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# Linking Inventory Component Stickiness to Credit Ratings: The Moderating Role of Environmental Dynamism and Complexity

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*This study aims to investigate the impact of sticky inventory management on credit ratings for all the three inventory components (raw materials, work-in-process, and finished goods). Taking a group of listed manufacturing firms in China from 2011 to 2019, we employed the ordered probit regression model combined with the moderation model to examine the relationship between three inventory component stickiness and credit ratings from two dimensions: environmental dynamism and complexity. We find an inverted U-shaped effect of raw material inventory stickiness and work-in-process inventory stickiness on corporate credit ratings, while sticky inventory management of finished goods exerts a positive association with credit ratings. Further moderation analysis suggests that environmental dynamism positively moderates the impact of sticky inventory management of raw materials and finished goods on credit ratings, but negatively moderates the relationship between work-in-process inventory stickiness and credit ratings. In addition, the impact of sticky inventory management of work-in-process and finished goods on credit ratings is positively moderated by environmental complexity. The results of this study provide a more detailed picture regarding the ratings agencies' perceptions of inventory stickiness.*

Keywords: *Sticky Inventory Management; Credit Ratings; Moderation Analysis; Manufacturing Firms.*

## Introduction

Optimism about future growth induces inventory to be managed in a sticky manner (Kroes & Manikas, 2018), which rating agencies may see as a positive sign for the outlook. However, the excess inventory caused by sticky inventory management may also be interpreted as a waste from a lean philosophy. Given this picture, rating analysts are likely to view sticky inventory management with guarded optimism. Especially in conditions of high uncertainty, sticky inventory management allows manufacturing enterprises to mitigate the negative effects of excess inventory and increase survivability (Zhu *et al.,* 2021a). Considering the importance of credit ratings to manufacturing enterprises, it is important to explore the impact of sticky inventory management on credit ratings. However, research on whether and how sticky inventory management affects credit ratings remains nascent.

Research on the impact of lean inventory management on credit ratings provides preliminary evidence for understanding the role of sticky inventory management in influencing credit ratings. As argued by Bendig et al. (2017), inventory leanness is positively associated with credit ratings in a concave relationship, indicating that credit ratings initially increase with leanness, until a certain turning point, beyond which the incremental effects of inventory leanness become negative. This suggests that there should be a natural trade-off between maintaining production stability and reducing waste. In the case of sticky inventory management, recent studies supporting this trade-off point of view indicate that there is a turning point in the impact of inventory stickiness on performance, such as productivity, product quality and venture survival (Lin *et al.,* 2021; Shi *et al.,* 2019; Wang *et al.,* 2022; Zhu *et al.,* 2021a). In this vein, rating analysts are likely to be aware of this trade-off when assessing operational risk. In addition, since inventory components come from distinct process steps, the implications for the performance improvement of each inventory component are different (Steinker & Hoberg, 2013). It is argued that raw material inventory is primarily related to the relationship with suppliers, but work-in-process inventory is mainly affected by managerial capabilities, while finished goods inventory is closely related to demand forecasts (Bendig *et al.,* 2018). Following the logic discussed above, it is an important issue that needs to be considered when making sticky inventory management strategies given the functional differences of the three inventory components in the supply chain.

Additionally, since environmental uncertainty can interfere with the accuracy of the information and the predictability of external events, and ultimately affect operational activities (Azadegan *et al.,* 2013b), rating analysts should be aware of the impact of environmental uncertainty on sticky inventory management and credit ratings. Recent studies have suggested that the benefits of sticky inventory management depend on environmental uncertainty. More specifically, it is argued that sticky inventory management enables manufacturers to enjoy better survival in a dynamic environment (Zhu *et al.,* 2021a). Similar results apply to the impact of environmental dynamism on the relationship between inventory stickiness and productivity (Wang *et al.,* 2022). Also, empirical evidence suggests that market instability can alleviate the negative impact of sticky inventory management on financial performance (Kroes & Manikas, 2018). In addition to environmental dynamism, recent studies have also focused on the impact of environmental complexity on inventory management (Wang *et al.,* 2019b; Zhu *et al.,* 2018). It is believed that the vicious competition among manufacturing enterprises in a complex environment makes them tend to conservative inventory management strategies (Bendig *et al.,* 2018). With the external environment of manufacturing enterprises becoming ever more complex and dynamic, it is important for managers to understand the role of environmental uncertainty in affecting the relationship between sticky inventory management and credit ratings. However, researchers have not yet investigated the role of environmental dynamism and complexity in influencing the relationship between inventory component stickiness and credit ratings. Given all that, we attempt to fill the aforementioned research gaps under the guidance of the following questions:

(1): How do the three indicators of sticky inventory management, namely raw material inventory stickiness, work-in-process inventory stickiness, and finished goods inventory stickiness affect credit ratings?

(2): How do the proposed impact of inventory component stickiness on credit ratings change according to the levels of environmental dynamism and complexity?

To answer these questions, this study develops and empirically tests an overarching theoretical framework that integrates the relationship between inventory component stickiness and credit ratings. Our theoretical basis allows us to conceptually explain the non-linear impact of sticky inventory management on credit ratings. Drawing on the listed manufacturing firms from 2011 to 2019, the ordered probit regression model is used to examine the relationship between inventory component stickiness and credit ratings. Furthermore, we employ moderation models to test the role of environmental dynamism and complexity in influencing this relationship. The empirical results provide detailed insights into the linkages among inventory component stickiness, environmental dynamism and complexity, and credit ratings, thereby contributing to the theory development of inventory management-credit risk linkage.

Our results reveal that both raw material inventory stickiness and work-in-process inventory stickiness have an inverted U-shaped relationship with credit ratings. In contrast, finished goods inventory stickiness exerts a positive relationship with credit ratings. Moreover, we examine the moderating effects of environmental dynamism and complexity on the relationships between inventory component stickiness and credit ratings. Our findings suggest that sticky inventory management contributes to the improvement of credit ratings in a dynamic environment, while managers should carefully increase the work-in-process inventory stickiness in a stable environment. Meanwhile, we find that environmental complexity can positively moderate the relationship between work-in-process inventory stickiness and credit ratings, as well as the relationship between finished goods inventory stickiness and credit ratings. Overall, the results provide considerable support for our model and yield important academic and managerial implications.

This study makes important contributions to our understanding of sticky inventory management strategies by exploring the individual characteristics of each underlying inventory component. Specifically, this paper contributes to the growing literature on sticky inventory management, by showing its role in influencing credit ratings. To the best of our knowledge, ours is the first study relating inventory component stickiness to credit ratings. The contribution of this study also extends to the literature by providing empirical evidence to demonstrate how environmental dynamism and complexity affect the relationship between inventory component stickiness and credit ratings.

In the following sections, we present the literature review and hypotheses development. Subsequently, the research methodology will be described. Then, we provide the empirical results as well as robustness checks. Finally, we discuss the theoretical contributions and managerial implications followed by conclusions.

## Literature Review

Inventory stickiness originates from cost stickiness, which refers to the fact that the increase in inventory when sales revenue increases is greater than the decrease in inventory when sales revenue decreases (Kroes & Manikas, 2018). The idea is that managers of manufacturing firms, being mindful of higher adjustment costs or potential future sales growth, are willing to hold excess inventory. The perspective of inventory slack enables managers to view sticky inventory management as a buffer against environmental threats rather than a waste (Zhu *et al.,* 2021a).

