaire to confirm adoption date) Financial data from Compustat	JIT adoption	Number of employees per sales dollar, inventory turnover, unit manufacturing costs, operating margins, earnings per share	JIT adopters experienced increase in inventory turnover and reduction in number of employees per sales dollar. However, unit costs were increased. Operating margins were also decreased but to a lesser extent compared to competitors which did not adopt JIT. JIT has a positive impact on earnings per share.
Balakrishnan et al. (1996)	46 JIT firms (From public announcements) plus 46 control firms Financial data from Compustat	JIT adoption	Inventory turnover ROA	JIT firms showed superior inventory utilisation. But no significant different in ROA compared to non-JIT firms.
Kinney and Wempe (2002)	201 JIT adopters (From public announcements) plus 201 non-adopters Financial data from Compustat	JIT adoption	ROA Asset turnover Profit margin	JIT adopters showed an improvement in financial performance. Profit margin, rather than asset turnover, is the primary source of the improvement. JIT adopters below a firm-size threshold did not show improvement in financial performance.

2.3 Studies examining associations between inventory and performance

Similar to the second stream of literature, the third stream employs secondary data to analyse relationships between inventory management and performance. However, rather than classifying firms into JIT and non-JIT, this stream of studies uses inventory leanness, a presumed outcome of lean and JIT adoption, and examines whether it has any associations with firm performance. Summary of this stream of literature is shown in Table 3.

As can be seen from Table 3, majority of this stream of research draws on data from Compustat. However, they have yielded inconclusive results. While findings from Capkun et al. (2009) suggest a linear negative association between inventory levels and financial performance, Eroglu and Hofer (2011) find a non-linear association. Similar to Eroglu and Hofer (2011), Isaksson and Seifert (2014) find a non-linear relationship but the relationship found suggests decreasing return from leanness rather than an optimal level. Koumanakos (2008) finds different types of relationship in different sectors. On the other hand, Cannon (2008) finds no significant relationship. Chen et al. (2005, 2007) find no evidence that firms with low inventory have higher stock returns although firms with abnormally high inventory level have abnormally poor long-term stock returns.

Taking the three streams of literature together, it can be seen that prior research investigating relationships between inventory leanness and firm performance has yielded, at best, inconclusive results. Next section discusses research questions emerged from the literature review.

Table 3 Studies on inventory leanness and performance

	Sample/Data Source	Inventory measure(s)	Performance measure(s)	Results
Lieberman and Demeester (1999)	52 suppliers/assemblers in Japanese automobile industry	Work-in-process/ sales ratio	Labour productivity	Labour productivity increased during the periods of substantial inventory reduction.
Chen et al. (2005)	7,433 US manufacturing companies 1981-2000 Compustat	Inventory days Inventory-to-sales Inventory-to-assets	Tobin's Q Stock-price performance	Firms with abnormally high inventories have abnormally poor long-term stock returns. Firms with slightly lower than average inventories perform best over time.
Gaur et al. (2005)	311 US retailers 1987-2000 Compustat	Inventory turnover	Gross margin	Inventory turnover and adjusted inventory turnover declined during the 1987-2000 period. Annual inventory turnover is negatively associated with gross margin and positively correlated with capital intensity and sales surprise.

Table 3 Studies on inventory leanness and performance (cont.)

	Sample/Data Source	Inventory measure(s)	Performance measure(s)	Results
Chen et al. (2007)	1,662 US retailers, wholesalers 1981-2004 Compustat	Inventory days Inventory-to-sales Inventory-to-assets Deviation of inventory days from industry norm	Stock returns	No evidence that firms with low inventory have higher stock returns. However, firms with abnormally high inventories exhibit abnormally poor long-term stock returns.
Swamidass (2007)	800 manufacturers (SIC codes 3400-3900) Compustat data	Total inventory/ sales	Altman's Z	Firms with better performance have lower inventory level. During the period of study, top 10% performers showed a decrease in inventories while bottom 10% performers showed inventory growth.
Cannon (2008)	244 firms 1991-2000 Stern Stewart Performance 1000® and Compustat	Percentage increase/ decrease inventory turnover from previous year	ROA, ROI, Tobin's Q, market value added	Improvement in inventory performance is not significantly associated with market value added and Tobin's Q, but negatively associated with ROA and ROI.

