Inventory leanness, risk taking, environmental complexity, and productivity

A mediated moderation model

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Abstract

Purpose – The purpose of this paper is to examine the effect of inventory leanness on productivity. In particular, the authors explore the moderating role of environmental complexity and the mediating role of risk taking.

Design/methodology/approach – In the mediated moderation analysis of the relationship among inventory leanness, risk taking, environmental complexity and productivity, the authors adopt the instrumental variable method to test the hypotheses based on data collected from 1,709 Chinese listed manufacturing firms.

Findings – The results show that there is an inverted U-shaped relationship between inventory leanness and productivity. The authors then demonstrate the role of risk taking in mediating this relationship. Furthermore, the authors find that environmental complexity not only negatively moderates the relationship between inventory leanness and productivity, but also negatively moderates the relationship between risk taking and productivity.

Practical implications – Managers should not be excessively pursuing inventory leanness improvements, so as not to damage the ability to increase productivity.

Originality/value – This paper may be the first study to empirically demonstrate the moderating effect of environmental complexity and the mediating effect of risk taking on the inverted U-shaped relationship between inventory leanness and productivity.

Keywords Environmental impact, Inventory management, Production management

Paper type Research paper

1. Introduction

Inventory management has become one of the most prominent fields in operations management. From the perspective of lean philosophy, inventory is always supposed to be a waste and should be eliminated (Womack *et al.*, 1990; Eroglu and Hofer, 2011). As a result, inventory reduction is believed to be positively related to productivity growth (Lieberman and Asaba, 1997; Lieberman and Demeester, 1999). This conclusion provides preliminary evidence for managers to understand the importance of inventory management for their productivity growth. However, in practice, the presence of demand fluctuation and storage cost may deeply affect inventory management (Nakandala *et al.*, 2017), and, consequently, too low or too high inventory holding may reduce productivity. Inventory leanness, an important indicator of inventory management, has garnered worldwide attention due to the ability to better capture relative inventory reduction for similar size firms within the same industry (Eroglu and Hofer, 2011; Isaksson and Seifert, 2014). Therefore, the relationship between inventory leanness and productivity is of great significance in the context of modern production and operations management.

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Prior studies mainly argue the importance of inventory leanness in improving financial performance and highlight the nonlinear impact of inventory leanness. Concerning productivity, the literature focuses primarily on the relationship between inventory reduction and productivity. However, inventory reduction ignores the importance of firm size and industry-level characteristics, which may lead to selection bias. To address this problem, we employ inventory leanness to capture inventory reduction as this indicator has controlled the firm size and industry heterogeneity (Eroglu and Hofer, 2011). In addition, previous studies have concentrated on the nonlinear impacts of inventory leanness. Then, there seems to be an implicit assumption that much more inventory leanness may not always lead to better productivity. Therefore, we question the simplistic linear relationship between inventory leanness and productivity in order to better understand how inventory leanness impacts productivity by showing that risk taking provides significant linking effects between inventory leanness and productivity, indicating a mediating role of risk taking on this relationship. Moreover, we examine when these linking effects are further boosted—that is, in the presence of environmental complexity, indicating a moderating impact on this relationship. Thus, the aim of this paper is to add to our understanding of inventory management by exploring the relationship between inventory leanness and productivity, with a focus on the mediating role of risk taking and the moderating role of environmental complexity. Results of this research are central to the field of operations management and of high practical relevance. However, empirical evidence remains scarce.

This study contributes to existing literature in several ways. First, this paper contributes to the fast-growing literature that empirically investigates the relationship between inventory leanness and productivity. While previous studies only focus on the linear impact of inventory reduction on productivity, the use of nonlinear functional form provides a richer perspective on this relationship. To our knowledge, this is the first study to empirically examine the inverted U-shaped relationship between inventory leanness and productivity. Second, identifying risk taking as a mediating process may advance understanding of the influence of inventory leanness on productivity. Prior studies on the role of risk taking mainly focus on its effects on productivity, while largely ignoring the effects of inventory leanness on risk taking. Finally, we propose that environmental complexity moderates the relationship between inventory leanness and productivity, but also moderates the impact of risk taking on productivity. As a result, we further test whether risk taking mediates the moderating effect of environmental complexity on the relationship between inventory leanness and productivity.

The data used in empirical analysis come from a large set of listed manufacturing firms in China over the period from 2003 to 2014. Empirical results provide detailed insight into the linkages among inventory leanness, risk taking, environmental complexity and productivity, thereby contributing to the theory of inventory management. Furthermore, to minimize endogenous problems caused by reverse causality or omitted variables, we apply the instrumental variable (IV) method and employ the two-stage least squares (2SLS) estimator to make the empirical analysis.

The rest of the paper is organized as follows. The relevant literature is reviewed, and hypotheses are proposed in Section 2. Then, Section 3 provides the data and measurement issues. In Section 4, we present the 2SLS/IV estimation results to test our hypotheses. In Section 5, we discuss our findings, research and managerial implications. Finally, Section 6 addresses the limitations of our study, and opportunities for future research.

2. Literature review and hypothesis development

2.1 Inventory leanness and productivity

Inventory leanness refers to the ability to optimize inventory, which could capture the relative reduction in inventory among firms of similar size, and has always been regarded as an important indicator of inventory management recently (Eroglu and Hofer, 2011). As inventory flows from node to node along supply chains, inventory management is critical to smooth production process and increase productivity (Lieberman and Demeester, 1999; Koumanakos, 2008; Cannon, 2008). From the perspective of inventory leanness, when wastes caused by excess inventory are eliminated, it is bound to bring the cost advantage and maximize the output-to-input ratio (Barker and Santos, 2010; Sharma and Mishra, 2012; Mishra *et al.*, 2013). There is, thus, a natural linkage between eliminating excess inventory and improving the production process. In this view, inventory leanness is not mainly so much about cash flow, but about changes in productivity. However, recent research works on inventory leanness mainly focus on the impact on financial performance, not on productivity (Eroglu and Hofer, 2011; Isaksson and Seifert, 2014; Elking *et al.*, 2017). Concretely, Eroglu and Hofer (2011) argued that the relationship between inventory leanness and financial performance may be nonlinear by using a large set of US manufacturing firms. In their subsequent articles, this relationship is demonstrated to be inverted U-shaped, and partially be moderated by environment dynamic based on similar samples (Eroglu and Hofer, 2014). Furthermore, Isaksson and Seifert (2014) also provided evidence on the inverted U-shaped relationship between inventory leanness and financial performance by employing the IV method analysis. However, with respect to productivity, relative studies mainly focus on the relationship between inventory reduction and productivity growth. Specifically, Lieberman and Asaba (1997) argued that inventory reduction is closely related to productivity growth by comparing the Japanese and US automotive industries. Furthermore, the empirical analysis on firm-level historical data of 52 Japanese automotive companies from the late 1960s to the early 1980s indicates that inventory reduction has a positive effect on productivity growth. More detailed tests suggest that on average, labor productivity can gain 1 percent growth after reducing inventories by 10 percent (Lieberman and Demeester, 1999).