Recent research has promoted interest in sticky inventory management strategies, especially in exploring its impact on performance. For the first time, Kroes and Manikas (2018) empirically provided evidence of the existence of inventory stickiness and confirmed the negative impact of sticky inventory management on financial performance. They argued that, from the perspective of maximizing financial performance, inventory stickiness should be reduced and lean inventory management strategies should be taken. However, on the one hand, lean or agile strategies are difficult to successfully execute in practice. On the other hand, reducing inventory does not always lead to improved financial performance (Eroglu & Hofer, 2011). For example, recent studies have generally confirmed the inverted U-shaped impact of inventory leanness on performance, such as profitability (Isaksson & Seifert, 2014), credit rating (Bendig *et al.,* 2017), productivity (Zhu et al., 2018), and venture survival (Wang et al., 2019b). This is because the lack of inventory may affect production stability and bring risks. Therefore, like lean inventory management, the trade-off under sticky inventory management has attracted the attention of scholars and managers in recent years, followed by the nonlinear impact of sticky inventory management on performance. Concretely, Shi et al. (2019) argued that there is an inverted U-shaped relationship between operational stickiness and venture survival. Subsequently, Lin et al. (2021) found the inverted U-shaped effect of inventory stickiness on product quality. Wang et al. (2022) further demonstrated the inverted U-shaped relationship between inventory stickiness and productivity. In this vein, lean inventory management and sticky inventory management may exert similar effects on performance, echoing the view that there should be a trade-off between maintaining production stability and reducing waste in inventory management.

Concerning credit ratings, Bendig et al. (2017) empirically explored the influencing factors of credit ratings from the perspective of inventory management for the first time and confirmed the inverted U-shaped relationship between inventory leanness and credit ratings. From the perspective of venture survival, it is argued that there is an inverted U-shaped relationship between inventory leanness and corporate bankruptcy, which partially supports the non-linear link between lean inventory management and credit ratings. Similarly, Zhu et al. (2020) verified the inverted U-shaped impact of inventory stickiness on venture survival. In this vein, sticky inventory management may also exert a non-linear effect on credit ratings. However, to our best knowledge, the nature and empirical evidence on the relationship between inventory stickiness and credit ratings remains equivocal. Furthermore, as argued by Steinker and Hoberg (2013), the differential effects of inventory components on performance may be more important for inventory management. As a result, probing into inventory component stickiness contributes to a better understanding of the behavior of sticky inventory management in affecting credit ratings. Hence, in an attempt to fill this research gap, this study theoretically and empirically investigates the relationship between inventory component stickiness and credit ratings.

## Hypotheses Development

### *Inventory Component Stickiness and Credit Ratings*

Traditionally, raw material inventory is mainly affected by procurement and production functions as well as by macro-economic price developments (Bendig *et al.,* 2018). From an operational management perspective, in order to achieve efficient production and ensure reliable quality, managers usually overestimate the demand for raw materials (Niranjan et al., 2014). This may induce raw material inventories to be managed in a sticky manner. Also, as far as managers' motivation is concerned, anticipation of future sales growth is an important factor in their decision to adopt sticky inventory management (Kroes & Manikas, 2018). Meanwhile, relationships with suppliers are also a crucial factor (Eroglu & Hofer, 2011). For example, the shortage of raw materials caused by the supplier's inability to supply in time may affect the overall production plan of the manufacturer, and even cause production interruptions, which may be viewed negatively by rating analysts. Hence, sticky inventory management of raw materials is conducive to maintaining production stability, which is an important guarantee for corporate credit. In addition, creditors are usually risk-averse and react even more strongly to increases in raw material prices caused by macro-economic price developments (Bendig *et al.,* 2017). Rating agencies thus should be positive on a certain degree of raw material inventory stickiness, as this releases a signal that raw materials are plentiful and helps reduce operational risks.

However, if raw material inventory stickiness is too high, manufacturers may be burdened with excessive costs, resulting in reduced liquidity and increased credit risk. Meanwhile, large quantities of raw material inventory may also lead to increased storage costs and obsolescence risks (Bendig et al., 2018), which may be negatively viewed by rating analysts. Furthermore, from the perspective of risk management, rating agencies are likely to regard the excess raw material buildups as a manufacturer's inability to effectively resolve potential risks in production and operations, thereby reducing its competitive advantage over competitors (Bendig *et al.,* 2017; Steinker *et al.,* 2016). This means that excessive raw material inventory stickiness may be negatively viewed by rating analysts. As a result, this points to a curvilinear relationship in which the positive impact of raw material inventory stickiness on credit ratings is available only up to a certain level, and becomes negatives as inventory stickiness grows beyond this level, indicating an inverted U-shaped relationship between raw material inventory stickiness and credit ratings. Therefore, we propose the following hypothesis:

H1a. Raw material inventory stickiness has an inverted U-shaped relationship with credit ratings.

It is argued that work-in-process inventory is primarily influenced by inventory management capabilities (Hoberg *et al.,* 2017). For products with multiple production processes, it is difficult to avoid production waiting between different production processes. In order to smooth the production process, a certain degree of work-in-process inventory stickiness is beneficial to reduce production waits and improve production stability (Shi *et al.,* 2019). Meanwhile, for unexpected orders in the market, in addition to maintaining some finished goods inventory, it is more important for manufacturers to improve the ability to production in time (Zhu *et al.,* 2021b). To this end, for manufacturers with insufficient production process management capabilities, a certain degree of work-in-process inventory stickiness helps reduce production preparation time and achieve rapid production. Moreover, considering the risks to raw material inventory supply due to supplier relationships and rising prices, work-in-process inventory stickiness can alleviate the operational risks brought about by raw material shortages, thereby avoiding a credit crisis in the short term. In this vein, a certain degree of work-in-process inventory stickiness should be positively evaluated by rating agencies.

However, there are always two sides to a coin. Credit rating agencies usually regard the work-in-process inventory as a proxy for assessing operational management capabilities (Bendig *et al.,* 2017; Sarkar & Chung, 2020). Then, excessive work-in-process inventory stickiness can easily be labeled as weak production management capabilities, which may be evaluated negatively by rating agencies. Furthermore, due to the relatively weak cash flow conversion ability of work-in-process inventory (Hemalatha *et al.,* 2021), excessive work-in-process inventory stickiness not only aggravates the cost burden but also reduces the liquidity and solvency. Considering the potential credit risk, rating agencies are more likely to negatively evaluate this excessive sticky inventory management of work-in-process. Thus, there may be an optimal level of work-in-process inventory stickiness beyond which the marginal effect becomes negative. This gives us the following hypothesis:

H1b. Work-in-process inventory stickiness has an inverted U-shaped relationship with credit ratings.

As argued by Niranjan et al. (2014), finished goods inventory is closely related to demand forecasts and operations management capabilities. Failure to meet customer demand for finished goods may damage reputation and miss revenue opportunities (Bendig *et al.,* 2018). As a result, sticky inventory management of finished goods allows manufacturers to be ready to seize opportunities to take more orders and deliver products in a timely manner, thus enjoying sustainable competitive advantages (Zhu *et al.,* 2020). Meanwhile, since the finished goods inventory has the highest unit value among all inventory types (Rumyantsev & Netessine, 2007), a certain degree of finished goods inventory stickiness is beneficial to improving the mortgage capacity, which may be positively evaluated by rating agencies. From the perspective of marketing, finished goods inventory stickiness provides the basis for realizing active marketing strategies and market expansion. In addition, considering the positive effect of inventory slack against external threats, finished goods inventory stickiness allows manufacturers to act more rapidly and effectively to supply chain disruptions (Azadegan *et al.,* 2013a). In this vein, a certain finished goods inventory stickiness should be positively evaluated by rating agencies.

However, product backlog caused by excessive finished goods inventory stickiness can increase the warehousing and management costs, thereby reducing liquidity and solvency. Moreover, if the finished goods inventory stickiness was too high, the continuous emergence of new products on the markets may increase the potential risk of a mismatch between finished goods and market demand preferences. Additionally, the unreliable quality caused by obsolete inventory products may reduce consumers' perceived quality and satisfaction, thus leading to negative reviews by rating agencies (Niranjan *et al.,* 2014; Shi *et al.,* 2019). Therefore, finished goods inventory stickiness may initially increase credit ratings, but could decrease credit ratings after a certain threshold level, we hypothesize the following:

H1c. Finished goods inventory stickiness has an inverted U-shaped relationship with credit ratings.

### *Moderating Effect of Environmental Dynamism*

Environmental dynamism refers to the degree of instability and turbulence within an industry, which is characterized by unpredictable and rapid change. It is difficult for manufacturers to respond to changes in demand through effective prediction and preparation in a dynamic environment (Azadegan *et al.,* 2013b). In this situation, the rapid response of manufacturing enterprises is even more important to maintain the competitive advantage (Bradley *et al.,* 2011).