Table 3 Studies on inventory leanness and performance (cont.)

	Sample/Data Source	Inventory measure(s)	Performance measure(s)	Results
Koumanakos (2008)	1,358 Greek firms in food, textiles and chemicals sectors 2000-2002 ICAP database	Inventory days	Gross margin Net operating margin	In most sectors, relationships between inventory days and profitability are negative. Linear relationship between inventory holdings and financial performance was found in chemicals sector, but not in food and textiles sectors.
Capkun et al. (2009)	US manufacturing firms 52,254 firm-years 1980-2005 Compustat	Inventory scaled by sales	EBIT Gross profit	A lower inventory-to-sales ratio is positively associated with financial performance, measured by gross and operating profit. The strength of the correlation varies across inventory types.
Eroglu and Hofer (2011)	US manufacturing firms 7804 firm-years, 54 industires 2003-2008 Compustat	ELI	ROA, ROS	In two-thirds of the 54 industries, there is a significant relationship between inventory and financial performance. In most instances, the relationship is concave suggesting an optimal level of inventory leanness beyond which firm performance deteriorates.

Table 3 Studies on inventory leanness and performance (cont.)

	Sample/Data Source	Inventory measure(s)	Performance measure(s)	Results
Isaksson and Seifert (2014)	4,324 US manufacturing companies 1980-2008 Compustat	ELI, Days of inventory	EBIT to sales	Relationships between inventory performance and financial performance varied across industries. Non-linear relationship between inventory leanness and financial performance was found. However, the maximum point of the inverted U-shaped relationship often lied at the extreme end of the sample, suggesting a decreasing return from leanness rather than an optimal level.

3. Research questions

From the literature review, it can be seen that many recent inventory management principles have suggested that carrying inventories is costly, and empirical evidence, primarily in the US, has shown that firms carry lower level of inventories. However, prior research has shown that lower inventory level does not necessarily associate with superior financial performance. Holding lower level of inventory may help companies reduce working capital and lower inventory handling costs. Nevertheless, with lower inventories, companies are also facing with higher risks of supply chain glitch, which in turn, negatively affects shareholder value (Hendricks and Singhal, 2003). Lower level of inventories also increases a firm's reliance on stability of its supply chain and could result in lost sales and/or higher costs from emergency purchases. Production technology and supply chain and market conditions can prevent firms from being successful in using JIT (de Haan and Yamamoto, 1999). As supply chain and market conditions may vary across industries, to achieve a better understanding of relationships between inventory leanness and firm performance, an industry-by-industry analysis is necessary.

While profitability and accounting returns might be able to capture cost savings from carrying lower inventories, accounting measures might not be able to capture costs of shortage and lost sales, as they are much more intangible. In addition, accounting returns may not reflect valuation of firms as viewed by investors. In order to understand whether low inventories are desirable from an investor perspective, an investigation into relationships between inventory leanness and stock returns is also crucial.

With regard to functional form of relationships between inventory leanness and performance, prior research has also yielded mixed results. JIT and inventory leanness carry both costs and benefits. Zipkin (1991) distinguishes between 'pragmatic JIT' and 'Romantic JIT'. 'Romantic JIT' believes in zero inventory and views inventory as 'inherently evil'. From this perspective, companies should not aim at just reducing inventories but eliminating them completely. On the contrary, 'pragmatic JIT' view focuses on improvement of production process in order to smooth flow of materials. From 'pragmatic JIT', inventories are held to compensate for obstacles in the production process, such as long changeover times, machine breakdowns, quality defects and capacity bottlenecks. If these obstacles are lowered, the need to carry inventories will be lowered. While 'Romantic JIT' views inventory reduction as a prompt to factory reforms, 'pragmatic JIT' considers inventory reduction as a result of reforms. From 'pragmatic JIT', once wasteful inventory is eliminated, further inventory reductions will require much more effort, time and expenses. Costs involved in lowering inventory, at this stage, may outweigh the financial benefits that companies can earn. Consequently, from 'pragmatic JIT' view, there is an optimal level of inventory which is not zero.

