The Financing Role of Inventory: Evidence from China's Metal Industries

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Classical inventory theory suggests that inventory plays vital roles in the matching of demand and supply. In this paper, we provide theoretical and empirical evidence that inventory can play a significant financing role in practice. In the context of global supply chain transaction, we develop a model to show that inventory can be leveraged to take advantage of the financial arbitrage opportunities in financial markets with frictions due to government regulation. Empirically, we first use country-level data in China to test the model prediction that the inventory levels of copper, aluminum, and zinc are positively associated with the expected returns of the financial arbitrage after controlling for other explanations, including input price trajectory, currency risk, industrial demand, and economic uncertainty. We then confirm the financing role of inventory at the firm-level using data from China's metal processing industries after controlling for inventory factors, including demand, lead-time, profitability, capacity, and firm size. We further substantiate that the firms who use inventory as a financing tool indeed increase their short-term debts. The economic impact of the financing role of inventory is more substantial than many classical demand-side or supply-side factors in inventory management.

Key words: inventory financing, operations-finance interface, empirical research, China.
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1. Introduction

It is well-known that inventory plays an essential role in facilitating the matching of demand and supply. The classical inventory theory has studied various drivers of inventory such as demand-side or supply-side uncertainty, procurement lead time, economies of scale in production and transportation. In this paper, we complement the literature by providing theoretical and empirical evidence that inventory can play a vital financing role in financial markets with significant frictions.

Consider China, the world's second largest economy by GDP and the leading consumer and importer of metal commodities. Despite four decades of high growth and market reforms, its financial market is relatively closed to the world with capital control and other non-market-oriented

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measures. This often creates financial arbitrage opportunities. For example, it is well recognized that the borrowing cost, e.g., the lending interest rate, in China is usually much higher than that in the overseas (outside China mainland) financial markets such as Hong Kong[1].

Figure 1 plots, over the past 10 years, (a) the 3-month London Interbank Offered Rate (Libor), a key benchmark interest rate that serves as reference rate to short-term commercial loans in USD; (b) the 3-month Shanghai Interbank Offered Rate (Shibor) which serves as reference rate to many short-term loans in CNY; and (c) the USD/CNY exchange rate. We see that from 2010 to 2018, the average Shibor rate is 3.79%, while the average Libor rate is only 0.63%. Although Shibor is volatile, suggesting China's central bank (People's Bank of China) has been actively adjusting its monetary policy such as deposit reserve and interest rates, it is consistently higher than Libor. Moreover, the chart shows that CNY is in a clear appreciation channel in the entire time window except for the year 2016 and 2018. This clearly presents a financial arbitrage opportunity if a certain amount of overseas capital (in USD) can be brought into China to earn a higher return (in CNY) and then be allowed to flow back to the overseas capital market (in USD). However, such economic benefits are difficult to attain due to strict capital control in China[2].

There is documented evidence that many importers will circumvent the capital control by picky backing the overseas low-interest capital on their imported inventory into China to earn higher interest returns (see Section 3.1 for a more detailed description of the practice). For example, Garvey and Shaw (2014) observe a significant scale of "financial consumption" of the metal in China due to the "arbitrage between US letter of credit interest rates and Chinese wealth management products." They suggested that "as much as one-third of monthly imports of the metal pass through financing deals" at the time of their study. Yam (2015) reports that more than 50% of China's refined copper inventory in 2012-2013 was used for collateral-based financing.

Based on our recent interaction with Zijin Mining Group Co., Ltd. (public listed as 2899.HK), a major global commodity supplier and trader based in China, a typical process of using inventory as a financing tool involves the following three steps (see also Garvey and Shaw 2014). In the first step, the importer will utilize a bank credit (called a letter of credit, or LC) provided by a domestic bank to secure a low-interest loan in US dollars (USD) from an overseas bank to purchase a batch

[1] China private sector lending rate is over 20% in 2012 and still as high as 15% in 2015, reflecting the high growth opportunity and the private sector's high willingness to pay to finance their business (`https://www.ceicdata.com/en/china/private-lending-rate-wenzhou`). However, in the same period, U.S. dollar loans from Hong Kong banks are charged annual interest rates of about 1.5-2% according to Yam (2015).

[2] The capital inflows to China's financial markets are controlled by the "Qualified Foreign Institutional Investor" (QFII) program, under the management of the State Administration of Foreign Exchange (SAFE). SAFE grants the QFII status to selected foreign institutions, which can then invest in China's financial markets. According to the Xinhua News Agency, a total of 287 overseas institutions have received quotas amounting to 100.46 billion in 2018 (`http://www.xinhuanet.com/english/2018-09/01/c_137436073.htm`).

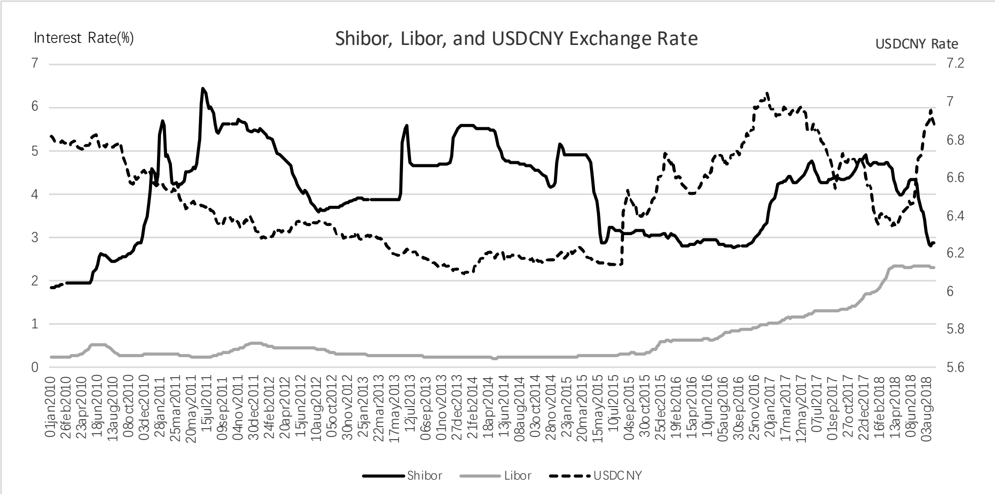

Figure 1 **Shibor, Libor, and USDCNY exchange rate from 2010 to 2018. The solid black line is 3-month Shibor (Shanghai Interbank Offered Rate), a proxy for the short-term interest rate in CNY. The solid gray line is 3-month Libor (London Interbank Offered Rate), a proxy for the short-term interest rate in USD. The dashed black line is the spot exchange rate for USD to CNY.**