As the main purpose of maintaining raw material inventory stickiness is to be optimistic about future demand growth, environmental dynamism poses a serious challenge for sticky inventory management of raw materials (Bendig *et al.,* 2018; Kroes & Manikas, 2018). This is because of the need for accurate forecasting of future demand, which is easy to achieve in a stable environment but difficult in a dynamic environment. Therefore, rating agencies regard raw material inventory stickiness as a signal that managers are optimistic about future sales growth, so that they can give a more positive evaluation in a stable environment. Nevertheless, the cost pressure caused by excessive raw material inventory stickiness could be more negatively evaluated by rating agencies. Therefore, the relationship between raw material inventory stickiness and credit rating should be more concave in a stable environment. Additionally, suppliers' aversion to uncertainty increases the risk of stock-outs for manufacturers with weak raw material inventory management (Bendig *et al.,* 2018; Hertzel *et al.,* 2008). In this case, sticky inventory management of raw materials enables manufacturers to maintain production stability, thus reducing operational risks. Hence, rating agencies should positively evaluate sticky inventory management of raw materials in a dynamic environment. This leads to the following hypothesis:

H2a. Environmental dynamism positively moderates the relationship between raw material inventory stickiness and credit ratings.

As mentioned, environmental dynamism may also moderate the relationship between work-in-process inventory stickiness and credit ratings. In particular, sticky inventory management of work-in-process can be used as a buffer against the shortage of raw materials or insufficient finished goods, so as to maintain the continuity and stability of production in a dynamic environment. Since work-in-process inventory stickiness contributes to rapid response, rating agencies should hence positively evaluate sticky inventory management of work-in-process in a dynamic environment. On the contrary, when environmental dynamism is low, relatively reliable supplier relations reduce the operational risk caused by the shortage of raw material inventory. Meanwhile, a more accurate forecast of market demand also reduces the need for rapid response (Kroes & Manikas, 2018). In this situation, sticky inventory management of work-in-process makes manufacturers bear more production costs and operational risks, which could be more negatively evaluated by rating agencies. Moreover, the weak cash flow conversion ability leads to a decrease in liquidity and an increase in the risk of default caused by the work-in-process inventory stickiness. Therefore, we propose the following hypothesis:

H2b. Environmental dynamism negatively moderates the relationship between work-in-process inventory stickiness and credit ratings.

It is argued that finished goods represent the principal buffer against demand uncertainty (Brandenburg, 2017). Uncertainty in demand disrupts the original supply chain system, leading to scattered and random orders for market production (Azadegan *et al.,* 2013b; Giri & Bardhan, 2017). The ability to grab unexpected rush orders has become an important way for manufacturers to expand market influence and gain competitive advantages in a dynamic environment (Anatan, 2014; Zhang & Wong, 2017). Indeed, in order to avoid consumer dissatisfaction and negative reviews from rating agencies due to stock-outs, when demand cannot be accurately predicted, managers usually maintain a certain degree of finished goods inventory stickiness to avoid potential reputation damage in a dynamic environment. However, sticky inventory management of finished goods is more likely to be misunderstood as a downturn in sales caused by production problems in a stable environment (Zhu *et al.,* 2020). In addition, a decline in consumer perceived quality and an increased cost burden due to product obsolescence further exacerbate rating agencies' negative evaluation of sticky inventory management of finished goods. As a result, we propose the following hypothesis:

H2c. Environmental dynamism positively moderates the relationship between finished goods inventory stickiness and credit ratings.

### *Moderating Effect of Environmental Complexity*

Environmental complexity refers to the degree of heterogeneity and range, which reflects the competitive situation and price pressure within an industry. The more complex the environment, the more competitors in the industry (Wiengarten *et al.,* 2017). It has been argued that organizations in a complex environment have multiple inputs (suppliers and materials) and outputs (customers and products), which limit the ability to identify, evaluate, and predict factors affecting normal operations (Azadegan *et al.,* 2013b).

As mentioned above, multiple inputs make it difficult for manufacturing enterprises to effectively coordinate supplier relations in a highly complex environment, which increases the possibility of managers making mistakes in predicting raw material demand (Bendig *et al.,* 2018). In such settings, sticky inventory management of raw materials helps avoid production interruptions caused by stock-outs, thereby improving production stability and reducing operational risk. Meanwhile, sticky inventory management of raw materials is an effective means to reduce its volatility. It is argued that manufacturers with high raw materials volatility have to endure the risk of increased costs and additional stock-outs (Hendricks & Singhal, 2014). In this vein, compared with competitors, sticky inventory management of raw materials enhances manufacturers' competitive advantage in a highly complex environment, which should be more positively evaluated by rating agencies. In contrast, insufficient competition reduces the risk of raw material shortages in a low complex environment. In this case, the increase in cost and decrease in quality caused by raw material inventory stickiness may in turn damage the competitive advantage. These arguments suggest the following hypothesis:

H3a. Environmental complexity negatively moderates the relationship between raw material inventory stickiness and credit ratings.

In general, sticky inventory management of work-in-process, as a buffer, not only contributes to lower risks of raw material shortages but also helps to improve production stability, thus expanding the competitive advantage in the market. As such, due to the lack of sufficient competitors, this advantage is more prominent in a low complex environment, which should be more positively evaluated by rating agencies. In fact, when manufacturers are unable to smooth the production process by effectively solving production problems, they have to retain excessive work-in-process inventory to maintain production stability (Wang *et al.,* 2019a). However, this also brings higher costs and operational risks to manufacturing enterprises. In particular, it is more difficult for manufacturers to effectively identify factors that disrupt production in a highly complex environment (Wang *et al.,* 2019b). In this case, increasing work-in-process inventory in order to avoid production interruptions is actually self-defeating. Sticky inventory management of work-in-process may not be able to cover up production problems and eventually lead to production interruptions, thus increasing operational risks (Shi *et al.,* 2019). Additionally, since multiple inputs and outputs increase the diversity of work-in-process, the cost pressure of sticky inventory management of work-in-process is also unbearable for manufacturers in a highly complex environment. Thus, we hypothesize:

H3b. Environmental complexity positively moderates the relationship between work-in-process inventory stickiness and credit ratings.

Similar to the case with environmental dynamism, environmental complexity is also expected to positively moderate the relationship between finished goods inventory stickiness and credit ratings. Traditionally, customer demand for differentiated products leads to order diversification, which increases the probability of out-of-stocks in a highly complex environment (Azadegan *et al.,* 2013b). In this case, the finished goods inventory stickiness can satisfy customers' product availability and improve their satisfaction, which should be more positively evaluated by rating agencies. Also, multiple outputs make customer orders more disorderly and random in a highly complex environment. Sticky inventory management of finished goods enhances manufacturers to obtain more unexpected orders and improve competitive advantage. In addition, sticky inventory management of finished goods may be conducive to the implementation of price competition strategies in cooperation with marketing, thus enhancing the competitive advantage relative to competitors. In this vein, rating agencies are expected to be more positive in evaluating manufacturers who manage finished goods inventories in a sticky manner in a highly complex environment. Conversely, in the absence of enough competitors, the main goal of manufacturers is no longer to get as many orders as possible in a low complex environment. Decreased perceived quality from excess finished goods inventory, in turn, reduces competitive advantage (Lin et al., 2018), which could be more negatively evaluated by rating agencies. Hence, we propose:

H3c. Environmental complexity positively moderates the relationship between finished goods inventory stickiness and credit ratings.

Figure 1 summarizes our conceptual model and associated hypotheses.