In line with prior studies (Lieberman and Demeester, 1999; Eroglu and Hofer, 2011; Isaksson and Seifert, 2014), inventory leanness may impact productivity from two aspects. On the one hand, inventory leanness can reduce inventory carrying costs and management costs, but also improve customer response time and responsiveness to demand changes. On the other hand, according to the traditional inventory management theory, some operational problems may be covered up such as poor work balancing, low process quality and vendor delinquency under high inventory (Ortega and Lin, 2004; Wang *et al.*, 2010; Slack *et al.*, 2013). Inventory leanness could help solve problems in the production process, such as rework, long setup time and machine failure. Moreover, eliminating wastes caused by excess inventory has become an effective way for enterprises to gain the cost advantage (Obermaier and Donhauser, 2012; Manzouri *et al.*, 2014). Therefore, enterprises with high inventory leanness can spend more on innovation activities and hold enough skilled workers, thus enjoying high productivity growth (Arvanitis, 2005; Cassiman and Veugelers, 2006; Eroglu and Hofer, 2011). However, when the inventory on hand cannot meet demand, the shortage, also called the stockout, makes it impossible for enterprises to maintain enough inventory to satisfy customer demand, resulting in a decline in customer consume willingness and satisfaction (Eroglu and Hofer, 2011). Hence, inventory leanness is not haphazard and sudden (Bragg, 2010). As many causes of inventory exist including fluctuations in the supply of materials or labors, poor quality, demand uncertainties and machinery breakdowns, chaos would be a result if we overpursue the improvement of inventory leanness. Inventory control theory suggests that there is an optimal level of inventory that depends on trade-offs among multiple factors such as shortage costs, inventory carrying costs and production technology (Chen *et al.*, 2005; Nahmias and Olsen, 2015). Therefore, the relationship between inventory leanness and productivity may be the inverted U-shaped. Taken together, we propose the following hypothesis:

H1. Inventory leanness has an inverted U-shaped relationship with productivity.

2.2 Inventory leanness and risk taking

Corporate risk taking refers to the tendency of firms to chase high margins through selecting high-risk and high-yielding projects in investment decisions (Lumpkin and Dess, 1996; Boubakri *et al.*, 2013). As argued by Arif and Lee (2014), entrepreneurs would be more risk appetite under fine economic environment (McLean and Zhao, 2014). Bargeron *et al.* (2010) provided evidence that institutional arrangement is closely related to risk taking by investigating the impact of Sarbanes–Oxley. From the perspective of corporate management, Nakano and Nguyen (2012) demonstrated the positive relationship between board size and risk taking based on Japanese samples. However, this relationship may also be negative (Cheng, 2008; Wang, 2012). Similarly, prior studies also provide mixed results on the relationship between equity incentives and risk taking (Coles *et al.*, 2006; Hayes *et al.*, 2012). In addition, empirical evidence suggests that ownership structure is also closely associated with risk taking.

As mentioned above, we could find that prior studies mainly stress the importance of business management and institutional factors in impacting risk taking. Few literatures focus on the impact of operational management, especially the impact of inventory management. In our study, we try to explore the relationship between inventory leanness and risk taking in two ways. First, from the perspective of credit rating, Bendig *et al.* (2017) first demonstrated the inverted U-shaped relationship between inventory leanness and credit rating based on US data from 1985 to 2012. Meanwhile, Kuang and Qin (2013) indicated that credit rating-troubled firms will gear down managerial incentives of risk taking, which provides evidence on the linkage between credit rating and risk taking. That is, inventory leanness may concavely impact risk taking through credit rating. The second, perhaps more important, is that inventory leanness plays an importing role in relaxing cash flow by eliminating excess inventory, and the impact of inventory leanness on cash flow may be concaved (Eroglu and Hofer, 2011; Hofer *et al.*, 2012; Zhu and Lin, 2017). Furthermore, it is argued that adequate cash flow helps to counteract the risk caused by uncertainty factors and improve manager self-confidence, thus encouraging entrepreneurs to take some risk-taking actions. As a result, there may be a trading-off between inventory leanness and risk taking. Therefore, we hypothesize:

H2. Inventory leanness has an inverted U-shaped relationship with risk taking.

2.3 The mediating role of risk taking

Currently, the relevant studies on risk taking mainly focus on its impact on financial performance, but few of which involve productivity. Concretely, results regarding the relationship between risk taking and financial performance are mixed. Taking firm value as an example, it is argued that risk taking helps in accelerating capital accumulation and technology improvement, thus improving firm value (Dushnitsky and Lenox, 2006; Faccio *et al.*, 2016). However, empirical studies also provide evidence that risk taking may harm firm value (Armstrong and Vashishtha, 2012; Pérez-González and Yun, 2013). In this, Habib and Hasan (2015) intended to explain these mixed results from the perspective of enterprise life cycle theory. They indicated that the relationship between risk taking and performance is positive for both growing and maturing firms, while this relationship may be negative during the periods of development and recession. With respect to the impact of risk taking on productivity, John *et al.* (2008) argued that firms in high-risk-taking country usually enjoy better productivity, which provides the preliminary evidence that risk taking may be positively related to productivity.

To address this relationship, we try to explain the impact of risk taking on productivity from two aspects. On the one hand, risk taking is believed to be closely linked to research and development (R&D) investment. It is argued that firms with high-risk taking seem to be more willing to invest in the high-risk and high-return project, such as R&D investment (Coles *et al.*, 2006; Dewett, 2007). And R&D investment helps to enhance the capacity to absorb technology spillover and drive technological advancement, thus improving productivity (Rosell *et al.*, 2014; Legros and Galia, 2012). On the other hand, high-risk-taking firms are more willing to innovate through investing in advanced machinery and equipment or through licensing in other patented technology (March and Shapira, 1987; Tan, 2001). In this view, risk taking should be positively related to productivity. Taken together, we propose that:

H3. Risk taking mediates the relationship between inventory leanness and productivity.

2.4 The moderating role of environmental complexity

Environmental complexity refers to the degree of heterogeneity and range in the industry, which is an indicator of changes in the level of monopoly power within an industry (Dess and Beard, 1984; Heeley *et al.*, 2006). As argued by Keats and Hitt (1988), the degree of environmental complexity decreases as industries consolidate, becoming more concentrated, and increases as industries fragment, becoming less concentrated. In other words, complex environment means many competitors and significant price pressure in industry, and as the industry moves away from large firm dominance, environmental complexity increases (Wiengarten *et al.*, 2017).

In general, product heterogeneity increases with increasing competition in a complex environment (Kay and Keen, 1983; Jacobs *et al.*, 2007). In other words, product diversification induced by heterogeneity would accelerate consumer demand changes, leaving enterprises unable to capture changes in consumer demand in a timely manner (Wan and Hoskisson, 2003; Bernard *et al.*, 2010). This means that firms have to maintain more inventories to meet consumer demand, increasing management cost and inventory cost. Besides, along with the increasing competition under complex environment, the competition for senior managers and skilled workers becomes even heater, whether or not a firm can retain talent as the key to gaining a competitive advantage within the industry (King *et al.*, 2001; Porter and Kramer, 2002). As we all know, these talents are the important basis for enterprises to improve the production process and enhance operation efficiency through inventory management. This suggests that inventory leanness under complex environment may experience more cost and production problems, as well as lower operational efficiency. This leads to the following hypothesis:

H4. Environmental complexity negatively moderates the curvilinear relationship between inventory leanness and productivity.