of product in the global market. In step two, the imported inventory will either be immediately sold in the domestic market or be collateralized through inventory financing to obtain capital in Chinese Yuan (CNY), which will then in turn be invested in short-term assets with a higher yield. In the last step, the importer will collect the investment returns and repay the overseas loan when the LC comes due.

In this paper, we develop a three-period model that captures the essential trade-offs an importer faces when he adopts this process to purchase a batch of inventory (in period 1) to meet a stochastic demand (in period 2 or 3) and further engages in a short-term investment with stochastic returns (in period 3). The model's insight suggests that an increase in the expected rate of domestic investment return or a decrease in the overseas' borrowing rate (after hedging foreign exchange risk) will lead to a rise in the importer's optimal order quantity. This behavior will be amplified when the importer can borrow more capital by leveraging the domestic bank credit to acquire a large amount of low-interest loan from the overseas financial market. Thus, our model reveals that inventory under certain circumstances could play dual roles in a firm's supply chain decisions: One is the operational role in classical inventory theory, i.e., to buffer the supply-side uncertainty and to meet the real demand from the consumption, and the other is the financing role.

Though focusing on the optimal inventory decision of a single product made by a single firm, the insights from our model should lead to a number of predictions about inventory and financing dynamics at the aggregated level in certain industries in which the practice of inventory-facilitated USD borrowing as a mean of funding higher return CNY investment is widespread. Our observations in China suggest that imported inventories of many products have been used to take advantage of the financing opportunities. However, the practice is most prevalent in the metal industries in general, and in particular, in non-ferrous commodity metal such as copper, aluminum, and zinc due to the imported products' large demands and their ease of liquidation. We therefore empirically test the main prediction from our model that the inventory levels are positively associated with the financing arbitrage opportunity, or the expected net *investment return*, at two segments of the metal supply chains – the country-level raw material segment of the metal commodity markets and the firm-level metal processing segment for firms in China's manufacturing sector that use metal commodity as direct inputs.

For the country-level empirical analysis, we obtained data from various sources spanning from January 2010 to May 2018, including the commodity price and inventory information from Shanghai Futures Exchanges (SHFE), domestic and overseas lending rates and currency exchange rates from China National Inter-bank Funding Center (NIFC) and Wind terminal[3], industrial demand proxies from National Bureau of Statistics of China (NBSC). Then we introduce the construction of key variables and conduct the empirical test to identify the impact of the interest rate spread on the commodity inventory level. We observe that primary non-ferrous metal inventories (i.e., copper, aluminum, zinc) are positively related to the investment return significantly after controlling for supply-side and demand-side operational factors such as price trajectory of the metal commodity, exchange rate risk between USD and CNY, production demand proxied by China's macroeconomic indicators, and economic uncertainty measured by the stock market and interest rate volatility. Further, we find that the economic impact of the financing role is more substantial than most of the operational factors identified in classical inventory theory.

For the firm-level empirical investigation, we obtained firm-level data from the balance sheets for the manufacturing sector of the China A-Share market[4]. The firm-level data includes 2,131 manufacturing firms out of all 3,276 public-listed firms in China and spans from January 2010 to June 2018. We first confirm the positive association between the firm-level inventory and the investment return for all manufacturing firms, after controlling other inventory factors, including demand, lead-time, profitability, capacity, and firm size. Furthermore, we have also tested a hypothesis suggested by our theoretical findings that a firm who uses its inventory as a financing tool is more likely to also leverage its borrowing capacity in seeking higher financial returns. Specifically, we find that the investment return is positively associated with the firms' short-term borrowing. More

[3] Wind is a financial data and analytical tools provider in mainland China and is headquartered in Shanghai Lujiazui Financial Center. In the domestic market, Wind Information's clients include more than 90% of Chinese securities companies, fund management companies, insurance companies, banks, and investment companies; in the international market, 75% of the Qualified Foreign Institutional Investors (QFII) are customers of Wind Information.

[4] A-shares are the stocks of Chinese companies incorporated on the mainland, quoted in CNY, and listed in the Shanghai Stock Exchange and the Shenzhen Stock Exchange.

convincingly, we find that the positive association between the investment return and inventory level is only significant among firms whose short-term borrowing moves in the same direction as the investment return, supporting the hypothesis that the firm-level inventory raises short-term capital for financial arbitrage.

These three observations together confirm the mechanism depicted by our theoretical model that a firm who uses inventory as a financing tool will do so through short-term borrowing. In the industry breakdown analysis of the manufacturing sector, we further recognize that only firms in the metal processing industry fully support the three observations. The fact that the metal processing industry is the main driver for the result of the entire manufacturing sector agrees with the country-level empirical finding.

This paper makes two important contributions to the existing literature. To our best knowledge, our paper is among the first in the literature to offer empirical evidence that financing can be a major factor in making inventory decisions based on our modeling insight. This suggests that the traditional inventory theory should incorporate the financing role in making the optimal decision.