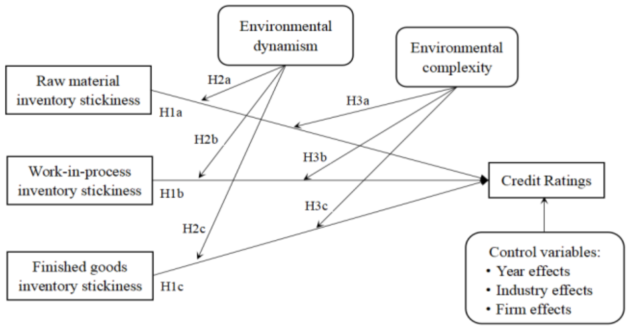


**Figure 1**. Conceptual Framework

## Research Methodology

### *Sample Description*

To test our hypothesis, an empirical analysis is conducted based on secondary annual data. Our sample draws on credit ratings and financial-accounting data from the China Stock Market and Accounting Research (CSMAR) database. The CSMAR database provides accurate basic financial information collected from public annual reports of Chinese listed companies. We utilize a sample of listed manufacturing firms over the period from 2011 to 2019. In addition, we deleted samples with a credit rating of C or D to exclude companies on the verge of bankruptcy. For our regression variables, we focus on observations without missing values. In line with Kroes and Manikas (2018), we select a sample of periods of declining sales revenue. The resulting dataset contains 404 firm-year observations.

### *Variable Measurement*

**Credit ratings**. In line with Bendig et al. (2017), we use the long-term ratings to measure the firm-level credit ratings. It is noted that long-term ratings are assigned based on a more fine-grained sequential level from CC to AAA ("extremely strong obligor"). We assign a separate value to each of the 20 micro-rating classes from 1 (CC) to 20 (AAA). In addition, we assign eight values from 1 (CC) to 8 (AAA) for an additional robustness test.

**Inventory stickiness**. In order to better capture inventory stickiness, based on the method proposed by Kroes and Manikas (2018), we calculated the inventory stickiness of raw materials, work-in-process, and finished goods respectively. For example, in terms of raw material inventory stickiness, the model is as follows:

$$RM\_Stickiness_{i,t} = \log\frac{RM\_INV_{i,t}}{RM\_INV_{i,t-1}} - \log\frac{SALE_{i,t}}{SALE_{i,t-1}} \tag{1-1}$$

$$WIP\_Stickiness_{i,t} = \log\frac{WIP\_INV_{i,t}}{WIP\_INV_{i,t-1}} - \log\frac{SALE_{i,t}}{SALE_{i,t-1}} \tag{1-2}$$

$$FG\_Stickiness_{i,t} = \log\frac{FG\_INV_{i,t}}{FG\_INV_{i,t-1}} - \log\frac{SALE_{i,t}}{SALE_{i,t-1}} \tag{1-3}$$

Hereafter, the subscript *i* is going to identify a firm, and *t* a year, where *RM_Stickiness* represents the raw material inventory stickiness; *WIP_Stickiness* represents the work-in-process inventory stickiness; *FG_Stickiness* represents the finished goods inventory stickiness; *RM_INV* represents the raw material inventory; *WIP_INV* represents the work-in-process inventory; *FG_INV* represents the finished goods inventory; *SALE* represents total sales. We calculate the stickiness of the other two inventory components in the same way, using work-in-process inventory and finished goods inventory instead of raw material inventory, respectively.

**Environmental dynamism**. Drawing on Azadegan et al. (2013a), we firstly regressed the industry's annual sales on time for each two-digit industry with moving five-year windows to capture environmental dynamism. Then we calculated the antilog of the standard error of the regression slope coefficient and used it to measure environmental dynamism (*ED*). That is, the higher the value, the greater the dynamics.

**Environmental complexity**. Mirroring Wiengarten et al. (2017), Herfindahl-Hirschman Index (HHI) is used to capture environmental complexity (*EC*). Specifically, we calculated the sum of the squares of the market shares of all enterprises in an industry as HHI. Note that HHI ranges from 0 to 1, where 1 represents a major competitor with few or large market shares and a less complex market. We multiply HHI by -1, so a larger number indicates a highly complex environment.

**Controls**. In line with Sun and Cui (2014), and Bendig et al. (2017), four firm-level control variables that may influence credit ratings were identified to ensure the robustness and generality of our analysis results. Concretely, firm size is incorporated into our model, which is calculated as the natural logarithm of the total sales. It is argued that large firms usually enjoy a lower default risk. Next, firm age, measured by the logarithm of the number of years since the establishment day, is used as a control variable in our model. It is believed that firm age could act as a proxy for firm knowledge, thus playing an important role in credit rating. As further controls, leverage, measured by the total long-term debt divided by total firm assets, is incorporated into the model to account for indebtedness, which is closely related to credit rating. Finally, since underlying assets can be sold in a default, capital intensity, measured by the ratio of gross property, plant, and equipment divided by total assets, is utilized in this analysis. Table 1 provides the means, standard deviations, and correlation matrices for our applied variables. In addition, the maximum variance inflation factor score for the variables is 1.07, well below the 10 cutoffs, so multicollinearity is not a concern in our model.

Table 1

**Descriptive Statistics and Correlations**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Credit ratings | 1.0000 | | | | | | | | | |
| 2. RM_Stickiness | 0.0027 | 1.0000 | | | | | | | | |
| 3. WIP_Stickiness | -0.0115 | 0.1329* | 1.0000 | | | | | | | |
| 4. FG_Stickiness | 0.0962 | 0.1836* | 0.0204 | 1.0000 | | | | | | |
| 5. Environmental dynamism | -0.0287 | 0.0547 | 0.0795 | 0.0831 | 1.0000 | | | | | |
| 6. Environmental complexity | 0.0444 | 0.0194 | 0.0238 | 0.0425 | 0.1364* | 1.0000 | | | | |
| 7. Firm size | 0.4599* | -0.1010 | 0.0145 | -0.0823 | 0.0941 | -0.1233 | 1.0000 | | | |
| 8. Firm age | -0.0620 | -0.0353 | -0.0015 | -0.0263 | 0.0764 | 0.1041 | 0.1338* | 1.0000 | | |
| 9. Leverage | 0.0419 | 0.0446 | 0.0685 | 0.0310 | 0.0221 | 0.0832 | 0.0167 | 0.0056 | 1.0000 | |
| 10. Capital intensity | -0.0967 | -0.0327 | 0.0853 | 0.0360 | 0.0431 | -0.0694 | 0.2300* | 0.0301 | 0.2283* | 1.0000 |
| Mean | 12.8342 | 0.1055 | 0.2212 | 0.1643 | 1.2904 | -0.0643 | 22.2350 | 2.8716 | 0.1425 | 0.2774 |
| Standard Deviation | 1.4843 | 0.3628 | 0.7434 | 0.5338 | 0.2135 | 0.0450 | 1.2924 | 0.3004 | 0.1029 | 0.1634 |

*[sample size = 404. *p<0.01. RM_Stickiness is Raw material inventory stickiness; WIP_Stickiness is work-in-process inventory stickiness; FG_Stickiness is finished goods inventory stickiness]*

***Model Specification***

To test the overall effects of inventory stickiness on credit ratings, we estimated ordered probit regression models following the methodology in Bendig et al. (2017). Meanwhile, for the analysis of the moderating effects of environmental dynamism and complexity, the interaction terms between inventory component stickiness and environmental uncertainty (i.e., environmental dynamism and environmental complexity) are incorporated into our models. In addition, our model includes year and industry fixed effects, and cluster standard errors at the firm level to account for possible serial correlation. Concretely, to investigate the direct effects of inventory component stickiness on credit ratings, we estimate the following model:

$$\begin{aligned} Rating &= \alpha_0 + \alpha_1 RM\_Stickiness + \alpha_2 RM\_Stickiness^2 \\ &+\alpha_3 WIP\_Stickiness+\alpha_4 WIP\_Stickiness^2 \\ &+\alpha_5 FG\_Stickiness+\alpha_5 FG\_Stickiness^2 \\ &+\alpha CONTROLS+\sum\alpha_t Y_t+\sum\alpha_m I_m+\varepsilon \end{aligned} \quad (2)$$