Next, it is difficult for enterprises to identify and respond to the cause of changes and to effectively predict changes in the environment (Azadegan *et al.*, 2013). Then, environmental complexity makes it impossible for corporate managers to adequately identify and judge investment opportunities. Therefore, managers are reluctant to engage in high-risk and high-return projects. In this, risk taking will be limited under complex environment. Risk decision making can be particularly challenging for firms in a complex environment. Enterprises will not tend to engage in high-risk investing activities, such as R&D investment, relative to a less complex environment (Zahra and Bogner, 2000; Cassiman and Veugelers, 2006). Meanwhile, competition may exacerbate the mutual imitation among firms and then reduce the motivation of R&D investment under complex environment (Caballero and Jaffe, 1993). Therefore, the increased environmental complexity has the implied potential for firms to make decisions about productivity improvement. In addition, due to a large number of competitors in the industry, the manager confidence decreases as competitors increase (Heinrichs and Lim, 2008; Wang and Xie, 2011), leading to the reduction in risk-taking capability. Therefore, the lack of risk-taking capacity under complex environment may limit the firm's ability to innovate. As a result, managers are more likely to take activities that are related to productivity improvement under lower complex environment. Therefore, the following relationship is hypothesized:

H5. Environmental complexity moderates the relationship between risk taking and productivity, such that the relationship between risk taking and productivity is stronger among firms with lower rather than the high level of environmental complexity.

Combining *H3*–*H5*, we further propose a mediated moderation model shown in Figure 1. Concretely, environmental complexity moderates the relationship between inventory leanness and productivity; and this moderating effect is due to the mediating effect of risk taking on the relationship between inventory leanness and productivity, and the moderating effect of environmental complexity on the relationship between risk taking and productivity. Stated formally, we hypothesize that:

H6. Risk taking mediates the moderating effect of environmental complexity on the relationship between inventory leanness and productivity.

3. Data and variable measurement

3.1 Data resource

To test our hypothesis, we conduct an empirical study based on secondary quarterly data. Our sample draws on two main resources of firm level and industry level. The firm-level data are obtained from the China Stock Market and Accounting Research database, which provides basic financial information of all Chinese listed companies. The industry-level data come from the CEInet statistics database, mainly used to measure environmental complexity. We utilize a sample of listed manufacturing firms over the period from 2003 to 2014, excluding special treatment firms and particular transfer firms. For our regression variables, we focus only observations without missing values. The resulting data set contains 42,939 firm-quarter observations of 1,709 firms in 30 distinct two-digit industries.

3.2 Measures

3.2.1 Measurement of productivity. As for the firm productivity, generally, total factor productivity (*TFP*) is a popular measure for it. We calculate *TFP* at the firm level following the methodology of Levinsohn and Petrin (2003). For the Levinsohn and Petrin (LP) method, the raw material inputs are used as a proxy for the unobservable productivity shocks. Hence, the main advantage of this method is, of course, a means to correct for the

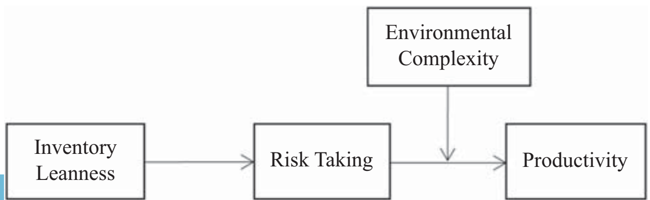

Figure 1.
Conceptual model of the study

simultaneity in the production function. Assuming a natural logarithm form of the Cobb–Douglas production function, the estimating equation for each two-digit industry in the sample is as follows:

$$Y_{it} = \alpha_0 + \alpha_1 L_{it} + \alpha_2 K_{it} + \alpha_3 M_{it} + \omega_{it} + \varepsilon_{it} \quad (1)$$

where Y_{it} denotes the logarithm of the total revenue of firm i in industry j at time t, L_{it} denotes the logarithm of the number of employees, K_{it} denotes the net fixed assets and M_{it} denotes the raw material expenditures, measured by the difference of costs about goods sold and labor hired. All variables are deflated to 2005 price. Note that ω_{it} is the productivity shock that cannot be observed but may be related to the choice of inputs, while ε_{it} is the classical error term. As assumed by the LP method, the raw materials can serve as a valid proxy if the demand for intermediate input, m, is monotonic for all relevant levels of capital. Then, the intermediate input function can be inverted, again allowing us to express unobserved productivity as a function of observed inputs: $\omega_{it} = f(M_{it}, K_{it})$. The coefficients on the K, L and M are obtained via GMM estimation with the contemporaneous natural log of capital and the lagged values of the materials variable as instruments.

3.2.2 Measurement of inventory leanness. Inventory leanness is measured by empirical leanness indicator (ELI) proposed by Eroglu and Hofer (2011). ELI has the advantage of capturing the industry-specific characteristics and economies of scale in inventories as well as presenting a good measure of the inventory leanness of a firm. In calculating the ELI, the natural logarithm of average inventories is regressed on the natural logarithm of sales for each industry j at the two-digit industry level and year t, and the estimation is as follows:

$$\ln(inventory_{ijt}) = \alpha_{jt} + \beta_{jt} \ln(sale_{ijt}) + \mu_{ijt} \quad (2)$$

To obtain the ELI for each firm i in year t, we studentize the residuals (u) and multiply them by -1 so that positive ELI values correspond to better inventory performance.

3.2.3 Measurement of risk taking. Various measures of risk taking have been used in the empirical literature, such as the volatility of firm performance (John *et al.*, 2008; Bargeron *et al.*, 2010), leverage (Dong *et al.*, 2010) or the likelihood of survival (Faccio *et al.*, 2016). In the present research, we operationalize corporate risk taking with the volatility of the return on assets (*ROA*) in line with previous studies (John *et al.*, 2008; Boubakri *et al.*, 2013). Concretely, we measure the industry-adjusted risk taking for each year with moving five-year windows. For example, to measure risk taking for the year 2005, we used a five-year window from 2003 to 2007, and so on. We calculate the deviation of the firm's *ROA* from the two-digit industry average for the corresponding year. Then, we calculate the standard deviation of this measure as risk taking for each firm. Explicitly, risk taking for firm i in year t is measured as follows:

$$RISK_{i,t} = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}\left(ROA_{i,t}^{adj} - \frac{1}{T}\sum_{t=1}^{T} ROA_{i,t}^{adj}\right)^2} \quad (3)$$

$$ROA_{i,t}^{adj} = ROA_{i,t} - \frac{1}{N_{j,t}}\sum_{i \in \Theta j} ROA_{i,t} \quad (4)$$

where $RISK_{i,t}$ is the risk taking of firm i in year t; $ROA_{i,t}^{adj}$ the industry-adjusted *ROA* of firm i in year t; $N_{j,t}$ the number of firms within industry j in year t; and Θj the set of firms within industry j.