Drawing on the literature review and discussions above, the paper addresses the following research questions:

1. How is inventory leanness associated with accounting returns?

2. What is the functional form of relationship between inventory leanness and financial performance?

3. How is inventory leanness associated with stock returns?

Firm-level inventory and performance data is used for the analysis. In order to capture industry-specific factors which may have an influence on effectiveness of lean inventory, the analysis is conducted on an industry-by-industry basis. Key variables and description of data and data analysis are discussed in the next section.

4. Research Method

4.1 Sample, data and study period

To answer the first research question, annual accounting data between 2002 and 2014 is collected from the SETSMART database. The database contains financial statement information for firms listed on the Stock Exchange of Thailand (SET). To be included in the sample, firms are required to have positive sales and inventory in order to compute the inventory leanness measure. Industry classification follows SET's sector classification. There are 8 industries which are further sub-classified as 28 sectors. Financial services sectors and sectors which contain less than 5 firms are excluded. After these data restrictions, there are 363 firms with 3,334 firm-year observations, covering 19 sectors. In addition to financial statement information, SETSMART database also contains stock returns data, which can be used to answer the third research question. In addition to the SETSMART database, Thompson Reuters Datastream is used to obtained stock characteristics (i.e. market capitalisation and the book-to-market ratio) in order to construct pricing factors used in the stock returns analysis.

4.2 Key measure – Inventory leanness

There are several approaches for measurement of inventory leanness in the literature. For example, Chen et al. (2005, 2007) employ abnormal inventory days, which is defined as the difference between the inventory days ratio of the particular firm and the industry-level mean of inventory days, scaled by the industry-level standard deviation of inventory days. Another approach by Eroglu and Hofer (2011) uses the studentised residuals from a regression of inventory versus sales for each industry-year to proxy for 'excess' inventory – what the authors refer to as the 'excess leanness indicator', or ELI. The basic idea is that in each industry, the relationship between inventory and sales should be similar; thus, any deviation from the predicted level of inventory suggests that the firm is using too much or too little inventory. In this paper, inventory leanness is classified in the same fashion Eroglu and Hofer (2011).

The first step in calculating the ELI is to regress average total inventories on sales. Following the notation used by Eroglu and Hofer (2011), the regression Equation (1) is estimated. To allow for the relationship in each industry and year to be different, the regression is repeated for each industry i and year t.

$$\ln\left(Inva_{ift}\right) = \alpha_{it} + \beta_{it}\ln\left(Sales_{ift}\right) + u_{ift}, \quad \forall i = 1, \dots, 19, t = 2002, \dots, 2014 \qquad (1)$$

The dependent variable is the natural logarithm of the firm's total inventory between year t and $t-1$, and the independent variable is the natural logarithm of the annual sales volume of firm f in industry i at year t. Industry i is defined as the 19 SET sectors described in the previous section. Overall, these regressions provide a reasonable fit, with the R-squared statistics averaging 77.8% across the 63 industry-year combinations.

As the residuals u_{ift} represent the difference between actual and predicted inventory levels as implied by the model, it can be used to classify firms that keep higher or lower level of inventory compared to their peers. Because researchers are interested in inventory leanness, a measure that increases in value as leanness increases is preferred; consequently, the residuals are multiplied by (-1) so that negative deviations produce positive ELI measures. To ascertain the calculated ELI measure is reasonable, the value of ELI for each firm-year is correlated with inventory turnover ratio for the corresponding firm-year. The average Pearson correlation coefficient across the 19 industries is 70.8%, suggesting that the ELI is indeed related to inventory leanness as required.

