



The role of innovation in inventory turnover performance



Hsiao-Hui Lee^{a,*}, Jianer Zhou^b, Po-Hsuan Hsu^a

^a Faculty of Business and Economics, University of Hong Kong, Hong Kong

^b Carroll School of Management, Boston College, Chestnut Hill, MA 02467, USA

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ABSTRACT

How a firm utilizes technological innovation to improve operations management is an important research question in today's knowledge economy but lacks empirical evidence in the literature. We use a dataset of all non-service U.S. public firms from 1976 to 2005 to examine how a firm's innovation performance is associated with its inventory turnover performance. In particular, we measure a firm's innovation performance by the ratio of its patents (either citations or counts) to its research and development (R&D) expenditure. Our fixed-effect panel regression results indicate a positive relation between innovation performance and inventory turnover ratio, and such a relation varies across industries. By differentiating process and product innovation according to patent usages, we find that process innovation has a consistent and long-lasting effect, whereas product innovation has an immediate but short-lasting effect. We also find supporting evidence for industry spillovers by showing that firms in a more innovative industry are likely to better manage their inventory performance. Our results confirm the benefit of using innovation in logistics and operations management and point to the strategic importance of integrating technology and operations management.

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1. Introduction

Over the past decade, firms have been investing heavily in innovation to maintain their competitive advantage. *Science and Engineering Indicators: 2010* [39] reports that global R&D expenditures doubled from \$525 billion in 1996 to \$1.1 trillion in 2007. The U.S. led all other countries in R&D expenditure, with \$369 billion in 2007. Among many innovative firms in the U.S., Apple Inc. spent \$1.8 billion in R&D (about 2.7% of its net sales) and filed 262 patent applications in 2010, according to the U.S. Patent and Trademark Office. Believing that “the ownership of such patents, copyrights, trademarks and service marks is an important factor in its business and that its success does depend in part on the ownership thereof”, Apple Inc. stated in its 2010 Annual Report that “[t]he Company regularly files patent applications to protect inventions arising from its research and development, and is currently pursuing thousands of patent applications around the world.” With innovative products such as iPhone and iPad and the adoption of *lean operations* throughout its supply chain, Apple Inc. has become one of the most valuable companies in the world. Moreover, Apple Inc. had an inventory turnover of 52.5 in 2010 (calculated from its 2010 Annual Report), much

higher than the industry average of 9.1 in the HiTech segment (calculated from the Compustat dataset). Given that firms like Apple Inc. deploy more resources in innovation to sustain their competitive advantage, the way in which innovation influences inventory management performance is an important issue and calls for empirical investigation.

Previous research mainly associates a firm's innovation with its financial performance measures [2,16,17,28], or associates a firm's tangible assets with its operational performance measures [13,34,50]. However, there has been little empirical work analyzing the impact of a firm's innovations on its inventory management, with the exception of the following papers focusing on specific process innovation. Balakrishnan et al. [3] and Huson and Nanda [25] investigate the improvement of inventory turnover after firms adopt just-in-time (JIT) manufacturing, a type of process innovation that moves inventories through the system as they are needed. However, to what extent product innovation (or together with process innovation) affects inventory performance remains an open question.

Instead of focusing on the effect of specific process innovation, we broadly investigate the relationship between a firm's innovation performance (including both process and product innovation) and inventory turnover in the paper. Based on the accounting and patent data of 6695 non-service U.S. public firms from 1976 to 2005 (the sample period is restricted by the availability of patent data), we examine the impact of innovation on inventory turnover by using fixed-effect panel regression models that consider both the firm and yearly fixed effects. Even with the control variables from the

* Corresponding author. Tel.: +852 3917 1082.

E-mail addresses: hhlee@hku.hk (H.-H. Lee), jianer.zhou@bc.edu (J. Zhou), paulhsu@hku.hk (P.-H. Hsu).

literature and the firm and yearly fixed effects, both process and product innovation exhibit a significantly positive correlation with inventory turnover, implying that a more innovative firm is likely to be more efficient in managing its inventory.

More interestingly, we examine how time and industry characteristics affect the impact of innovations on inventory turnover. First, because innovation can have profound implications for a firm's operational performance over time, we investigate the impact of innovation on inventory turnover in three consecutive years (year 0 to year 2). We find that in general innovation has a lasting but declining effect on inventory turnover, which indicates that an older invention has less influence than a newer one does. However, after differentiating "process-focused" firms from "product-focused" ones, we show that process innovation has a stronger and long-lasting effect on inventory turnover than product innovation does. This result implies that process innovation improves inventory turnover by facilitating ordering/delivery processes or reducing inventories in the long run whereas product innovation does it mainly by stimulating sales in the short run. Second, by examining the ten industry segments, we also observe that the declining effect might be reversed if firms (e.g., in the automobile industry) produce products with a longer development and product life cycle. Finally, we inspect the role of innovation spillovers in inventory management by including the industry-level innovation variables in regressions. We find that the same-year industry-level innovation variable has a significantly positive coefficient in explaining inventory turnover, suggesting that firm-level innovation and industry spillovers play distinct and substantial roles in inventory management. However, spillovers do not have a long-lasting effect, indicating that, to continuously improve operational performance, firms have to rely on their own innovation capabilities instead of simply copying their competitors. It is worth noting that our results are robust to alternative innovation measures (patent citations, patent counts, or citations per count), industry classifications, time-varying industry effects (by using industry-adjusted models), and inclusion or exclusion of non-innovative firms. Thus, our empirical findings cannot be attributed only to tangible assets, firm and industry characteristics, or macroeconomic conditions.