3.2.4 Measurement of environmental complexity. Mirroring Boyd (1995) and Wiengarten *et al.* (2017), the moderating variable in our analysis is environmental complexity, which is measured by the Herfindahl–Hirschman Index (HHI). Concretely, we calculate the sum of the squared market shares of all firms in an industry as HHI. Note that the value of HHI ranges from 0 to 1, with 1 being few competitors or dominant competitors with large market share and less complex markets. We multiplied the HHI by −1, so that larger numbers indicate more complex environment.

3.2.5 Controls. In some specifications, with the view to both improving the estimation accuracy and checking for the robustness of our core results, we identify the following variables that are likely to influence productivity, and thus outline some firm-level variables used as control variables in the empirical model. Previous literature has shown that large firms can better mobilize resources and achieve economies of scale, thereby contributing to productivity improvement (Wagner, 2002). Therefore, the logarithm of the total asset used as the proxy of firm size (*SIZE*) is incorporated into the model. As in Morikawa (2010), we control for the firm age (*AGE*) through the logarithm of the number of years since the firm was set up. Following the studies of Heshmati and Kim (2011), debt ratio (*DR*) measured by the sum of short-term and long-term debt divided by total sale is also incorporated into the model as a control variable. Previous literature argues that debt ratio reflects the financial constraints and is closely related to productivity (Musso and Schiavo, 2008; Chen and Guariglia, 2013). It is well known that enterprises with high R&D investment usually enjoy better productivity growth (Aw *et al.*, 2011). Therefore, R&D investment (*RD*) is introduced into the model, wherein R&D investment is measured by the ratio of R&D expenditures to sales. As further controls, capital intensity (*CI*) is also incorporated into the model, which is measured by the ratio of total assets to the number of employees, wherein the total assets are deflated by the 2005 constant price index of investment in fixed assets. It is believed that relative resource endowments may disproportionately affect productivity noted by Jerzmanowski (2007). In addition, we introduce ownership type (*OT*) into the model to control for differences between state-owned enterprises and non-state-owned enterprises (Hu, 2001). Note that the ownership type represents a time variant dummy variable equal to 1 if the ratio of paid-up capital to total capital exceeds 50 percent, and 0 otherwise.

3.3 Descriptive statistics

Table I provides descriptive statistics and correlations for the data collected. The average number of productivity is 7.83, with a standard deviation of 0.91 and a maximum of 12.17. Moreover, further control of the interrelation between our variables reveals no high correlations. The only relatively high correlation is found between the logarithm of sales and productivity (0.66), indicating a positive relationship between firm size and productivity.

4. Estimation results

4.1 Models

In order to better understand the relationship among inventory leanness, productivity, risk taking, and environmental complexity, we employ the mediation model to test the proposed hypotheses regarding the direct effect and mediating effect, and use the mediated moderation model to investigate the moderating effect and mediated moderating effect. The direct effect refers to the impact of inventory leanness on productivity. The mediating effect mainly tests the role of risk taking in facilitating the process through which inventory leanness affects productivity. Furthermore, the moderating effect mainly tests whether environmental complexity moderates the relationship between risk taking and productivity, whereas the mediated moderating effect tests whether risk taking mediates this moderating effect.

	1	2	3	4	5	6	7	8	9	10
1. Productivity	1.00									
2. Inventory leanness	0.19*	1.00								
3. Risk taking	−0.05*	0.01	1.00							
4. Environmental complexity	−0.14*	0.01	0.01*	1.00						
5. Firm size	0.66*	0.17*	−0.11*	−0.09*	1.00					
6. Firm age	0.06*	0.03*	0.03*	−0.08*	0.09*	1.00				
7. R&D investment	−0.08*	−0.03*	−0.02*	−0.07*	−0.09*	0.02*	1.00			
8. Debt ratio	0.01*	−0.05*	0.15*	0.04*	0.15*	0.12*	−0.10*	1.00		
9. Ownership type	−0.01*	−0.02*	−0.01	0.02*	−0.09*	−0.05*	0.01*	−0.20*	1.00	
10. Capital intensity	0.08*	0.01*	0.02*	−0.05*	0.08*	0.06*	0.02*	0.04*	0.02*	1.00
Mean	7.83	−0.01	0.03	−0.06	20.43	2.69	0.01	0.48	0.38	1.45
SD	0.91	0.09	0.09	0.06	1.52	0.34	0.02	0.23	0.48	1.54
Minimum	3.97	−0.23	0	−1	16.33	1.38	0	0.05	0	0.17
Maximum	12.17	1.45	7.11	−0.01	24.37	4.29	0.15	1.40	1	10.78
Observations	42,939	42,939	42,939	42,939	42,939	42,939	42,939	42,939	42,939	42,939

Note: $*p < 0.01$

Table I.
Descriptive statistics and correlations

Some words of caution are, however, necessary. Before investigating the moderating effect of environmental complexity, we first use the mediation model to examine the relationship between inventory leanness and productivity, and whether this relationship is mediated by risk taking. Following the methodology in Baron and Kenny (1986), we use a three-model system to demonstrate mediation (Equations (5)–(7)) as follows:

$$TFP_{it} = \alpha_0 + \alpha_1 IL_{it}^2 + \alpha_2 IL + \alpha_3 SIZE_{it} + \alpha_4 AGE_{it} + \alpha_5 DR_{it} + \alpha_6 OT_{it} + \alpha_7 CI_{it} + \alpha_8 RD_{it} + \sum \alpha_t Y_t + \sum \alpha_t I_t + \varepsilon \quad (5)$$

$$RISK_{it} = \beta_0 + \beta_1 IL_{it}^2 + \beta_2 IL + \beta_3 SIZE_{it} + \beta_4 AGE_{it} + \beta_5 DR_{it} + \beta_6 OT_{it} + \beta_7 CI_{it} + \beta_8 RD_{it} + \sum \beta_t Y_t + \sum \beta_t I_t + \varepsilon \quad (6)$$

$$TFP_{it} = \gamma_0 + \gamma_1 {IL^2}_{it} + \gamma_2 IL + \gamma_3 RISK_{it} + \gamma_4 SIZE_{it} + \gamma_5 AGE_{it} + \gamma_6 DR_{it} + \gamma_7 OT_{it} + \gamma_8 CI_{it} + \gamma_9 RD_{it} + \sum \gamma_t Y_t + \sum \gamma_t I_t + \varepsilon \quad (7)$$