4.3 Analyses

4.3.1 Accounting performance

To investigate the relationship between accounting performance and the ELI in each industry, panel regression with fixed effects is employed. Firm fixed effects and year fixed effects are included to control for unobservable characteristics that could potentially affect firm performance. The following regression equation is estimated for each of the 19 industries, where i denotes industry, f denotes firm and t denotes year:

$$Performance_{ift} = \alpha_f + \delta_t + \beta_1 ELI_{ift} + \beta_2 ELI_{ijt}^2 + \beta_3 \ln\left(Assets_{ift}\right) + \beta_4 Growth_{ift} + \varepsilon_{ift}, \quad \forall i = 1, \ldots, 19 \tag{2}$$

The accounting performance measures employed in this study are ROA and ROS. To account for factors that could affect performance measures such as economies of scale, the natural logarithm of firm's total assets ($\ln(Assets)$) and year-on-year percentage change in sales ($Growth$) are included as control variables in the regression equation. The ELI is incorporated in a way that allows for a quadratic functional form to allow greater flexibility in the relationship. The quadratic functional form permits non-monotonic relationship depending on the sign of β_1 and β_2, and for some combinations, an 'optimal' level of leanness may exist. There are 9 possible combinations, which are illustrated in Figure 4 of Eroglu and Hofer (2011).

The summary statistics of the data used in this section is shown in Table 4.

Table 4 Summary Statistics

The following table shows the summary statistics of data used in the analysis of accounting performance and inventory leanness. The main performance variables of interest are return on asset (ROA), which is defined as net income divided by average total assets and return on sale (ROS), which is defined as net income divided by sales. ELI is defined as the studentised residuals of the regression of natural logarithm of inventory on natural logarithm of sales. Growth is defined as the year-on-year percentage increase in sales. ROA, ROS and growth are measured in percentage points – that is, 1 equals 1 percent. Total assets, inventory and sales are measured in units of billion Baht.

Variable	Mean	Std Dev	1st Quartile	Median	3rd Quartile
ROA	1.36	3.15	0.10	1.43	2.85
ROS	6.08	29.92	0.45	5.74	13.21
ELI	0.00	1.00	-0.57	-0.12	0.45
Growth	8.99	30.95	-1.73	4.95	14.06
Total assets (THB bn)	13.64	34.78	1.42	3.17	8.75
Inventory (THB bn)	2.02	4.87	0.15	0.45	1.31
Sales (THB bn)	3.44	9.45	0.29	0.72	1.95

4.3.2 Stock returns

If inventory leanness is beneficial to the firm, then one may expect that superior performance is reflected in the firm's stock returns. As Equation (2) allows the leanness-performance relationship to be quadratic, the analysis in this section will also allow for non-monotonicity. Saengchote (2016) suggests that the portfolio construction method widely used in Asset Pricing research in Finance can be used to investigate business-related questions if firms of interest are listed on the stock exchange. This study will employ the portfolio construction method to explore the relationship between inventory leanness and stock returns. The method is implemented as follows.

In each year, stocks in each industry are sorted by their ELI value in the previous year and partitioned into 3 groups with equal number of firms. Portfolio number 1 contains stocks with lowest ELI, while portfolio number 3 contains stocks with highest ELI (i.e. the leanest inventory). For each portfolio, the equally-weighted average excess return $(xret_{it})$ (defined as the stock's monthly return minus the risk-free rate, measured as Thailand's one-month Treasury bill rate) is calculated every month. The ELI portfolios are rebalanced every year as the ELI is calculated on an annual basis.

If inventory leanness is also reflected in stock returns, one would expect to see the excess return of different portfolios corresponding to the shape found in the accounting performance analysis. For each industry, the differences between the excess returns of portfolio 2 versus portfolio 1 $(xret_{it}^{2-1})$, and portfolio 3 versus portfolio $(xret_{it}^{3-2})$ can be tested via the two-sample t-test to see of the differences are statistically significant.