First, we develop a model by jointly considering the product market demand and the financial arbitrage opportunity based on an inventory financing process in industry practice. The process also follows the typical international supply chain transaction protocol closely. Therefore, the model implication applies to all countries with frictions in their financial markets. Our theoretical analysis demonstrates the financing role of inventory in a firm's operations decisions. Specifically, we show that the financial arbitrage opportunity can cause a firm to strategically over-stock its inventory. This finding complements the classical inventory theory which does not identify financing as a significant driver for inventory decision making.

Second, we empirically test the model's predictions that the financial arbitrage opportunity will significantly affect companies' actual inventory decisions. Specifically, our study examines both the country-level of aggregated metal commodities and the firm-level of working inventories. The country-level empirical test confirms the relationship between the investment opportunity and the inventory levels for three commodities (copper, aluminum, and zinc) that are widely reported to be used as financing tools in practice. The magnitude of the impact of commodity-based financing on inventory level is large compared to other known operational factors used as control variables in the empirical identification. At the firm-level, using the firm-specific short-term debt on firm balance sheets, we not only verify the relationship between investment return and inventory but also establish the financing mechanism by providing evidence that the firms that use inventory as financing tool indeed rely on the short-term borrowing. The significance of the inventory's financing role at the firm level is also substantial compared to other known operational factors in a firm's inventory decision.

The rest of the paper is organized as follows. In the next section, we review the literature on related research. Section 3 presents the theoretical model which provides theoretical predictions for our empirical analysis. Section 4 offers empirical evidence that supports the model insight using the country-level metal inventory data. Section 5 confirms the empirical evidence again using firm-level data and further establishes the mechanism for the financing role of inventory. The last section summarizes the results and concludes the paper.

2. Literature Review

Classical inventory theory depicts the role of inventory as a buffer to facilitate the matching of demand and supply. Therefore, it suggests several key factors, such as supply and demand uncertainty, economic of scale in operations, process flexibility, and future price uncertainty, that will affect inventory decisions. A number of papers in the literature have empirically tested some of these inventory drivers. For example, using Compustat of public U.S. firm data, Gaur et al. (2005) find a firm's inventory turnover is negatively correlated with gross margin but positively correlated with capital intensity. Rumyantsev and Netessine (2007) empirically verify some of the inventory drivers identified by classical inventory models and find that aggregate inventory level is positively associated with factors such as demand uncertainty, procurement lead time, cost of inventory underage, and economies of scale in operations. Using data from U.S. automobile industry, Cachon and Olivares (2009) empirically show that two factors–the decrease of dealerships in a firm's supply network which leads to decrease in demand variability and the increase in production flexibility–are main drivers for inventory reduction. Jain et al. (2013) offer empirical evidence that an increase in global sourcing results in an increase in inventory investment and sourcing from more suppliers may lead to reduced inventory investment.

A number of empirical studies on inventory management focus on how a firm's inventory performance affect its stock returns. For example, Chen et al. (2005) concludes that firms with abnormally high inventory have poor long-term stock market performance. Hendricks and Singhal (2009) show that excess inventory announcements are associated with statistically negative stock market reactions. Using data from a sample of public U.S. retailers, Alan et al. (2014) find that inventory productivity can strongly predict a firm's future stock returns.

To the best of our knowledge, this paper is the first in the literature that theoretically and empirically show that inventory can be used as a financing tool to take advantage of the financial arbitrage opportunities in a financial market with capital flow frictions, such as the case of China. Our study therefore complements the classical inventory literature by identifying the financing role as an additional driver affecting inventory decisions.

Our paper is also related to a stream of research that studies operational decisions with various short-term financing options such as trade credit, bank credit or inventory-based financing. Examples include Buzacott and Zhang (2004), Ho et al. (2008), Gupta and Wang (2009), Caldentey and Chen (2009), Chen and Cai (2011), Giannetti et al. (2011), Kouvelis and Zhao (2011), Jing et al. (2012), Iancu et al. (2017), Yang and Birge (2017), Lee et al. (2017), Tunca and Zhu (2017), Fu et al. (2017), Alan and Gaur (2018), and Wuttke (2018). In particular, Fu et al. (2017) study a multi-period stochastic inventory management model in which a cash-constrained firm uses its inventory as collateral to obtain loans. They show that the availability of the inventory-based financing may cause the firm to strategically over-stock its inventory in order to secure more loans with which to meet future demands. Our study differs from the above paper in two major ways: (a) The financing-motivated over-stocking inventory behavior in our paper is caused by financial arbitrage opportunity; and (b) Our paper provides both theoretical analysis and empirical evidence of this behavior.

Most relevant to our study is the paper by Tang and Zhu (2016) which is motivated by the observations in China that commodity importers used their inventory as collateral to take advantage of the financial arbitrage opportunity. Through theoretical and empirical analysis, the paper finds that a higher collateral demand for commodities is associated with higher spot market commodity prices and makes the inventory-convenience yield relation less negative. The latter finding complements a commodity storage theory which suggests that a lower inventory should correspond to a higher convenience yield of holding commodities because it increases the real option value of consuming a commodity anytime.

Our paper differs from Tang and Zhu (2016) in several major ways. First, Tang and Zhu (2016) develop a game-theoretic model that captures the interaction of two players representing exporting and importing countries respectively. The model is then used to predict certain demand and supply dynamics such as price changes in country-level commodity markets. Our theoretical model focuses on how financing role of inventory impacts a single firm's optimal inventory and financing decisions. The theoretical findings are then used to predict the aggregated inventory behaviors at both country and firm levels. Second, aside from testing different model predictions, the empirical analysis in Tang and Zhu (2016) uses the country-level aggregated data only, while our paper tests the inventory behavior at both country and firm levels. In addition, our firm-level data also confirms the mechanism used by firms that utilize inventory as a financing tool–those firms tend to leverage short-term borrowing. Third, Tang and Zhu (2016) contributes to the commodity finance theory while our paper contributes to the inventory theory in Operation Management by studying the financing role of inventory.