Next, following Muller *et al.* (2005), we employ another three-model system to infer mediated moderation (Equations (8)–(10)) as follows:

$$TFP_{it} = \alpha_0 + \alpha_1 {IL^2}_{it} + \alpha_2 IL + \alpha_3 IL^2 \times COMPLEX_{it} + \alpha_4 IL \times COMPLEX_{it} + \alpha_5 COMPLEX_{it} + \alpha_6 SIZE_{it} + \alpha_7 AGE_{it} + \alpha_8 DR_{it} + \alpha_9 OT_{it} + \alpha_{10} CI_{it} + \alpha_{11} RD_{it} + \sum \alpha_t Y_t + \sum \alpha_t I_t + \varepsilon \quad (8)$$

$$RISK_{it} = \beta_0 + \beta_1 IL_{it}^2 + \beta_2 IL + \beta_3 IL^2 \times COMPLEX_{it} + \beta_4 IL \times COMPLEX_{it} + \beta_5 COMPLEX_{it} + \beta_6 SIZE_{it} + \beta_7 AGE_{it} + \beta_8 DR_{it} + \beta_9 OT_{it} + \beta_{10} CI_{it} + \beta_{11} RD_{it} + \sum \beta_t Y_t + \sum \beta_t I_t + \varepsilon \quad (9)$$

$$TFP_{it} = \gamma_0 + \gamma_1 IL_{it}^2 + \gamma_2 IL + \gamma_3 IL^2 \times COMPLEX_{it} + \gamma_4 IL \times COMPLEX_{it} + \gamma_5 COMPLEX_{it} + \gamma_6 RISK_{it} + \gamma_7 RISK_{it} \times COMPLEX_{it} + \gamma_8 SIZE_{it} + \gamma_9 AGE_{it} + \gamma_{10} DR_{it} + \gamma_{11} OT_{it} + \gamma_{12} CI_{it} + \gamma_{13} RD_{it} + \sum \gamma_t Y_t + \sum \gamma_t I_t + \varepsilon \quad (10)$$

The high dimensionality of the data set employed here requires some definitions. Hereafter, index i will identify a firm, and t a year. Where *TFP* is the productivity; *IL* represents inventory leanness, and IL^2 is the quadratic term of inventory leanness; *RISK* indicates the risk taking; *COMPLEX* denotes the environmental complexity; *SIZE* represents the firm size; *AGE* represents the firm age; *DR* is the debt ratio; *OT* represents the ownership type; *CI* is the capital intensity; and *RD* represents the R&D investment intensity. In addition, year fixed effects (Y) and industry fixed effects (I) are controlled for. Mirroring Aiken *et al.* (1991), the continuous variables were mean centered to minimize potential multicollinearity. The variance inflated factor scores are all lower than 2.7, well below the acceptable value of 10.

Concretely, Equation (5) captures the direct effect of inventory leanness on productivity (*H1*). To examine the effect of inventory leanness on risk taking (*H2*), the regression model is provided by Equation (6). Then, Equation (7) is used to demonstrate the mediating effect of risk taking on the relationship between inventory leanness and productivity (*H3*). In addition, we add the interaction term between inventory leanness and environmental complexity into Equation (5) to obtain Equation (8) for testing the role of environmental complexity in moderating the direct effect of inventory leanness on productivity (*H4*). Similarly, Equation (9) is used to examine the moderation effect of environmental complexity on the relationship between inventory leanness and risk taking, while Equation (10) captures the effect of environmental complexity in moderating the relationship between risk taking and productivity (*H5*). Furthermore, based on these results estimated from Equation (8) to Equation (10), we examine whether risk taking mediates the moderating effect of environmental complexity on the relationship between inventory leanness and productivity (*H6*).

4.2 Correcting for endogenous problems

A concern while evaluating the impact of inventory leanness on productivity is the endogenous nature of inventory leanness. The sources of endogenous problems may come from reverse causality (simultaneity) or omitted variables (Wooldridge, 2010). For example, inventory leanness may be influenced by some omitted variables which also impact productivity thus leading to endogenous problems. On the other hand, enhanced inventory leanness may improve productivity, while a change in productivity will likely lead to changes in inventory leanness. To minimize endogenous problems, we adopt the 2SLS/IV estimator to investigate the direct and indirect effects of inventory leanness on productivity (Bai *et al.*, 2016).

Following the studies of Isaksson and Seifert (2014), we use lagged inventory leanness as IVs. Our argument is that inventory leanness in previous years is closely related to inventory leanness in the current year, but it would not directly influence the productivity of the current year. Concretely, in the first stage, inventory leanness should be regressed on the IV and control variables. Then, we apply the predicted value in the first stage as an indicator of inventory leanness in the three-model system.

4.3 Testing direct effects and mediating effects

Table II provides estimation results for the main effects of the quadratic term of inventory leanness on productivity and the mediating effect of R&D investment on this relationship.

Table II.
Results of the mediation analysis

Variables	(1) Risk taking	(2) Risk taking	(3) Productivity	(4) Productivity	(5) Productivity
Controls					
Firm size (*SIZE*)	−0.0098*** (−29.8002)	−0.0112*** (−31.5424)	0.3266*** (152.1673)	0.3016*** (132.8213)	0.3038*** (132.2071)
Firm age (*AGE*)	0.0042*** (3.0231)	0.0036*** (2.6180)	0.0697*** (7.7923)	0.0567*** (6.4367)	0.0560*** (6.3598)
Debt ratio (*DR*)	0.0677*** (34.2304)	0.0707*** (35.4490)	−0.2273*** (−17.6895)	−0.1702*** (−13.3316)	−0.1839*** (−14.1983)
Ownership type (*OT*)	0.0030*** (3.1987)	0.0028*** (3.0027)	0.0118* (1.9546)	0.0091 (1.5343)	0.0086 (1.4440)
Capital intensity (*CI*)	0.0014*** (5.2380)	0.0016*** (5.7393)	0.0181*** (10.2083)	0.0200*** (11.4260)	0.0197*** (11.2528)
R&D intensity (*RD*)	−0.0682*** (−3.2610)	−0.0657*** (−3.1482)	−1.7002*** (−12.5100)	−1.6342*** (−12.2300)	−1.6215*** (−12.1387)
Direct effects					
Inventory leanness (*IL*)		0.0733*** (10.6148)		1.3827*** (31.2959)	1.3685*** (30.9258)
Inventory leanness^2 (IL^2)		−0.0730*** (−5.5360)		−0.9984*** (−11.8298)	−0.9843*** (−11.6609)
Mediator					
Risk taking (*RISK*)					0.1935*** (6.2609)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	42,957	42,939	42,957	42,939	42,939
R^2	0.057	0.061	0.620	0.633	0.633

Notes: *t*-Statistics in parentheses. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

Empirical models used to analyze the direct impacts of inventory leanness are first estimated using control variables (Columns (1) and (3) in Table II). The result in Column (4) of Table II reports the direct effects of inventory leanness on productivity. We find that the coefficient for the quadratic term of inventory leanness is significant ($p < 0.01$) and negative (−0.9984), in support of *H1*. That is, an inverted U-shaped relationship exists between inventory leanness and productivity, indicating the diminishing productivity of high levels of inventory leanness. Clearly, inventory leanness has a positive impact on productivity when it is low, but exhibits a negative relationship with productivity when it is high.