Our research makes four significant contributions to the innovation management literature. First, not only are we, to the best of our knowledge, the first to empirically link innovation to firms' operational performance, but also, in doing so, we find that firms with better innovation performance achieve higher inventory turnover. Second, we demonstrate how innovation affects inventory turnover with the declining coefficients of the innovation variables in the three yearly windows. Third, by comparing firms intensive in process innovation with those intensive in product innovation, we find that process and product innovations play distinct roles in inventory turnover performance. This result provides new insights into why firms should devote resources to improving their processes in order to achieve superior inventory performance in the long run. Fourth, we show the positive effect of industry-level innovation on firm-level inventory turnover, which supports the idea of innovation spillovers and adds to the literature of technology externalities from an operations management perspective.

2. Theory and hypothesis

When applying innovations in their businesses, firms could achieve higher inventory turnovers by either generating more sales in the market or by reducing inventories in the production process. Manu and Sriram [36] suggest a need to examine innovation in multiple dimensions, e.g., innovation type. We therefore first motivate our hypothesis by discussing how the two types of innovation—*product innovation* and *process innovation*—might be associated with inventory turnover.

2.1. Product innovation and inventory turnover

Product innovation—the introduction of a new or improved product—mainly affects inventory turnover by identifying/satisfying new customer demand and hence generating more sales. The Bass diffusion model [4] illustrates the demand pattern for a new product over the product life cycle. Thus, inventory turnover is mostly determined by how the firm matches its capacity and inventory with the diffusion process. According to Norton and Bass [41] that extends the Bass model to incorporate successive generations of technology, if a firm invents new products on a regular basis, the same Bass diffusion process is valid for each generation. This result implies that the effect of each product innovation on inventory turnover could be repetitive and consistent, and a firm might achieve a more accurate demand forecast for its new products over successive innovations by refining its coefficient estimates of innovation and imitation in the Bass diffusion model. As a result, changes in market demand can result in high inventory turnover if the firm uses advanced techniques to promptly adjust its production line and supply chain according to the more precise demand forecast. Rodgers [45] proposes the diffusion of innovation theory and argues that relative advantage, technical compatibility, and technical complexity can affect the rate of innovation adoption. Following this theory, Zhang et al. [57] show that firms (e.g., designing social virtual world) can accelerate sales of a new product by simplifying its configuration and reducing customer learning. Moreover, although an increase in sales leads to an increase in inventory, such increase is usually less than proportional because of the economy of scale [43]. It follows that product innovation is positively associated with inventory turnover.

However, as product innovation affects inventory turnover mainly by improving sales, considering fast new-product introductions and short product life cycles in recent decades, we hypothesize that the impact of product innovation on inventory turnover can be short-lived, that is, product innovation may affect sales significantly only in the same year. We state our first hypothesis formally as follows:

Hypothesis 1. Product innovation is positively correlated with inventory turnover; its effect on inventory turnover is immediate but short-lasting.

2.2. Process innovation and inventory turnover

Process innovation affects inventory turnover mainly by either facilitating orders and sales or reducing the inventory level in the production process. The former effect (i.e., facilitating orders and sales) receives support from prior studies showing that inventions in coordinating supply-chain participants result in growing and more cost-efficient sales [23], fewer out-of-stock problems [27], and more efficient replenishment [32]. Such an effect can also be illustrated by the following examples from the patent database. Stamps.com Inc. filed a patent (No. 7,035,832) in 2004 for its system and method of automatically providing information of shipping and transportation fees to its customers. Kroger, a retail food chain, was granted a patent (No. 7,124,098) in 2006 for its shopping system that permits a customer to submit online orders for items/services from a store that serves both walk-in and online customers. This system allows customers to change their shopping decisions even after submitting their orders, and allows customers to pick up their orders. Both process innovations can potentially generate more sales by improving customer shopping and ordering experience, which in turn lead to higher inventory turnover.

We next elaborate on the latter relation (i.e., reducing the inventory level) from three perspectives: flow time, defects, and safety stocks. If a process innovation (such as an improvement in the manufacturing process) is successful, it can reduce production cost, increase production efficiency, and/or improve product quality. Process innovation will result in improved performance if it leads to more flexible, responsive, coordinative, and team-oriented work at the operational level, as suggested in

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