3. A Model for the Financing Role of Inventory

In this section, we will first introduce typical financial transaction between two unrelated firms in global supply chains and then develop a model for a firm who imports a batch of a product to take advantage of the financial arbitrage opportunity. The model will be used to establish hypotheses for our subsequent empirical analysis.

3.1. Financial Transaction in Global Supply Chains

International trade between two unrelated firms in a global supply chain must work around a fundamental trade dilemma: the foreign supplier wants to be paid before it ships the goods and the domestic buyer or importer does not want to pay until they possess the imported goods. Because of the distance between the two, it is challenging for the pair of seller and buyer to simultaneously hand over goods with one hand and accept payment with the other.

The fundamental dilemma is solved by using respected banks as the intermediary. According to international trade protocols (Eiteman et al. 2001), a greatly simplified view of global supply chain transaction with intermediary banks is described in Figure 2.

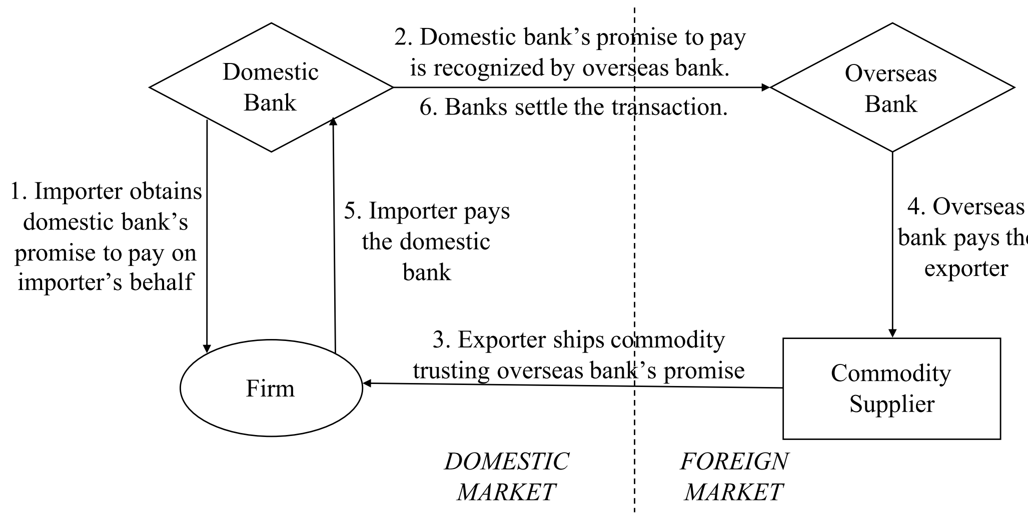

Figure 2 **International supply chain transaction with banks as the import/export intermediary**

In this simplified view, both the domestic firm and the foreign supplier will use respective banks whom they trust, denoted as the domestic bank and the overseas bank. The domestic firm obtains the domestic bank's promise to pay on its behalf, which is also recognized by the overseas bank. The bank's commitment to pay is called a letter of credit (LC), which will be explained in more details in the next subsection. As the foreign supplier trusts the overseas bank, it will ship the commodity to the importer firm and receives immediate payment from the overseas bank. After the goods are delivered, the domestic firm will reimburse the domestic bank. Lastly, the two banks will settle their transactions. To summarize, the standard protocol used in global supply chains has the primary advantage to reduce risk – the foreign commodity supplier may now rely on the promise of the bank rather than on the promise of the domestic firm.

If the buyer uses its own capital to pay for the imported goods, the financial settlements between all parties can be carried out almost immediately after the imported goods are shipped. However, the domestic importer in our study will use the imported inventory as a financing tool to circumvent capital control by utilizing the aforementioned financial transaction process as follows. The importer will ask its domestic bank to issue a *usance LC* (also called a *time LC*), a type of LC commonly used in international trade, to guarantee payment to the overseas bank but with a deferred payment (typically three to six months) after the imported documents are accepted. The overseas bank essentially treats such delayed payment as a loan to the domestic buyer. As there is a time lag between the time when the overseas supplier ships the imported goods and the time when the domestic firm makes the payment, the importer effectively picky backs onto its imported inventory certain amount of overseas low-interest capital, which enters the domestic financial market to generate potentially higher rate of returns, and eventually flows back to the overseas capital market in the form of loan repayment. Therefore, the financing role of inventory is naturally embedded in the global supply chain transaction. The detailed process of the financing role of inventory based on the global supply chains is discussed in the following subsection.

3.2. Process Description

Consider a representative firm (i.e., a domestic importer) who imports a batch of a product. The imported inventory serves two purposes – to meet the domestic market demand for the product and to take advantage of the overseas and domestic interests spread. In the following, we describe the common process of such inventory financing in details. The glossary of key model variables is organized in Table 1. Figure 3 depicts the key steps in the process.

Suppose the firm has decided to purchase Q unit of the product in the overseas market at the unit price USD w. Following a standard international trade practice, the firm will first at time 0 (step 1 and 2 in Figure 3) go to a domestic bank (the issuing bank) to obtain a *usance LC*. Such an LC requires the importer to deposit a percentage α of the total payment as collateral capital in the issuing bank. Thus, the importer will deposit αwQ (CNY αwQf_S at the spot exchange rate f_S at time 0) in the bank which will earn interest at a deposit rate r_d[5]. The haircut percentage α depends on the importer's line of credit with the bank. Such a bank credit facility does not require the purchased inventory as additional collateral; rather, it is established based on the importer's

[5] For simplicity of notation, all interest rates in our model are expressed as the percentage of the principal for the entire duration of the deposit or loan.