Furthermore, we apply three-step approach as well as significant tests to test the mediating effect of risk taking on the relationship between inventory leanness and productivity (Baron and Kenny, 1986). First, we regressed the inventory leanness against the mediator, risk taking (Column (2) in Table II). We find that the coefficient of the quadratic term of inventory leanness on risk taking is significant ($p < 0.01$) and negative (−0.0730), supporting *H2*. Thus, the results support the presence of an inverted U-shaped relationship between inventory leanness and risk taking, indicating that firms face a decline in the positive effect of inventory leanness on risk taking after a certain level. Second, we regressed the inventory leanness against productivity. As mentioned above, inventory leanness has an inverted U-shaped effect on productivity significantly without controlling risk taking (Column (4) in Table II). Finally, we regressed both inventory leanness and risk taking against productivity (Column (5) in Table II). Results indicate that all these coefficients of the quadratic term of inventory leanness remain significant and negative. By contrast, the magnitude (in absolute value) of coefficients for the quadratic term of inventory leanness in Column (5) of Table II (−0.9843) is smaller than that in Column (4) of Table II (−0.9984). That is, risk taking partially mediates the inverted U-shaped relationship between inventory leanness and productivity, in support of *H3*.

4.4 Testing for mediated moderation

Table III shows the results of the mediated moderating effect of environmental complexity on the relationship among inventory leanness, risk taking and productivity. As Column (2) in Table III illustrated, the coefficient of the quadratic term of inventory leanness is significant ($p < 0.01$) and negative (−0.3445). As suggested by Aiken *et al.* (1991), we focus on the coefficient of the second-order interaction coefficients (i.e. quadratic term × moderator), while investigating the moderating effects of the curvilinear inverted U-shaped relationship. We find that the coefficient of the second-order interaction between inventory leanness and environmental complexity is significant ($p < 0.01$) and negative (−15.2106). That is, inventory leanness has an inverted U-shaped effect on productivity at the average level of environmental complexity, and this effect is moderated by environmental complexity, in support of *H4*. Furthermore, we investigate the moderating effect of environmental complexity on the relationship between inventory leanness and risk taking (Column (4) in Table III). Results show that the effect of the quadratic term of inventory leanness on risk taking at the average level of environmental complexity is significant ($p < 0.01$) and negative (−0.0830), while the coefficient of second-order interaction between inventory leanness and environment is not significant, indicating that this effect is not moderated by environmental complexity. Moreover, when the risk taking and its interaction term with environmental complexity are added into the model (Column (6) in Table III), we find that the effect of risk taking on productivity at the average level of environmental complexity is significant ($p < 0.01$) and positive (0.2111), and the interaction term between risk taking and environmental complexity is significant ($p < 0.05$) and negative (−1.8555). That is, the effect of risk taking on productivity is moderated by environmental complexity, supporting *H5*.

Overall, the relationship between inventory leanness and productivity is nonlinear (inverted U-shaped), and this relationship is moderated by environmental complexity.

Table III. Results of the mediated moderation analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Productivity		Risk taking		Productivity	
Controls						
Firm size (*SIZE*)	0.3079*** (140.8679)	0.3030*** (132.8445)	−0.0107*** (−31.3710)	−0.0112*** (−31.4699)	0.3102*** (140.2973)	0.3052*** (132.2487)
Firm age (*AGE*)	0.0551*** (6.2504)	0.0547*** (6.2173)	0.0035** (2.5508)	0.0036*** (2.6129)	0.0541*** (6.1423)	0.0538*** (6.1180)
Debt ratio (*DR*)	−0.1775*** (−13.9183)	−0.1676*** (−13.1173)	0.0700*** (35.1802)	0.0709*** (35.5009)	−0.1920*** (−14.8522)	−0.1817*** (−14.0213)
Ownership type (*OT*)	0.0122** (2.0455)	0.0096 (1.6139)	0.0030*** (3.2490)	0.0028*** (3.0510)	0.0112* (1.8832)	0.0088 (1.4755)
Capital intensity (*CI*)	0.0181*** (10.3872)	0.0195*** (11.1124)	0.0014*** (5.2565)	0.0016*** (5.7767)	0.0177*** (10.1559)	0.0191*** (10.8828)
R&D intensity (*RD*)	−1.6183*** (−12.0952)	−1.6323*** (−12.2222)	−0.0638*** (−3.0551)	−0.0654*** (−3.1338)	−1.6073*** (−12.0181)	−1.6211*** (−12.1427)
Direct effects						
Inventory leanness (*IL*)	1.0446*** (32.8278)	1.2808*** (27.5322)	0.0480*** (9.6618)	0.0741*** (10.1881)	1.0351*** (32.4928)	1.2667*** (27.1875)
Inventory leanness^2 (IL^2)		−0.3445*** (−2.5779)		−0.0830*** (−3.9711)		−0.3355** (−2.5098)
Mediator						
Risk taking (*RISK*)					0.2228*** (6.9716)	0.2111*** (6.6131)
Moderator						
Environmental complexity (*EC*)	0.0111 (0.1043)	0.1414 (1.3026)	0.0245 (1.4804)	0.0219 (1.2927)	−0.0033 (−0.0308)	0.1270 (1.1698)
Interactions						
$IL \times EC$	−4.8123*** (−8.7702)	−1.4632** (−2.2137)	−0.2376*** (−2.7730)	−0.1581 (−1.5294)	−4.7994*** (−8.7477)	−1.5039** (−2.2730)
$IL^2 \times EC$		−15.2106*** (−5.1219)		0.4292 (0.9242)		−14.9758*** (−5.0387)
$RISK \times EC$					−2.3149** (−2.5668)	−1.8555** (−2.0579)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	42,939	42,939	42,939	42,939	42,939	42,939
R^2	0.632	0.633	0.060	0.061	0.632	0.634

Notes: *t*-Statistics in parentheses. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

Furthermore, the relationship between risk taking and productivity is also moderated by environmental complexity. Therefore, the mediation of risk taking underlies the overall moderating effects of environmental complexity on the relationship between inventory leanness and productivity in such a way that inventory leanness has an inverted U-shaped impact on risk taking, and the relationship between risk taking and productivity is stronger while the environmental complexity is lower, in support of *H6*.

4.5 Robustness checks

We conduct three separate robustness checks to strength and support our hypotheses. We mainly repeat the quadratic and interaction models of our regression analysis. The corresponding results support our previous findings and are presented in Tables IV–VI.

First, we examine whether our results are robust to variations in the proxy variable of productivity while being used as dependent variables. In line with recent literature (Morikawa, 2010; Heshmati and Kim, 2011), we employ the labor productivity as the alternative dependent variable. Labor productivity can be used to measure the contribution of capital and labor to output growth, and is calculated as value added divided by the number of employees. Similar 2SLS/IV estimation results hold if we employ labor productivity as a dependent variable, and are shown in Table IV.

Second, we estimate the model with alternative indicators of risk taking to minimize concerns that our results are susceptible to different measurements of risk taking. Following the studies of Boubakri *et al.* (2013), we use profit margins instead of *ROA* to calculate risk taking. We obtain 2SLS/IV estimation results that do not differ significantly in Table V.