The moderation model is defined as follows:

$$\begin{aligned} Rating &= \alpha_0 + \alpha_1 RM\_Stickiness + \alpha_2 RM\_Stickiness^2 \\ &+\alpha_3 WIP\_Stickiness+\alpha_4 WIP\_Stickiness^2+\alpha_5 FG\_Stickiness \\ &+\alpha_6 ED+\alpha_7 EC+\alpha_8 RM\_Stickiness\times ED \\ &+\alpha_9 RM\_Stickiness^2\times ED+\alpha_{10} WIP\_Stickiness\times ED \\ &+\alpha_{11} WIP\_Stickiness^2\times ED+\alpha_{12} FG\_Stickiness\times ED \\ &+\alpha_{13} RM\_Stickiness\times EC+\alpha_{14} RM\_Stickiness^2\times EC \\ &+\alpha_{15} WIP\_Stickiness\times EC+\alpha_{16} WIP\_Stickiness^2\times EC \\ &+\alpha_{17} FG\_Stickiness\times EC+\alpha CONTROLS+\sum\alpha_t Y_t+\sum\alpha_m I_m+\varepsilon \end{aligned} \quad (3)$$

Where *Rating* denotes credit ratings; $RM\_Stickiness^2$ represents the quadratic terms of raw material inventory stickiness; $WIP\_Stickiness^2$ represents the quadratic terms of work-in-process inventory stickiness; $FG\_Stickiness^2$ represents the quadratic terms of finished goods inventory stickiness; *ED* represents environmental dynamism; *EC* represents environmental complexity; *CONTROLS* represents control variables, including firm size, firm age, leverage, and capital intensity, and $\varepsilon$ is the residual. In addition, year fixed effects (*Y*) and industry fixed effects (*I*) are controlled.

**Empirical Results**

***Testing Direct Effects***

Table 2 presents the results of the direct effect of inventory component stickiness on credit ratings. For completeness, we firstly introduce the linear model to analyze the impact of each of the three measures of inventory component stickiness on credit ratings in a single regression (Models 1, 3, and 5 in Table 2). Then we add the quadratic terms of inventory component stickiness in individual regressions to provide indications on the incremental importance of each for credit ratings (Models 2, 4, and 6 in Table 2). Finally, we introduce the full model comprising all three measures of inventory component stickiness and their quadratic terms to control the potential interdependencies among inventory components (Model 7 in Table 2). Results in Model 1 to Model 7 suggest that firm size, leverage, and capital intensity are strongly correlated with credit ratings and possess the expected sign. However, we find no effect for firm age.

In terms of the direct effects of inventory component stickiness, H1a and H1b argue that raw material inventory stickiness and work-in-process inventory stickiness have an inverted U-shaped relationship with credit ratings, respectively. The significant regression coefficients ($\beta$=-

0.4034, $p<0.05$ for the quadratic term of raw material inventory stickiness in Model 2, and $\beta=-0.0787$, $p<0.05$ for the quadratic term of work-in-process inventory stickiness in Model 4), provide support for H1a and H1b. However, as shown in Model 6, we find that the quadratic term of finished goods inventory stickiness is not significant ($\beta=0.0487$, $p>0.1$). Interestingly, for both estimations in Models 5 and 6, we find a positive effect of finished goods inventory stickiness on credit ratings significantly (Model 5: $\beta=0.4334$, $p<0.01$; Model 6: $\beta=0.3780$, $p<0.01$). Furthermore, these results are also confirmed in Model 7 (the most conservative model), in which the finished goods inventory stickiness is positive significantly ($\beta=0.3132$, $p<0.05$), but its quadratic term is not significant ($\beta=0.0541$, $p>0.1$). Overall, we only find a linear relationship between finished goods inventory stickiness and credit ratings. Thus, we reject H1c.

Table 2

**Results on the Association between Inventory Component Stickiness and Credit Ratings**

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|---|---|---|---|---|---|---|---|
| RM_Stickiness | 0.4544** | 0.6423*** | | | | | 0.4993** |
| | (2.4385) | (3.2456) | | | | | (2.5521) |
| RM_Stickiness$^2$ | | -0.4034** | | | | | -0.4007** |
| | | (-2.0372) | | | | | (-2.1586) |
| WIP_Stickiness | | | -0.0197 | 0.1796 | | | 0.1327 |
| | | | (-0.2019) | (1.2196) | | | (1.0266) |
| WIP_Stickiness$^2$ | | | | -0.0787** | | | -0.0575* |
| | | | | (-2.1505) | | | (-1.7488) |
| FG_Stickiness | | | | | 0.4334*** | 0.3780*** | 0.3132** |
| | | | | | (3.4182) | (2.6263) | (2.2089) |
| FG_Stickiness$^2$ | | | | | | 0.0487 | 0.0541 |
| | | | | | | (0.5726) | (0.6619) |
| Firm size | 1.0736*** | 1.0766*** | 1.0385*** | 1.0566*** | 1.0896*** | 1.0992*** | 1.1334*** |
| | (12.1186) | (11.9732) | (11.6168) | (11.8054) | (12.7301) | (12.8298) | (12.9328) |
| Firm age | -0.4226 | -0.4301 | -0.4409 | -0.4603 | -0.4321 | -0.4318 | -0.4451 |
| | (-1.4975) | (-1.5468) | (-1.5433) | (-1.6149) | (-1.5441) | (-1.5427) | (-1.6199) |
| Leverage | 2.2035*** | 2.4583*** | 2.2531*** | 2.2137*** | 2.2906*** | 2.2469*** | 2.4383*** |
| | (3.0777) | (3.3673) | (3.0252) | (2.9584) | (3.4858) | (3.3269) | (3.5279) |
| Capital intensity | -1.6993*** | -1.6392** | -1.6989*** | -1.6663** | -1.7661*** | -1.7859*** | -1.6968*** |
| | (-2.6164) | (-2.5503) | (-2.6011) | (-2.5429) | (-2.8858) | (-2.9456) | (-2.8037) |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.3186 | 0.3222 | 0.3123 | 0.3199 | 0.3239 | 0.3246 | 0.3364 |

*[***p<0.01, **p<0.05, *p<0.1. t statistics in parentheses. RM_Stickiness is Raw material inventory stickiness; WIP_Stickiness is work-in-process inventory stickiness; FG_Stickiness is finished goods inventory stickiness]*

### *Testing Moderating Effects*

For our second and third hypotheses, multiple moderated regressions are employed to understand how environmental uncertainty drives our examined relationships. We added the relevant interaction term to the full model. It is noted that we used mean-centered variables to compute interaction terms of all the regression models. Table 3 provides the moderating effects of environmental uncertainty on the relationship between inventory component stickiness and credit ratings. Specifically, Model 1 is the baseline model that contains only control variables; Model 2 is the main effect model that includes inventory component stickiness and two moderators (Environmental dynamism and environmental complexity); and Model 3 is the moderation model that adds interaction terms between inventory component stickiness and environmental dynamism. On this basis, Model 4 is the moderation model that further introduces the relevant interaction terms of environmental complexity. We observed a significant $R^2$ increase in each case, except for the moderation effects of environmental dynamism and complexity (Models 3 and 4).

Concretely, as shown in Models 3 and 4, the coefficient for $RM\_Stickiness^2 \times ED$ is positive and differs significantly from zero (Model 3: $\beta=2.4786$, $p<0.01$; Model 4: $\beta=2.3053$, $p<0.05$). For greater clarity, we plotted the predicted relationship between raw material inventory stickiness and credit ratings for low versus high environmental dynamism in Figure 2. We find that raw material inventory stickiness displays a strong inverted U-shaped relationship in a stable environment (Low environmental dynamism), whereas the relationship is approximately linear and positive in a dynamic environment (High environmental dynamism), supporting H2a. As expected, environmental dynamism has a significant negative moderating effect on the relationship between work-in-process inventory stickiness and credit ratings (Model 3: $\beta$=-0.4650, $p$<0.05; Model 4: $\beta$=-0.5053, $p$<0.01), in support of H2b. Figure 3 shows the negative moderating effect of environmental dynamism in this inverted U-shaped relationship, indicating that the relationship is more concave in a dynamic environment and an approximate negative correlation in a stable environment. Furthermore, the sign of the coefficient for *FG_Stickiness×ED* is significant and positive (Model 3: $\beta$=1.1376, $p$<0.05; Model 4: $\beta$=1.1560, $p$<0.05). We depicted the moderating effect of environmental dynamism on the linear relationship between finished goods inventory stickiness and credit ratings in Figure 4. Results from testing the statistical significance of the conditional effects of *FG_Stickiness* indicate that finished goods inventory stickiness positively affects the credit ratings under both low and high dynamic environments, with this effect being larger in magnitude in a dynamic environment. Thus, there is full support for H2c.