In order to ascertain that the differences are indeed due to inventory leanness and are not driven by other stock characteristics, such as their exposure to systematic risk, size or growth opportunities, the differential excess returns can be regressed on the pricing factors to isolate the portion of returns differentials that could be attributed to known characteristics. In this study, the pricing factors used follow the three factors proposed by Fama and French (1993), i.e. (1) the excess return on the market (MRP), (2) the performance of small stocks relative to big stocks (SMB), and (3) the performance of value stocks relative to growth stocks (HML). The factors for the Thai stock market can be constructed with data obtained from SETSMART and Datastream. For each industry, the following regression equation is estimated on the differential excess returns:

$$xret_{it}^{k} = \alpha_{kt} + \beta_{M} MRP_t + \beta_{SMB} SMB_t + \beta_{HML} HML_t + \nu_{it}^{k}, \qquad \forall i = 1, \dots, 19 \qquad (3)$$

Where k denotes the two differential portfolios, 2 minus 1 and 3 minus 2, as described above. The coefficient of interest here is α_{kt}, which captures the systematic abnormal returns which are not explained by pricing factors; in other words, it signifies that the returns differential can plausibly be attributed to differences in inventory leanness.

5. Empirical Results

5.1 Inventory leanness and accounting returns

Empirical results presented in Table 5 and Table 6 indicate that relationships between inventory leanness and firm performance vary across industries. These results are consistent with findings of previous studies (Koumanakos, 2008; Eroglu and Hofer, 2011; Isaksson and Seifert, 2014). When using ROA as a measure of firm performance, in 9 out of 19 industries (47%) investigated, no statistically significant association between inventory leanness and firm performance is found. In 6 industries (32%), the analysis indicates a linear form of relationship while an inverted U-shaped relationship is found in another 3 industries (16%). In one industry (5%), a U-shaped relationship is found. When using ROS as a measure of firm performance, results are generally similar. As the model tends to fit ROA better than ROS (as indicated by the adjusted R-squared statistics), the discussion that follows will focus on the shapes that correspond to ROA.

Various factors, at both firm and industry levels, could have an impact on effectiveness of lean inventory strategy, for example, product life cycle, demand uncertainty, industry size, and industry profitability (Mason-Jones, Naylor and Towill, 2000; Eroglu and Hofer, 2011). The industries in which a linear relationship is found are Agribusiness, Information and Communication Technology, Energy, Home and Office Products, Fashion and Steel industries, while the industry which a U-shaped relationship is found is Media.

A linear relationship and a U-shaped relationship suggest that for these industries, firms which are leaner than industry average exhibit superior performance. For Agribusiness, Information and Communication Technology, Fashion and Media industries, many of the products have short life cycles and some of them are perishable. Firms which carry low inventories face with lower risks of obsolete inventories. As for Energy, Home and Office Products and Steel industries, products tend to be well-established with a known consumption pattern, therefore, low demand uncertainty. As Mason-Jones et al. (2000) have argued, firms which have products with low demand uncertainty should focus on cost reduction in managing their supply chain. For these companies, lowering inventory level can help them save costs with no significant impact on their

Table 5 Inventory Leanness and ROA

The following table reports selected coefficients of the regression Equation (1). Only coefficients β_1 and β_2 corresponding to ELI and ELI-squared which govern the shape of the relationship between inventory leanness and performance measure are reported. The shapes implied by the estimated coefficients are reported. At least one coefficient must be statistically significant at 10% level in order for a shape to be designated. The performance measure of interest in this table is ROA, which measures the efficiency with which firm's assets are deployed. Equation (1) is estimated separately for each industry. Stars denote the level of statistical significance associated with the coefficient, with *, ** and *** indicating 10%, 5% and 1% level of significance respectively.

Industry	AGRI	FOOD	FASHION	HOME	PERSON	AUTO	IMM	PETRO	PKG	STEEL
Shape	Inc-Linear		Inc-Linear	Inc-Linear		Inv-U				Inc-Linear
ELI	0.572*	0.371	0.789**	1.562***	0.925	1.253***	0.950	0.149	0.00994	0.637*
ELI-squared	0.0276	-0.00741	0.0453	-0.100	-0.258	-0.284*	-0.0282	-0.276	-0.0168	0.0731
Observations	201	297	286	110	52	192	56	145	165	71
Adj. R-squared	0.322	0.439	0.290	0.162	0.749	0.338	0.370	0.413	0.186	0.296