Table 1 List of Modeling Variables

Parameter	Description
Q	the firm's ordering quantity of the commodity
w	the wholesale price of the commodity
α	collateral rate $\alpha < 1$, commonly it is 10%
f_S	the amount of CNY per USD at the spot exchange rate at time 0.
r_0	the oversea fixed lending rate
r_d	the domestic fixed lending rate
$\tilde{R}(Q)$	the revenue generated by selling the commodity in the domestic market
η	the domestic investment return with PDF $g(\cdot)$, $\eta \in [r_1, r_2]$
r	$r = E[\eta]$
f_T	T_2-forward exchange rate(CNY/USD) at $t = 0$
β	the ratio (usually 70 %) of CNY loan to the market value of the commodity

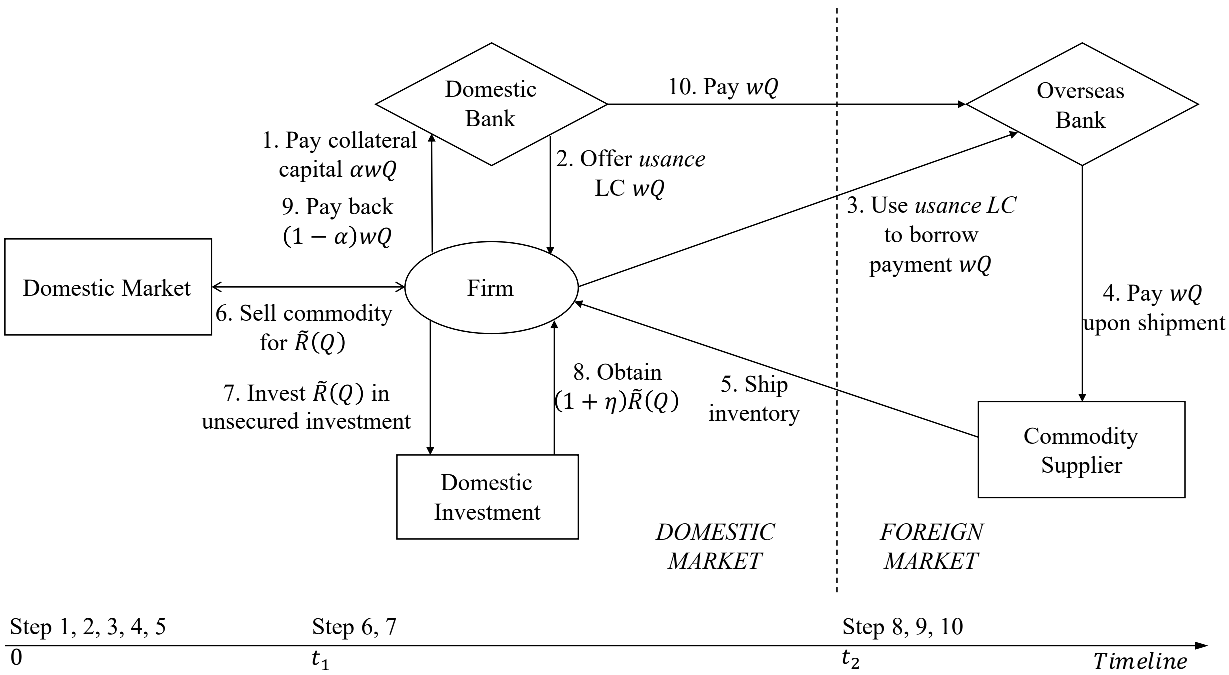

Figure 3 Steps for using inventory for financing in typical trade transaction

other collateralized assets or the bank's evaluation of the importer's creditworthiness. Since we focus on modeling the firm decision and the bank is passive, we take the fair haircut ratio as given.

The issuing bank will charge a service fee (assumed to be zero in our model without loss of generalizability) for issuing the LC. Due to the credit limit, we assume that the importer can only obtain an LC with a total payment of no more than $wQ_{\max}f_S$. In other words, the maximum amount the importer can purchase is $Q_{\max}$ units.

Next, the importer will (step 3-5) use the domestic LC to obtain a *sight LC* of USD wQ from an overseas bank who agrees to arrange the payment to the seller when the purchased product is shipped. Since the domestic LC will be paid later in its face value wQ at time t_2, the overseas bank would accept it at a reduced price. Thus, the importer will also pay a discount of USD r_0wQ (CNY r_0wQf_S at the spot exchange rate) upfront to overseas' lending bank at an interest rate r_0. Note that the overseas bank collects the almost risk-less discount payment (r_0wQ) as the face amount is back by the issuing bank's *usance* LC.

At time t_1, the importer receives the inventory which will either be immediately sold in the domestic market or used as collateral to back up a bank loan to obtain capital in CNY. In the main paper, we model the first option as it is the process suggested by our interview with Zijin Mining Group and the investment bank reports[6]. Specifically, upon receiving the imported inventory, the firm immediately sells the inventory in the domestic market to generate $\tilde{R}(Q)$ revenue in CNY (step 6).

Between time t_1 and t_2 when the LC comes due, the importer will invest the revenue (step 7) and obtain a return $(1+\eta)\tilde{R}(Q)$, where η is the stochastic investment return rate (step 8). At time t_2, the importer will pay the issuing bank the remaining LC value USD $(1-\alpha)wQ$ who will then, in turn, send a payment of USD wQ to the overseas bank as promised in the LC (step 9-10).

It can be seen from the above discussion that the major advantage of an LC to the domestic firm is that it needs not to pay until the inventory is received and the LC comes due. The main disadvantage is the fee charged by the bank and the fact that the LC reduces the domestic firm's borrowing line of credit with its bank. We also remark that by issuing the LC, the issuing bank may face certain credit risk. One type of risk is a possible slowdown in the economy which will lower the liquidation value of inventory and other assets, leading to a default on both the loan payment. Another type of risk lies in the domestic investment as it may be unsecured with the principal not guaranteed. As the domestic bank can adjust the haircut ratio to control the credit risk, we assume that the firm can fulfill complete liability in the following model analysis. This is also reasonable because, in practice, the financial damages to the firm are likely far greater than defaulting on a single loan. Still, in the worst case of limited liability, we have analyzed and verified offline that all model insights will stay the same qualitatively when bankruptcy is allowed.