The moderating effect of environmental complexity on the relationship between inventory component stickiness and credit ratings is assessed in Model 4. We find that environmental complexity significantly and positively moderates the curvilinear relationship between work-in-process inventory stickiness and credit ratings ($\beta$=1.5569, $p$<0.05), as well as the linear relationship between finished goods inventory stickiness and credit ratings ($\beta$=5.0670, $p$<0.05), in support of H3b and H3c. We plotted the predicted moderating effects of environmental complexity on these relationships in Figures 5 and 6 for further clarification, respectively. As shown in Figure 5, the inverted U-shaped relationship between work-in-process inventory stickiness and credit ratings is more concave in a low complex environment, whereas the linear relationship between finished goods inventory stickiness and credit ratings is more positive in a highly complex environment. However, the interaction between the quadratic term of raw material inventory stickiness and environmental complexity is not statistically significant. Thus, there is no support for H3a.

Table 3

**Results of the Moderation Analysis**

| | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
|---|---|---|---|---|
| Firm size | 1.0391*** | 1.1204*** | 1.1975*** | 1.2142*** |
| | (11.6076) | (12.6212) | (13.7258) | (13.6849) |
| Firm age | -0.4387 | -0.4422 | -0.4560* | -0.4746* |
| | (-1.5408) | (-1.5976) | (-1.6794) | (-1.7221) |
| Leverage | 2.2463*** | 2.4820*** | 2.6858*** | 2.7717*** |
| | (3.0240) | (3.6903) | (3.8888) | (4.0595) |
| Capital intensity | -1.6997*** | -1.6756*** | -1.9510*** | -1.9989*** |
| | (-2.6008) | (-2.7242) | (-3.4243) | (-3.3656) |
| *Direct effects* | | | | |
| RM_Stickiness$^2$ | | -0.4020** | -0.6255*** | -0.5148** |
| | | (-2.1404) | (-3.2664) | (-2.2737) |
| RM_Stickiness | | 0.4939** | 0.6211*** | 0.6059*** |
| | | (2.5022) | (2.8573) | (2.6840) |
| WIP_Stickiness$^2$ | | -0.0571* | -0.0432 | -0.0839** |
| | | (-1.7060) | (-1.2763) | (-2.5373) |
| WIP_Stickiness | | 0.1325 | 0.1481 | 0.3091** |
| | | (1.0205) | (1.0505) | (2.3048) |
| FG_Stickiness | | 0.3755*** | 0.2903** | 0.2421** |
| | | (3.0520) | (2.4700) | (1.9653) |
| *Moderator* | | | | |
| Environmental dynamism (ED) | | -0.1264 | -1.0878* | -1.3371** |
| | | (-0.2499) | (-1.8196) | (-2.3372) |
| Environmental complexity (EC) | | 0.2724 | -0.6729 | 2.0003 |
| | | (0.0778) | (-0.1652) | (0.4747) |
| *Moderating effects* | | | | |
| RM_Stickiness$^2$×ED | | | 2.4786*** | 2.3053** |
| | | | (2.8245) | (2.5141) |
| RM_Stickiness×ED | | | -1.4279** | -1.4476** |
| | | | (-2.0743) | (-2.0486) |
| WIP_Stickiness$^2$×ED | | | -0.4650** | -0.5053*** |
| | | | (-2.5156) | (-2.6726) |
| WIP_Stickiness×ED | | | 1.4398* | 2.0017** |
| | | | (1.7360) | (2.3607) |
| FG_Stickiness×ED | | | 1.1376** | 1.1560** |

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| | | | (2.0323) | (2.0470) |
| RM_Stickiness$^2$×EC | | | | -5.0097 |
| | | | | (-1.0588) |
| RM_Stickiness×EC | | | | 2.2240 |
| | | | | (0.4923) |
| WIP_Stickiness$^2$×EC | | | | 1.5569$^{**}$ |
| | | | | (2.1731) |
| WIP_Stickiness×EC | | | | -7.1697$^{**}$ |
| | | | | (-2.2662) |
| FG_Stickiness×EC | | | | 5.0670$^{**}$ |
| | | | | (2.4334) |
| $R^2$ | 0.3122 | 0.3356 | 0.3514 | 0.3586 |

*[***p<0.01, **p<0.05, *p<0.1. t statistics in parentheses. RM_Stickiness is Raw material inventory stickiness; WIP_Stickiness is work-in-process inventory stickiness; FG_Stickiness is finished goods inventory stickiness]*