Finally, we change the sample duration to avoid the potential impact of financial crisis on our result. The sample duration is from 2010 to 2014. We re-run the same regression analysis. Again, we obtain 2SLS/IV estimation results that do not differ significantly in Table VI.

According to these results of robustness checks, we find robust evidence that the relationship between inventory leanness and productivity is the inverted U-shaped, and this relationship is mediated by risk taking. Moreover, risk taking mediates the moderating effects of environmental complexity on the relationship between inventory leanness and productivity.

5. Discussion and implication

The goal of our study is to investigate the relationship between inventory leanness and productivity. We formulate a mediated moderation model to examine whether risk taking would mediate the moderating impact of environmental complexity on the relationship between inventory leanness and productivity. Three key findings of our study advance our understanding of the relationship between inventory leanness and productivity. First, we find that inventory leanness has an inverted U-shaped effect on productivity. Prior conceptual and empirical works generally show that the relationship between inventory reduction and productivity is linear (Lieberman and Asaba, 1997; Lieberman and Demeester, 1999). That is, increasing inventory leanness would be helpful to improve productivity by eliminating waste through optimizing production process. However, the increased inventory leanness may be not always positively related to productivity growth. Our study is based on a sample of Chinese listed manufacturing firms between 2003 and 2014. Empirical results suggest that there is an optimal level of inventory leanness for manufacturing firms to improve productivity. That is, inventory leanness initially has a positive effect on productivity; however, after reaching a threshold, this effect declines. This finding partly lends support to the studies of Eroglu and Hofer (2011) and Isaksson and Seifert (2014), which argues that the relationship between inventory leanness and financial performance is nonlinear, wherein productivity is closely related to financial performance. Second, risk taking is shown to mediate the relationship between inventory leanness and productivity. We find that inventory

Table IV. Robustness check results of alternative productivity indicators

Variables	Mediation test (1) Risk taking	(2) Productivity	(3) Productivity	Mediated moderation test (4) Productivity	(5) Risk taking	(6) Productivity
Controls						
Firm size (*SIZE*)	−0.0112*** (−31.5424)	0.1628*** (71.2480)	0.1646*** (71.1420)	0.1624*** (70.7516)	−0.0112*** (−31.4699)	0.1644*** (70.7826)
Firm age (*AGE*)	0.0036*** (2.6180)	0.0415*** (4.6818)	0.0409*** (4.6204)	0.0412*** (4.6448)	0.0036*** (2.6129)	0.0399*** (4.5024)
Debt ratio (*DR*)	0.0707*** (35.4490)	−0.0750*** (−5.8335)	−0.0858*** (−6.5803)	−0.0706*** (−5.4917)	0.0709*** (35.5009)	−0.0814*** (−6.2436)
Ownership type (*OT*)	0.0028*** (3.0027)	0.0492*** (8.2264)	0.0487*** (8.1563)	0.0500*** (8.3717)	0.0028*** (3.0510)	0.0492*** (8.2329)
Capital intensity (*CI*)	0.0016*** (5.7393)	0.3541*** (200.9007)	0.3538*** (200.7360)	0.3542*** (200.8384)	0.0016*** (5.7767)	0.3537*** (200.5935)
R&D intensity (*RD*)	−0.0657*** (−3.1482)	−1.7386*** (−12.9279)	−1.7286*** (−12.8549)	−1.7433*** (−12.9704)	−0.0654*** (−3.1338)	−1.7271*** (−12.8555)
Direct effects						
Inventory leanness (*IL*)	0.0733*** (10.6148)	2.1836*** (49.1052)	2.1724*** (48.7670)	2.1860*** (46.7476)	0.0741*** (10.1881)	2.1661*** (46.2032)
Inventory leanness^2 (IL^2)	−0.0730*** (−5.5360)	−1.9071*** (−22.4514)	−1.8959*** (−22.3131)	−2.0475*** (−15.4069)	−0.0830*** (−3.9711)	−1.9750*** (−14.6837)
Mediator						
Risk taking (*RISK*)			0.1532*** (4.9226)			0.1920*** (5.9760)
Moderator						
Environmental complexity (*EC*)				0.4601 (4.21)	0.0219 (1.2927)	0.4317*** (3.9504)
Interactions						
$IL \times EC$				−3.9793*** (−5.9823)	−0.1581 (−1.5294)	−4.1335*** (−6.2083)
$IL^2 \times EC$				−5.9660** (−1.9963)	0.4292 (0.9242)	−6.6945** (−2.2383)
$RISK \times EC$						−4.6238*** (−5.0962)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	42,939	42,939	42,939	42,939	42,939	42,939
R^2	0.061	0.709	0.709	0.709	0.061	0.710

Notes: *t*-statistics in parentheses. $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table V. Robustness check results of alternative risk taking indicators

Variables	Mediation test (1) Risk taking	(2) Productivity	(3)	(4) Productivity	Mediated moderation test (5) Risk taking	(6) Productivity
Controls						
Firm size (*SIZE*)	−0.0162*** (−20.1266)	0.3016*** (132.8213)	0.3027*** (132.6586)	0.3029*** (132.8409)	−0.0163*** (−20.0838)	0.3046*** (132.5993)
Firm age (*AGE*)	0.0041 (1.3112)	0.0567*** (6.4367)	0.0564*** (6.4076)	0.0548*** (6.2266)	0.0041 (1.3062)	0.0541*** (6.1450)
Debt ratio (*DR*)	0.0959*** (21.1855)	−0.1702*** (−13.3316)	−0.1765*** (−13.7573)	−0.1678*** (−13.1369)	0.0963***(21.2307)	−0.1773*** (−13.7727)
Ownership type (*OT*)	0.0030 (1.4473)	0.0091 (1.5343)	0.0089 (1.5008)	0.0095 (1.6007)	0.0031 (1.4822)	0.0089 (1.4966)
Capital intensity (*CI*)	0.0020*** (3.2116)	0.0200*** (11.4260)	0.0199*** (11.3523)	0.0195*** (11.1071)	0.0020*** (3.2351)	0.0192*** (10.9327)
R&D intensity (*RD*)	−0.1038** (−2.1893)	−1.6342*** (−12.2300)	−1.6274*** (−12.1813)	−1.6355*** (−12.2477)	−0.1035** (−2.1833)	−1.6255*** (−12.1751)
Direct effects						
Inventory leanness (*IL*)	0.0949*** (6.0576)	1.3827*** (31.2959)	1.3765*** (31.1405)	1.2837*** (27.6317)	0.0960*** (5.8145)	1.2721*** (27.3322)
Inventory leanness^2 (IL^2)	−0.1144*** (−3.8221)	−0.9984*** (−11.8298)	−0.9908*** (−11.7401)	−0.3684*** (−2.7902)	−0.1298*** (−2.7357)	−0.3431** (−2.5674)
Mediator						
Risk taking (*RISK*)			0.0660*** (4.8469)			0.1251*** (5.7842)
Moderator						
Environmental complexity (*EC*)				−0.1413 (−1.30)	−0.0273 (−0.7098)	−0.1233 (−1.1356)
Interactions						
$IL \times EC$				−1.5628** (2.3808)	0.2863 (1.2203)	−1.5390** (2.3271)
$IL^2 \times EC$				−14.4747*** (−4.9906)	0.7087 (0.6723)	−14.8314*** (−4.9924)
$RISK \times EC$						−2.4317*** (−3.5097)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	42,939	42,939	42,939	42,939	42,939	42,939
R^2	0.027	0.633	0.633	0.633	0.027	0.633