Industry	CONMAT	PROP	ENERG	COMM	HELTH	MEDIA	TOURISM	ETRON	ICT
Shape	Inv-U	Inv-U	Inc-Linear			U-Shaped			Inc-Linear
ELI	1.333***	1.327***	0.994**	0.268	0.252	0.953	0.460	0.924	1.647**
ELI-squared	-0.481***	-0.185***	-0.148	-0.0226	0.0370	0.198*	-0.0140	0.186	-0.183
Observations	231	337	195	159	152	165	148	126	246
Adj. R-squared	0.362	0.413	0.232	0.498	0.279	0.464	0.365	0.342	0.259

Table 6 Inventory Leanness and ROS

The following table reports selected coefficients of the regression Equation (1). Only coefficients β_1 and β_2 corresponding to ELI and ELI-squared which govern the shape of the relationship between inventory leanness and performance measure are reported. The shapes implied by the estimated coefficients are reported. At least one coefficient must be statistically significant at 10% level in order for a shape to be designated. The performance measure of interest in this table is ROS, which measures the profitability of the firm. Equation (1) is estimated separately for each industry. Stars denote the level of statistical significance associated with the coefficient, with *, ** and *** indicating 10%, 5% and 1% level of significance respectively.

Industry	AGRI	FOOD	FASHION	HOME	PERSON	AUTO	IMM	PETRO	PKG	STEEL
Shape				Inc-Linear		Inc-Linear				Dec-Linear
ELI	4.644	1.782	3.399	6.548***	5.622	6.644**	5.765	2.576	-7.001	-15.59**
ELI-squared	1.033	-0.301	-0.304	-0.802	-1.922	0.574	-0.672	-0.438	1.560	-5.515
Observations	201	297	286	110	52	192	56	145	165	71
Adj. R-squared	0.137	0.392	0.122	-0.106	0.603	0.346	0.395	0.336	0.075	0.455

Industry	CONMAT	PROP	ENERG	COMM	HELTH	MEDIA	TOURISM	ETRON	ICT
Shape	Inv-U	Inv-U				U-Shaped			
ELI	10.94**	21.41***	12.36	4.731	3.943	8.817	-7.420	2.699	7.537
ELI-squared	-7.987***	-2.718*	-1.615	-4.093	1.369	0.853*	-1.269	0.789	-0.345
Observations	231	337	195	159	152	165	148	126	246
Adj. R-squared	0.336	0.273	0.429	0.372	0.066	0.450	0.213	0.378	0.332

ability to respond to customers' needs. Therefore, lean inventory strategy is likely to be effective.

While a linear and U-shaped associations suggest that leaner firms have superior financial performance, an inverted U-shaped relationship indicates that firms with leaner inventories generally exhibit positive returns but only at a decreasing rate. When the inventory leanness reaches certain level, the incremental benefits from inventory leanness become negative. That is, there is an optimal degree of leanness (Eroglu and Hofer, 2011). Based on empirical results, an inverted U-shaped relationship is found in Property Development, Automotive and Construction Materials industries. For Property Development and Construction Materials, the production process has a long lead time. These firms need to carry certain level of inventories; otherwise, they would face a risk of not being able to respond to customers' needs. Such nature of their production process may help explain why financial performance is worsened when firms become too lean. As for Automotive industry, majority of automotive companies listed on the SET are original equipment manufacturers (OEMs), manufacturing auto-parts for foreign assembling plants, such as Toyota, Honda and Nissan. Competition among the OEMs is intense, and foreign assembling plants have put pressure on the domestic OEMs to enhance their flexibility (Boonsthonsatit and Jungthawan, 2015). With such pressure, the domestics OEMs which carry too low inventories are risking not being able to meet the foreign assembling plants' demands.

5.2 Inventory leanness and stock returns

In this part, the 10 industries that exhibit statistically significant relationship between ROA and inventory leanness are further investigated to see if the relationship also holds when stock returns are used as a measure of performance. First, firms in the 10 industries are classified annually based on their ELI. Table 7 presents the average ELI of stocks classified into 3 equally-divided portfolios. Portfolio 1 contains stocks with the least inventory leanness, and their ELI are negative; portfolio 2 contains stocks with moderate leanness with ELI around 0; finally, portfolio 3 contains stocks with the highest level of inventory leanness, with ELI in excess of 1.