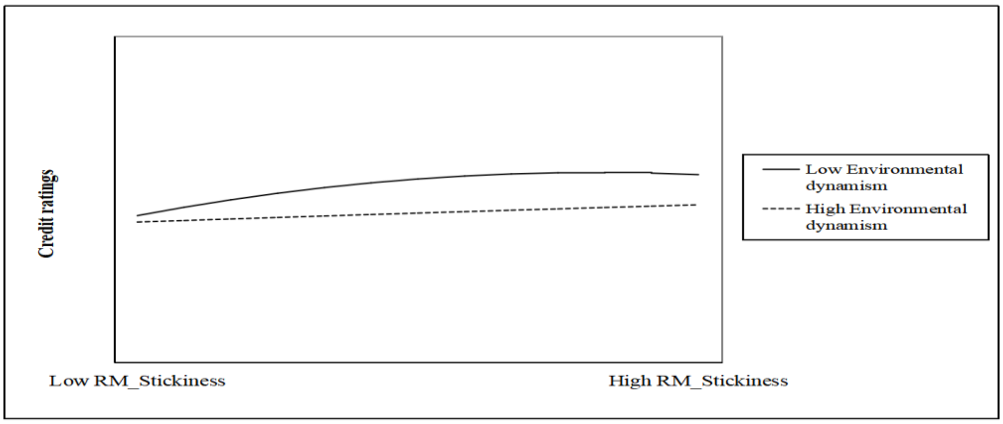


**Figure 2.** Moderating Effect of Environmental Dynamism on RM_Inventory Stickiness-Credit Ratings

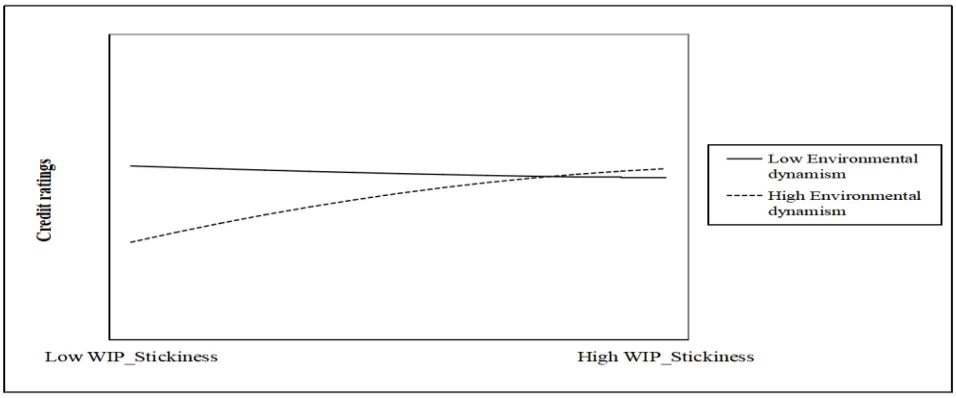


**Figure 3.** Moderating Effect of Environmental Dynamism on WIP_Inventory Stickiness-Credit Ratings

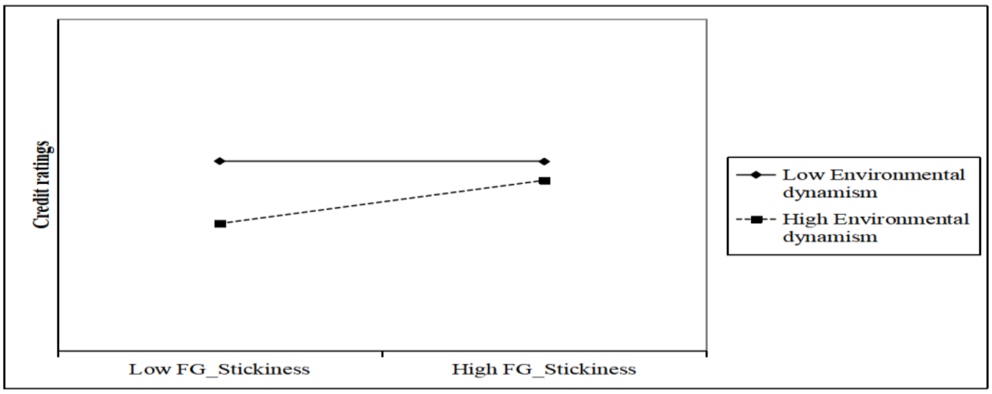

**Figure 4.** Moderating Effect of Environmental Dynamism on FG_Inventory Stickiness-Credit Ratings

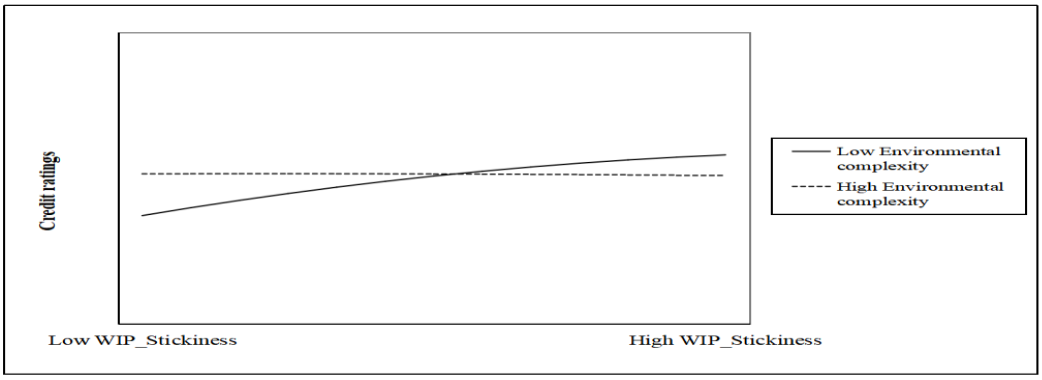


**Figure 5.** Moderating Effect of Environmental Complexity on WIP_Inventory Stickiness-Credit Ratings

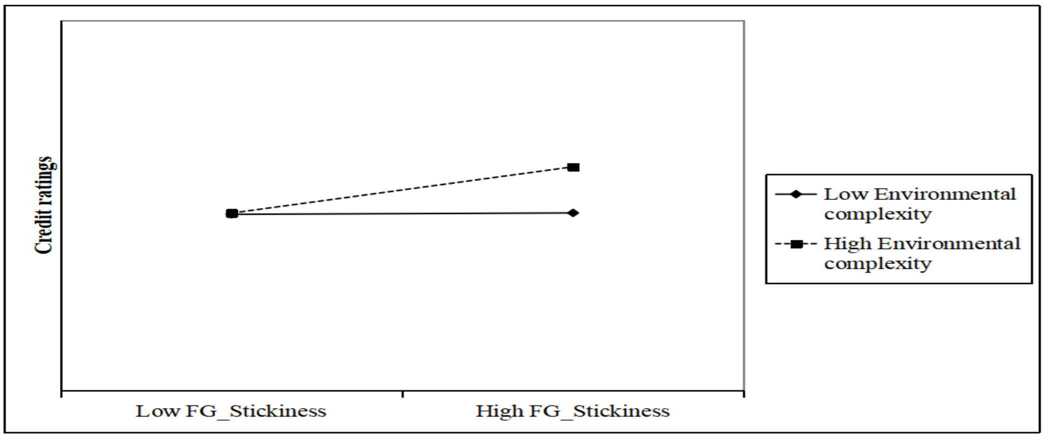


**Figure 6.** Moderating Effect of Environmental Complexity on FG_Inventory Stickiness-Credit Ratings

***Robustness Checks***

To strengthen and support our hypotheses, we vetted three separate checks to ensure the robustness of the results. We repeat the full model (Model 7 in Table 2) and the moderation model (Model 4 in Table 3) of our regression analysis. The corresponding results support our previous findings and are presented in Table 4.

First, we examine whether variations in the regression model affect our results. We employed logit instead of probit regression models on the same sample. The results of the logit regression model are provided in Columns (1) and (2) in Table 4. It is shown that the sign and statistical significance of main variables and interactions remain unchanged.

The purpose of the second robustness check is to minimize concerns that our results are susceptible to estimation bias caused by outliers. We winsorized all variables at 1th and 99th percentile, which is a widely used approach to deal with outliers in empirical management research. Results are reported in Columns (3) and (4) in Table 4. Concluding, the results increase our confidence in the robustness of our results.

As a third robustness check, we assess whether our results are sensitive to the measurement of credit ratings. Following the methodology in Bendig et al. (2017), we assigned eight values from 1 (CC) to 8 (AAA) for the alternative rating variable. Results are reported in Columns (5) and (6) in Table 4 and are consistent with findings before. Finally, we examine whether our results are sensitive to the measurement of inventory stickiness. In line with Shockley and Turner (2015), we calculated inventory stickiness using cost of goods sold as a proxy for sales revenue to reduce measurement bias caused by price volatility. Results are reported in Columns (7) and (8) in Table 4. The coefficient and significant of main variables remain broadly the same as before.

Table 4

**Results of the Robustness Checks**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| $RM\_Stickiness^2$ | -0.7723** | -0.9932** | -0.4052** | -0.5148** | -0.5015*** | -0.6148*** | -0.4336** | -0.5314** |
| | (-2.1610) | (-2.1860) | (-2.1953) | (-2.2737) | (-2.7179) | (-2.6915) | (-2.3274) | (-2.3183) |
| RM_Stickiness | 0.8885** | 1.1734*** | 0.4955** | 0.6059*** | 0.5296** | 0.6406*** | 0.3611** | 0.4868** |
| | (2.3342) | (2.6423) | (2.5390) | (2.6840) | (2.5318) | (2.6957) | (2.0482) | (2.2854) |
| $WIP\_Stickiness^2$ | -0.0967** | -0.1471** | -0.0569* | -0.0839** | -0.0555* | -0.0780** | -0.0559* | -0.0808** |