Note that step 1-5 and 9-10 are the typical trade transaction under the international finance setting shown in Figure 2. The additional step 6-8 are to leverage the financing role of inventory to earn expected high investment returns in the domestic market.

[6] Both our interview with Zijin Mining Group and the Credit Suisse report (Garvey and Shaw 2014) indicate that one of the widespread industry practices is to cash out the metal inventory in the domestic market immediately. We have analyzed the other popular alternative method disclosed in the Goldman Sachs report (Yuan et al. 2014), i.e., to use the metal inventory as collateral for borrowing at lower rates than what would otherwise be available for unsecured lending, and found the two different methods are similar in nature and lead to similar insights for our empirical hypothesis.

3.3. Model Development

In this subsection, we develop a three-period model based on the importer's inventory decision, i.e., Figure 3's 10-step process discussed in the last subsection.

In the first period (step 1-5), at time 0, the firm needs to decide the purchasing quantity Q to maximize his expected profits at time t_2 net of his debt. As discussed earlier, we will assume in our base model that the importer will aim to fulfill full liability for his debt when making the single inventory purchase decision.

In the first period, the firm incurs the discount cost $r_0 wQf_S$ to secure the *sight LC* from the overseas bank. We also assume that the firm will hedge the exchange rate risk of the USD payment by signing a forward USDCNY contract with an exchange rate f_T[7].

The cost to repay the loan born by the firm is, therefore, CNY wQf_T. For simplicity without diluting the main insight, we ignore some other costs, such as the cost of spot exchange for converting its interest payment, storage cost, and the shipping cost.

In the second period (step 6), at time t_1, the importer receives the inventory shipment and sell it in the domestic market. We assume that the revenue from the sales $\tilde{R}(Q)$ is a stochastic random variable with mean $R(Q)$. We also assume that:

Assumption 1. *R(0)=0 and R(Q) is strictly increasing in Q for $Q \in \mathcal{Q}$, where $\mathcal{Q} = [0, Q_{\max}]$.*

This assumption is reasonable because the products popularly used as financing tools in practice are typically commodities which can be sold in spot markets. Thus, we can assume that the importer in our model can always sell every unit of his inventory (up to $Q_{\max}$ units) for a positive marginal revenue.

In period 3 (step 7-9), the firm will invest the sales revenue to seek higher yield at time t_1. We assume that the expected domestic investment return rate $\eta \in [r_1, r_2]$ is stochastic with mean $r \equiv E[\eta]$. We assume that:

Assumption 2. *For any fixed $Q \in \mathcal{Q}$, The sales revenue $\tilde{R}(Q)$ and the domestic investment return rate η are independent random variables.*

At time t_2, the investment returns have realized, and the firm pays the issuing bank $wQf_T - (\alpha wQf_S)(1+r_d)$ to settle the USD wQ payment to the overseas bank.

The importer decides the optimal inventory quantity Q^* at time 0 to maximize the expected profit given by

$$\Pi(Q,r) = (1+r)R(Q) - [r_0 f_S + f_T - (1+r_d)\alpha f_S]wQ$$

where $r \in [-1, +\infty)$, $r = -1$ implies that the firm loses all of his investment. We have the following proposition.

[7] Without loss of generality, we do not consider the hedging cost in the model as it will not affect the insights. In the empirical part, we include the exchange rate risk as a control variable.

PROPOSITION 1. *The optimal order quantity is a non-decreasing function of the expected investment return r and is a non-increasing function of the overseas lending rate r_0.*

We will only prove the first part of the proposition with respect to the expected domestic investment return rate r. The second part with respect to r_0 can be shown similarly. Define

$$Q^*(r) = inf \arg\max_{Q \in \mathcal{Q}} \Pi(Q, r).$$

By Assumption 1, it is easy to show that $\Pi(Q,r)$ satisfies increasing differences in $(Q,r) \in \mathcal{Q} \times [-1, +\infty)$. Thus, we have

LEMMA 1. $\Pi(Q,r)$ *is supermodular in* (Q,r) *for* $(Q,r) \in \mathcal{Q} \times [-1, +\infty)$

Applying Topkis's Theorem (Topkis 1978), we have shown that $Q^*(r)$ is increasing in r.

Proposition 1 provides a number of predictions for our subsequent empirical analysis. It suggests that the financial arbitrage opportunity, i.e., the difference between the overseas lending rate and the expected domestic investment return rate, will strongly impact the importer's optimal inventory decision. Specifically, optimal inventory quantity is non-decreasing in $(r - r_0)$, i.e., non-increasing in r and non-decreasing in r_0. Taking the aggregate effects of many importers in the metal processing industries who use inventory as a financing tool, our model predicts that the inventory level at the aggregated country level, as well as the firm level in these industries, should be positively associated with the expected return of the financial arbitrage using inventory.

Another implication of the results in Proposition 1 is that the importer's short-term debt level is also non-decreasing in $(r - r_0)$. Therefore, we predict that the short-term debt level of a firm should also be positively associated with the expected return of the financial arbitrage.

Now we are ready to verify the model empirically on the country-level aggregated metal commodity inventory (section 4) as well as the firm-level metal-processing inventory (section 5).

4. Country-level Inventory Empirical Analysis

This section describes the data on metal commodity and macroeconomic indicators, the construction of variables, and empirically test the model predictions on the country-level aggregated metal commodity inventory.