Notes: *t*-Statistics in parentheses. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table VI. Robustness check results of alternative sample duration

Variables	Mediation test (1) Risk taking	(2) Productivity	(3) Productivity	Mediated moderation test (4) Productivity	(5) Risk taking	(6) Productivity
Controls						
Firm size (*SIZE*)	−0.0122*** (−21.4079)	0.2848*** (94.8250)	0.2863*** (94.4248)	0.2861*** (94.9996)	−0.0122*** (−21.3562)	0.2877*** (94.6020)
Firm age (*AGE*)	0.0068*** (2.9977)	0.0841*** (6.9858)	0.0832*** (6.9155)	0.0822*** (6.8346)	0.0068*** (3.0055)	0.0808*** (6.7121)
Debt ratio (*DR*)	0.0730*** (22.1778)	−0.2568*** (−14.7665)	−0.2659*** (−15.1405)	−0.2541*** (−14.6021)	0.0733*** (22.2559)	−0.2636*** (−14.9975)
Ownership type (*OT*)	0.0041*** (2.7616)	0.0154** (1.9910)	0.0149* (1.9258)	0.0175** (2.2618)	0.0042*** (2.8450)	0.0167** (2.1530)
Capital intensity (*CI*)	0.0011** (2.2989)	0.0140*** (5.5522)	0.0139*** (5.4985)	0.0140*** (5.5566)	0.0011** (2.3836)	0.0137*** (5.4310)
R&D intensity (*RD*)	−0.0546** (−2.0211)	−1.6560*** (−11.5971)	−1.6491*** (−11.5514)	−1.6547*** (−11.5963)	−0.0551** (−2.0401)	−1.6482*** (−11.5533)
Direct effects						
Inventory leanness (*IL*)	0.0918*** (8.4696)	1.4866*** (25.9490)	1.4751*** (25.6989)	1.4450*** (23.4672)	0.0971*** (8.3083)	1.4299*** (23.1295)
Inventory leanness^2 (IL^2)	−0.0756*** (−3.7891)	−1.1396*** (−10.8036)	−1.1302*** (−10.7118)	−0.4450** (−2.1796)	−0.0946** (−2.4191)	−0.4270** (−2.0684)
Mediator						
Risk taking (*RISK*)			0.1251*** (3.7144)			0.1523*** (4.1931)
Moderator						
Environmental complexity (*EC*)				−0.1505 (−0.62)	−0.0365 (−0.7928)	−0.1497 (−0.6162)
Interactions						
$IL \times EC$				−3.4575*** (3.1712)	0.3746 (1.4025)	−3.3592*** (3.0616)
$IL^2 \times EC$				−14.8630*** (−3.1595)	−0.7152 (−0.7895)	−15.0010*** (−3.1367)
$RISK \times EC$						−2.2751* (−1.9538)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,705	24,705	24,705	24,705	24,705	24,705
R^2	0.051	0.611	0.611	0.612	0.051	0.612

Notes: *t*-Statistics in parentheses. $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$

leanness has an inverted U-shaped effect on risk taking, which, in turn, is associated with productivity. Thus, risk taking may be one of the explanatory mechanisms for manufacturing firms which are more likely to obtain productivity improvement. Along with the work of John *et al.* (2008), our findings indicate that productivity improvement rests upon the degree to which a firm can enhance its risk taking via increasing inventory leanness. Finally, we find that environmental complexity moderates the relationship between inventory leanness and productivity. Furthermore, risk taking induced by enhanced inventory leanness may also result in more productivity improvement under lower complex environment. Therefore, these findings accentuate the importance of the industry heterogeneity as a boundary condition on the impact of inventory management on productivity.

Two managerially relevant implications seem important to note. First, the traditional wisdom holds that the more the inventory reduction is, the greater the productivity growth will be. However, an absolute positive view of the inventory leanness–productivity relationship may be oversimplified. Our study warns that the relationship between inventory leanness and productivity may be more complex. Managers should not overpursue the improvement of inventory leanness. Too low or too high inventory leanness may result in instability in production. The inverted U-shaped effect of inventory leanness on productivity provides an obvious warning to mangers about the value of inventory leanness: over-high levels of inventory leanness will damage the ability to improve productivity. Second, empirical results suggest that risk taking partly mediates the relationship between inventory leanness and productivity. Managers should use risk taking as one of their major ways to improve productivity. Furthermore, we document the inverted U-shaped effect of inventory leanness on risk taking. That is, managers can obtain the funds for risk taking by increasing their inventory leanness. However, managers should avoid two pitfalls. The first is pursuing overly high inventory leanness. Results suggest that overly high inventory leanness does not necessarily result in more current funds for risk taking than a mediocre one. The second pitfall is relying too much on the risk taking to improve productivity. As we all know that risk taking refers to high-risk investment, which may harm the development of enterprises. Therefore, while trying to improve productivity by enhancing risk taking, managers should also pay attention to operations management, such as inventory management.

6. Conclusion and future research

To sum up, this paper provides a more complete picture of inventory leanness–risk-taking–productivity triangle. This research adds to the theory of inventory management by focusing and exploring the mediating role of risk taking and the moderating role of environmental complexity. As such, this study underscores the importance of inventory management with the broader realm of operations management. In this paper, we first investigate the relationship among inventory leanness, risk taking and productivity based on a sample of listed manufacturing firms between 2003 and 2014 in China. By using the lagged value of inventory leanness as an IV, we apply 2SLS/IV estimator to correct for endogeneity. Furthermore, the three-model system is used to examine mediated moderation relationship among inventory leanness, risk taking, environmental complexity and productivity. We find that risk taking mediates the moderating effect of environmental complexity on the relationship between inventory leanness and productivity.

The findings reported here should be considered alongside their limitations. First, although inventory leanness can provide valuable information about inventory management, future studies should use other inventory management indicators to investigate their effects on productivity, which can provide us more practical results. Second, the research design only examines the mediating role of risk taking. Some other mediators related to human resource management or corporate governance should be incorporated into the model. Third, even though the 2SLS/IV estimator is applied to minimize endogeneity, endogenous problems may still exist. Future research should consider some other methods, such as the use of the quasi-experimental method to study the causal effects of inventory performance on product quality. Finally, this study focuses on the moderating role of environmental complexity, which is typically regarded as the main industry heterogeneity. Future research should consider some firm heterogeneity factors, such as ownership structure, to provide a broader view of the impact of inventory leanness on productivity.

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Further reading

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