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | (-2.3541) | (-2.2212) | (-1.7112) | (-2.5373) | (-1.6817) | (-2.3190) | (-1.7203) | (-2.4326) |
| WIP_Stickiness | 0.1529* | 0.4808* | 0.1321 | 0.3091** | 0.1100 | 0.2637* | 0.1007 | 0.2543* |
| | (1.6655) | (1.6784) | (1.0243) | (2.3048) | (0.8436) | (1.9149) | (0.8147) | (1.9003) |
| FG_Stickiness | 0.5869** | 0.4145* | 0.3749*** | 0.2421** | 0.2900** | 0.1779 | 0.3423*** | 0.1810 |
| | (2.4060) | (1.6524) | (3.0604) | (1.9653) | (2.3824) | (1.4092) | (2.7936) | (1.4058) |
| Environmental dynamism (ED) | | -2.2374* | | -1.3371** | | -1.1860** | | -0.8685* |
| | | (-1.8464) | | (-2.3372) | | (-1.9706) | | (-1.8644) |
| Environmental complexity (EC) | | 3.5018 | | 2.0003 | | 1.8847 | | 2.7147 |
| | | (0.3933) | | (0.4747) | | (0.4278) | | (0.6647) |
| RM_Stickiness²×ED | | 4.0225** | | 2.3053** | | 1.9601** | | 1.4226** |
| | | (2.2711) | | (2.5141) | | (2.0276) | | (2.4782) |
| RM_Stickiness×ED | | -2.6984** | | -1.4476** | | -1.2676 | | -1.3597** |
| | | (-1.9664) | | (-2.0486) | | (-1.6161) | | (-1.9627) |
| WIP_Stickiness²×ED | | -0.8551** | | -0.5053*** | | -0.4735** | | -0.4506** |
| | | (-2.2278) | | (-2.6726) | | (-2.4631) | | (-2.2382) |
| WIP_Stickiness×ED | | 3.3308* | | 2.0017** | | 1.6755* | | 1.6288* |
| | | (1.9153) | | (2.3607) | | (1.9244) | | (1.7997) |
| FG_Stickiness×ED | | 2.0483* | | 1.1560** | | 0.9933* | | 1.5331* |
| | | (1.7681) | | (2.0470) | | (1.6808) | | (1.9013) |
| RM_Stickiness²×EC | | -8.9082 | | -5.0097 | | -3.6290 | | -3.8294 |
| | | (-0.9568) | | (-1.0588) | | (-0.7531) | | (-0.8308) |
| RM_Stickiness×EC | | 5.0234 | | 2.2240 | | 0.4590 | | 0.8562 |
| | | (0.5501) | | (0.4923) | | (0.0961) | | (0.2034) |
| WIP_Stickiness²×EC | | 2.6744** | | 1.5569** | | 1.3469* | | 1.4895** |
| | | (1.9782) | | (2.1731) | | (1.8583) | | (2.1137) |
| WIP_Stickiness×EC | | -12.9395** | | -7.1697** | | -6.4174** | | -6.8723** |
| | | (-2.0065) | | (-2.2662) | | (-1.9942) | | (-2.2212) |
| FG_Stickiness×EC | | 9.3174** | | 5.0670** | | 4.7509** | | 4.1743** |
| | | (2.2494) | | (2.4334) | | (2.3325) | | (1.9935) |
| Control variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.3398 | 0.3622 | 0.3356 | 0.3586 | 0.3582 | 0.3768 | 0.3311 | 0.3504 |

*[***p<0.01, **p<0.05, *p<0.1. t statistics in parentheses. RM_Stickiness is Raw material inventory stickiness; WIP_Stickiness is work-in-process inventory stickiness; FG_Stickiness is finished goods inventory stickiness. Due to space limitations, the control variables are not listed one by one.]*

## Discussions

### *Theoretical Contributions*

Our findings contribute to theory in several ways. First, we extend the literature by explicitly examining inventory stickiness and its three key underlying dimensions (raw materials, work-in-process, and finished goods) as driving factors to improve credit ratings. Prior studies examining the role of inventory management in impacting bankruptcy risks do not acknowledge the diverse natures of raw materials, work-in-process, and finished goods (Bendig *et al.,* 2017; Wang *et al.,* 2019b; Zhu *et al.,* 2020). The results show that certain dimensions act as facilitators, while other dimensions act as inhibitors of credit ratings. We offer a theoretical explanation of why sticky inventory management of raw materials and work-in-process should display an inverted U-shaped relationship with credit ratings, which is similar to the conclusion that lean inventory management affects credit ratings (Bendig *et al.,* 2017). On this basis, our results once again confirm the view that sticky inventory management and lean inventory management are not in conflict, and both argue that excessive inventory is a waste (Zhu *et al.,* 2020). Also, this study provides new evidence for the prior studies which emphasize that moderate implementation of sticky inventory management can improve performance (Lin *et al.,* 2021; Wang *et al.,* 2022). In addition, the positive impact of finished goods inventory stickiness on credit ratings partially agrees with the argument that inventory slack helps avoid bankruptcy (Azadegan *et al.,* 2013a).

The second way our work contributes to theory is by exploring the role of environmental dynamism in moderating the relationship between inventory stickiness and credit ratings. We found support for the assertion that sticky inventory management is vital for achieving improved performance in a dynamic environment (Kroes & Manikas, 2018; Wang *et al.,* 2022; Zhu *et al.,* 2020). In particular, the stickiness of these three inventory components exerts a positive impact on credit rating in a dynamic environment. This result supports the argument that inventory stickiness helps defend against environmental threats (Kroes & Manikas, 2018). Interestingly, we find that sticky inventory management can enjoy higher credit ratings in a stable environment, consistent with the impact of inventory stickiness on productivity (Wang *et al.,* 2022). Additionally, it must be borne in mind that sticky inventory management of work-in-process may hurt credit ratings in a stable environment, echoing the negative impact of excessive inventory stickiness on survival ability in a stable environment (Zhu *et al.,* 2020).

Finally, our contribution is finding evidence concerning the moderating role of environmental complexity on the relationship between inventory stickiness and credit ratings. This extends prior work by Wang et al. (2019b) who found a negative moderating impact of environmental complexity on the relationship between inventory leanness and venture survival. Our finding is partially consistent with our theory insofar as the impact of finished goods inventory stickiness on credit ratings has a significantly steeper positive slope in a highly complex environment. This aligns with our explanation that excessive inventory contributes to lower operational risks in a highly complex environment (Azadegan *et al.,* 2013a; Zhu *et al.,* 2018). Meanwhile, sticky inventory management of work-in-process exerts a positive impact on credit ratings in a low complex environment, whereas this impact is significantly reduced in a highly complex environment. This result supports the view that sticky inventory management, while maintaining production stability, can only mask, rather than solve, production problems (Zhu *et al.,* 2020).

### *Managerial Implications*

This research provides several implications for operations managers. The results underscore the importance of sticky inventory management for managers by showing that the stickiness of the three inventory components affects credit ratings differently. In particular, managers are cautioned to appropriately implement sticky inventory management of raw materials and work-in-process to improve credit ratings; otherwise, operational risks will occur to hurt credit ratings. Also, this study guides managers to increase finished goods inventory stickiness, which is conducive to improving credit ratings. However, managers should avoid the trap of increasing finished goods inventory stickiness indefinitely in order to improve credit ratings. Indeed, the manufacturer's inventory of finished goods is capped.

Furthermore, this study provides evidence suggesting that managers should pay special attention to environmental uncertainty when implementing sticky inventory management. Our findings suggest that managers can obtain higher credit ratings by increasing the stickiness of the three inventory components in a dynamic environment, whereas managers should avoid sticky inventory management of work-in-process in a stable environment. In addition, managers can achieve higher credit ratings by implementing sticky inventory management of finished goods in a highly complex environment. In contrast, managers can enjoy higher credit ratings by increasing work-in-process inventory stickiness in a low complex environment. Thus, we provide a road map for managers to achieve good credit ratings by implementing sticky inventory management in an uncertain environment.

## Conclusions

In summary, this study takes a more sophisticated assessment of how sticky inventory management can be implemented to improve credit ratings. This research provides evidence that sticky inventory management of raw materials and work-in-process has an inverted U-shaped impact on credit ratings, while finished goods inventory stickiness is positively related to credit ratings. Moreover, this study details how and why environmental dynamism and complexity moderate the relationships between inventory component stickiness and credit ratings. Concretely, we found that environmental dynamism can positively moderate the impact of sticky inventory management of raw materials and finished goods on credit ratings, but negatively moderate the relationship between work-in-process inventory stickiness and credit ratings. In addition, we further found evidence that the impact of sticky inventory management of work-in-process and finished goods on credit ratings is positively moderated by environmental complexity.

Although we attempted to address multiple issues associated with inventory stickiness and credit ratings, this study is not free from limitations. The first limitation concerns our measures of inventory stickiness. The inventory stickiness indicator only applies to periods when revenue is decreasing, which prevents us from capturing more information on sticky inventory management. Future research should pay more attention to the development of new indicators based on full samples. The second limitation, which is pervasive in studies such as ours, is that it has not yet verified the underlying theoretical mechanisms mentioned in our hypothetical relationship. It is worth noting that there may be a mediating effect between inventory stickiness and credit ratings. Future research may attempt to disentangle some mediators to understand the mechanisms in this relationship. Finally, we limited our models to investigate the moderating effect of environmental uncertainty on the relationship between inventory stickiness and credit ratings. Thus, future research should consider some other moderators, such as corporate governance.

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