We select metal commodities by two criteria. First, the metal commodities should have active futures or forward prices in China since at least the start of 2010, when the domestic lending rate started to increase substantially above the overseas lending rate. Second, they are among the major varieties in China's metal inventory. Applying these two criteria, we end up with copper, aluminum, and zinc, which also dominate the majority of trading volume in the non-ferrous metal on Shanghai

Futures Exchanges (SHFE), the leading metal commodity exchange in China. Proposition 2 in the model analysis suggests the following main hypothesis.

Hypothesis: The inventory level of a metal commodity (copper, zinc, and aluminum) is positively associated with the net investment returns.

4.1. Metal Commodity and Macro Data

We use Shanghai Futures Exchanges (SHFE) as the data source for copper, aluminum, and zinc. SHFE also operates the major inventory warehouse in China. Ideally, we would like to measure the quantity of each metal inventory involved in the financing for each firm. Unfortunately, such data is unavailable as only aggregated inventory value is available in the firm-level balance sheets. Therefore, following the standard approach in the literature such as Gorton et al. (2012), we construct a proxy for the market-wide financing need of metal inventory using the SHFE inventory data. This proxy of country-level inventory data allows us to examine the exact variety of metal inventory. In the next section, we provide empirical evidence on the financing role and the mechanism using the firm-level inventory and short-term borrowing data, but without information on the exact inventory type.

Table 2 summarizes the data sources for metal commodity and macroeconomic variables. The metal inventory data are weekly observations from January 2010 to May 2018, while the commodity spot and forward prices are available for each trading day. Similar to literature (Tang and Zhu 2016), the prices of the nearest unexpired futures are used as spot prices.

The interest rates and other macroeconomic indicators are collected from several different sources. We use the 3-month Shanghai Interbank Offered Rate (Shibor) from China National Interbank Funding Center (NIFC) to proxy the short-term interest rate in CNY and 3-month London Interbank Offered Rate (Libor) from Wind terminal to proxy the short-term interest rate in USD. We also acquire spot exchange rate USDCNY and 3-month non-deliverable forward exchange rate form Wind terminal to construct the proxy for currency risk. We use the Industrial Value Added (IVA), the Purchasing Manager Index (PMI), and the electricity production (ep) to proxy the industrial demand. We use the volatility of the Shanghai Composite Index (sz) to construct a proxy for economic uncertainty.

4.2. Variable Construction

For the dependent variables, we use log inventory levels of copper, aluminum, and zinc ($lginv.cu$, $lginv.al$, $lginv.zn$). For the independent variable, we explain how we calculate the proxy for the net investment returns in the below discussion.

Table 2 Commodity & Macro Data Description

Variable	Description	Source
$inv.cu$	weekly inventory of copper	SHFE
$inv.al$	weekly inventory of aluminium	SHFE
$inv.zn$	weekly inventory of zinc	SHFE
$spot.cu$	weekly spot price of copper	SHFE
$spot.al$	weekly spot price of aluminium	SHFE
$spot.zn$	weekly spot price of zinc	SHFE
$forward_{i,t+\Delta}$	metal $i \in \{copper, aluminium, zinc\}$'s Δ-month forward price	SHFE
$shibor$	Shibor: 3 months	NIFC
$libor$	USD Libor: 3 months	Wind
$exchangerate$	USDCNY spot rate	Wind
$usdcnyndf$	USDCNY Non-deliverable Forwards: 3 months	Wind
sz	Shanghai (Securities) Composite Index	Wind
iva	Industry Value Added	NBS
pmi	Purchasing Managers' Index	NBS
ep	Electricity Production	NBS

Notes: SHFE is the abbreviation of the Shanghai Futures Exchange. The price data is available for all trading days, and the inventory data is weekly. The prices of the nearest unexpired futures are taken as spot prices. Based on the literature, the prices of the futures that will be deliverable in 3 months are used to calculate the convenience yields. To avoid multicollinearity, prices of the futures that will be deliverable in 6 months are used to calculate the price gap instead of the 3-month data. NIFC is the abbreviation of National Interbank Funding Center, and NBS is the abbreviation of National Bureau of Statistics of China. Wind is a Chinese Financial Data Company. $shibor$, $libor$, $exchangerate$, $usdcnyndf3$ are available for all trading days. pmi, iva, and ep are monthly data.

Note that the unsecured investment returns in China are usually much higher than Shibor, but an accurate measurement is difficult to obtain due to heterogenous risk premiums chosen by individual firms. Instead, we use Shibor to proxy for the market lending rate in China. As the financing role of inventory facilitates the firm to borrow from overseas, we first calculate the interest rate spread (irs) between the domestic Shibor and the overseas Libor below.

$$irs_{it} = shibor_t - libor_t \tag{1}$$

In addition, when a firm uses commodity inventory for financing, the natural gain for holding that commodity, i.e., the convenience yield (cy), cannot be obtained. The convenience yield is calculated below, which also endogenizes considerations such as the holding cost and the lead time of metal inventory.

$$cy_{it} = shibor_t - \frac{ln(forward_{i,t+\Delta}) - ln(spot_{it})}{\Delta/12} \tag{2}$$

where i denotes the metal type ($i \in \{\text{copper}, \text{aluminum}, \text{zinc}\}$), $spot_{it}$ is the spot price of metal i, and $forward_{i,t+\Delta}$ is the price of the metal i futures that will be delivered in Δ months. We take $\Delta = 3$ to calculate the convenience yields as the 3-month is the typical length for the financing.

Therefore, the net interest rate spread ($nirs$), or the net investment returns, based on the financing role of inventory should be the interest rate spread adjusted by the convenience yield.

$$nirs_{it} = irs_{it} - cy_{it} \tag{3}$$

After constructing the main variables, we plot Figure 4 to demonstrate the net investment returns and the inventory level for copper, aluminum, and zinc in the China market. As the figure shows, there is clear evidence that the inventory level co-moves with the net investment returns, most noticeably for copper, then followed by aluminum and zinc.