Table 7 Average ELI of ELI-sorted Portfolio

This table shows the average ELI of stocks sorted by ELI and classified into portfolios by industry. Portfolios are formed and rebalanced annually. Portfolio 1 contains stocks with the lowest values of ELI (least lean) and portfolio 3 contains stocks with the highest values of ELI (leanest).

Portfolio	1	2	3
Industry	Least Lean		Leanest
AGRI	-0.99	-0.08	1.37
FASHION	-1.12	0.09	1.14
HOME	-1.05	0.17	1.29
AUTO	-1.13	0.12	1.18
STEEL	-0.98	-0.13	1.22
CONMAT	-1.02	0.05	1.14
PROP	-0.78	-0.15	1.06
ENERG	-0.93	-0.13	1.38
MEDIA	-0.85	-0.18	1.64
ICT	-0.90	-0.19	1.43

Next, average excess returns $(xret_{it})$ are calculated for each portfolio and industry, and the results are presented in Table 8. For industries which exhibit increasing linear relationship between accounting performance and inventory leanness to show the same relationship in stock returns, one would expect to see the excess returns of portfolio 2 be greater than portfolio 1, and portfolio 3 be greater than portfolio 2 respectively. The results are mixed: Of the 6 industries that are classified as having linear relationship, only Steel exhibits a monotonic relationship while the rest are mixed. For the 3 industries that have inverted U-shaped relationship, none of the results is in the same direction as one might expect. Finally, for the Media industry, a U-shaped relationship found using ROA is mirrored in excess returns.

Table 8 Excess Returns of ELI-sorted Portfolios

This table shows the equally-weighted average excess returns of stocks sorted by ELI and classified into portfolios by industry. Portfolios are formed and rebalanced annually. Returns are calculated as total return (capital gains plus dividends) at the monthly frequency, and excess returns are calculated by deducting the one-month Treasury bill rate (calculated over one month holding period) from the monthly total return. Portfolio 1 contains stocks with the lowest values of ELI (least lean) and portfolio 3 contains stocks with the highest values of ELI (leanest).

Portfolio Industry	1 Least Lean	2	3 Leanest	Shape of ROA-ELI relationship
AGRI	0.693%	0.456%	0.912%	Inc-Linear
FASHION	0.237	1.065	0.527	Inc-Linear
HOME	0.974	1.443	1.039	Inc-Linear
AUTO	0.396	0.774	1.161	Inv-U
STEEL	-1.535	0.976	1.626	Inc-Linear
CONMAT	0.703	1.175	1.295	Inv-U
PROP	1.068	0.877	0.961	Inv-U
ENERG	1.522	0.580	1.603	Inc-Linear
MEDIA	0.239	0.021	0.708	U-Shaped
ICT	0.796	1.435	0.659	Inc-Linear

The differences between portfolios with different inventory leanness can be investigated more rigorously by examining the differences between the average returns of two different portfolios. For example, take the average returns of portfolio 1 and portfolio 2 for the Steel industry. The average excess returns for portfolio 2 is 0.976% per month, while the average for portfolio 1 is -1.535% per month. The differences between the excess returns of the two portfolios is 2.51%, but is this difference statistically significant? With excess returns data from two different samples, one can use the student t-test to investigate. In this case, the differences between the two is statistically significant at 5% level. The same exercise can be repeated for other industries and portfolio pairs, and the results are reported in Panel A of Table 9.

Table 9 Excess Returns of Differential Portfolios

This table shows the differential returns between portfolios with different levels of inventory leanness. For example, the excess returns of the differential portfolio 2 minus 1 in each month is calculated as the excess returns of portfolio 2 minus excess returns of portfolio 1. Panel A presents the raw excess returns, while panel B presents the Fama-French 3-Factor alpha estimated using Equation (3). Stars denote the level of statistical significance associated with the coefficient, with *, ** and *** indicating 10%, 5% and 1% level of significance respectively.

	Panel A: Excess Returns		Panel B: 3-Factor Alpha		
	Differential Portfolio		Differential Portfolio		Shape of
Industry	2 minus 1	3 minus 2	2 minus 1	3 minus 2	ROA-ELI relationship
AGRI	-0.237%	0.456%	-0.416%	0.376%	Inc-Linear
FASHION	0.828**	-0.538	0.482	-0.320	Inc-Linear
HOME	0.469	-0.404	0.392	-0.418	Inc-Linear
AUTO	0.377	0.387	0.600	0.102	Inv-U
STEEL	2.512**	0.650	2.150	0.022	Inc-Linear
CONMAT	0.471	0.121	0.642	-0.050	Inv-U
PROP	-0.190	0.084	-0.338	0.395	Inv-U
ENERG	-0.941**	1.023**	-0.763	0.809	Inc-Linear
MEDIA	-0.218	0.687	0.085	0.663	U-Shaped
ICT	0.639	-0.776	0.425	-0.716	Inc-Linear

Of the 20 industry-portfolio-pairing combinations, only 4 are statistically significant. Firms with higher inventory leanness in the Fashion, Steel and Energy industries tend to provide higher excess returns. These return differences are all statistically significant at 5% level. However, are these differences truly attributable to inventory leanness or are they driven by other firm-specific characteristics that are not currently controlled for? The factor pricing model allows for such characteristics to be incorporated, and any unexplained return differences that are statistically significant could then more confidently attributed to inventory leanness. To implement this, Equation (3) is estimated for all industry-portfolio-pairing combination, and the resulting alphas are reported in Panel B of Table 9. Once pricing factors are incorporated, the return differences are no longer statistically significant: Inventory leanness does not seem to deliver abnormal stock market performance.

Although the analysis of associations between inventory leanness and accounting performance shows some statistically significant relationships, further analysis of inventory leanness and stock returns shows no statistically significant difference in returns between low and high ELI portfolios in all industries. These findings are inconsistent with Chen et al. (2005, 2007) which find that firms with abnormally high inventories exhibit poor stock returns. Empirical findings from the study seems to suggest that the investors in the SET are not concerned about inventory level.

6. Conclusion

This paper examines relationships between inventory level and firm performance. The study is based on a sample of Thai companies listed on the SET between 2002 and 2014. Following Eroglu and Hofer (2011), the study uses the ELI to measure inventory leanness, as it takes into account economies of scale and industry-specific norms. The analysis of firm performance is extended to stock returns using portfolio construction method. When using stock returns as proxies for firm performance, no statistically significant relationship is found suggesting that inventory leanness may not matter to investors in the SET. However, when using accounting returns as measures for firm performance, empirical results from the study indicate that inventory leanness is associated with superior performance but only in some industries. And among these industries, forms of relationships vary. While in some industries, an inverted U-shape form is found, suggesting 'pragmatic JIT' view, in other industries, a linear or a U-shaped relationship is found supporting 'romantic JIT' view. Findings from the study confirms the necessity of an industry-by-industry analysis (Eroglu and Hofer, 2011; Isaksson and Seifert, 2014).

With variations in significance and form of relationships across industries, one key managerial implication is that managers should consider product, production, technology, demand and supply characteristics of the industry to evaluate whether and the extent to which lean inventory strategy should be adopted. This is by no means suggesting that firms in the industries which no significant relationship is found would not gain any benefits from lean management principles. Rather, it suggests that these firms may wish to consider focusing on other aspects of lean management rather than on lean inventory specifically.

It should be noted that caution should be exercised when interpreting the results. Correlations between inventory leanness and financial performance do not imply causality. As any study, the study is subject to limitations, and several areas for further research can be identified. The study relies on accounting data to measure inventory leanness. More detailed insights on inventory reduction programs of firms could help enhance our understanding why lean inventory strategy is effective for some firms but not for others. In addition, although lean inventory forms an important part of lean management principles, other elements of lean management could have a significant impact on firm performance. A further investigation into broader package of lean management could shed lights on interactions of various lean elements and how they may affect firm performance. Moreover, an analysis of sub-components of inventories could provide further insights into inventory management strategy.

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