To consider alternative explanations, we introduce control variables for various classical factors on the matching of demand and supply, including price trajectory, currency risk, industrial demand, and economic uncertainty.

For the price trajectory, the metal commodity price risk suggests that a firm should place a large order now if the future metal commodity price is expected to rise given the current spot price. Therefore, we control for both the spot price (*spot*) and the spot-futures price gap (pg). To avoid multicollinearity in the variable estimation, the price of the 6-month futures ($\Delta = 6$) is used to calculate the price gap below.

$$pg_{it} = forward_{i,t+\Delta} - spot_{it} \tag{4}$$

For the currency risk, the exchange rate risk suggests that a firm should place a large order now if CNY is expected to depreciate against USD and vice versa. We construct the expected exchange rate change ($eerc$) by taking the difference between USDCNY 3-month forwards and the spot rate below.

$$eerc_t = usdcnyndf_t - exchangerate_t \tag{5}$$

To consider alternative explanations, we introduce control variables for various classical factors on the matching of demand and supply, including price trajectory, currency risk, industrial demand, and economic uncertainty.

For the price trajectory, the metal commodity price risk suggests that a firm should place a large order now if the future metal commodity price is expected to rise given the current spot price. Therefore, we control for both the spot price (*spot*) and the spot-futures price gap (pg). To avoid multicollinearity in the variable estimation, the price of the 6-month futures ($\Delta = 6$) is used to calculate the price gap below.

$$pg_{it} = forward_{i,t+\Delta} - spot_{it} \tag{6}$$

For the currency risk, the exchange rate risk suggests that a firm should place a large order now if CNY is expected to depreciate against USD and vice versa. We construct the expected exchange

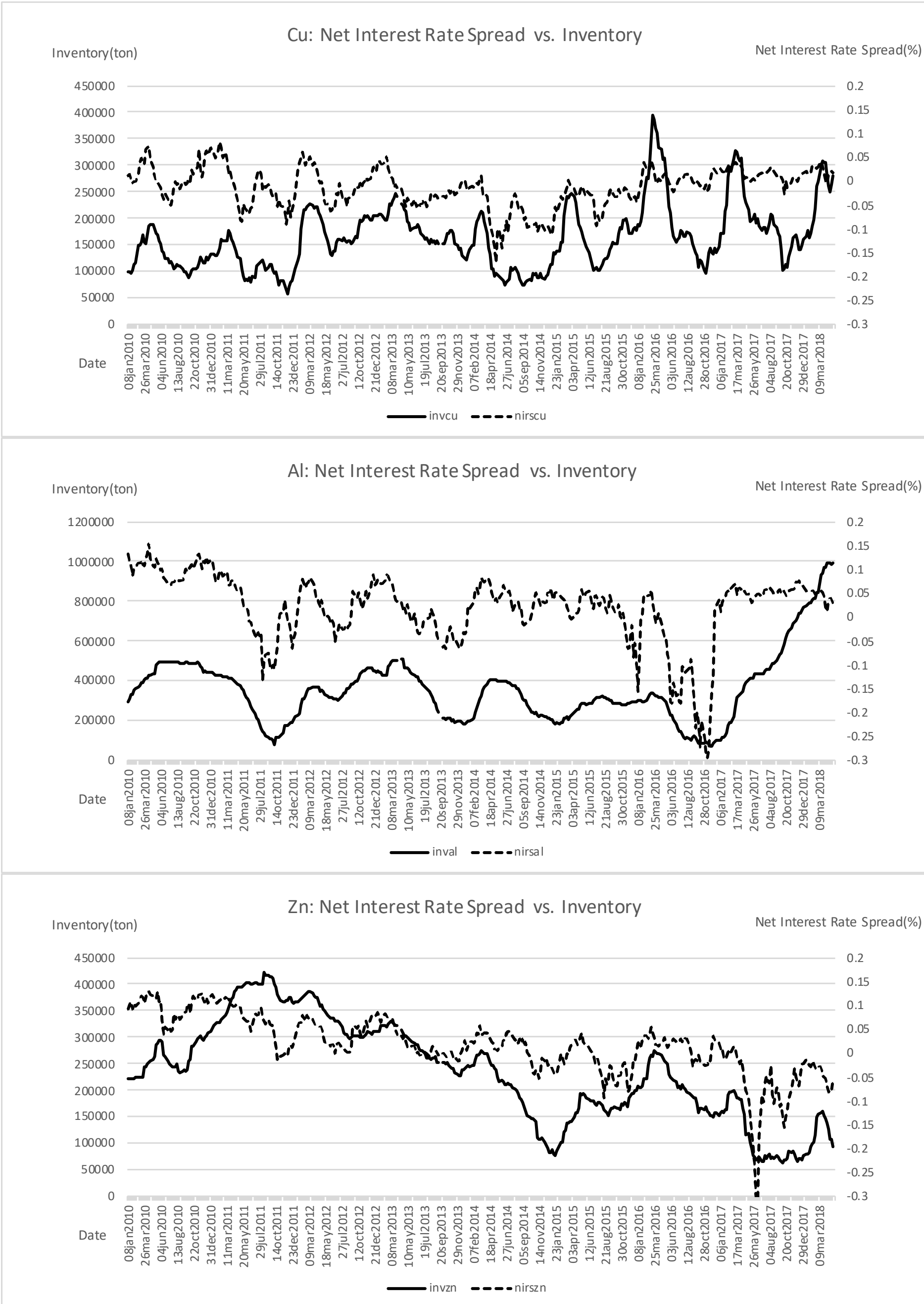

Figure 4 **(top) The net investment returns and the inventory level for copper in China, for year 2010-2018. Solid line is the log inventory level, and the dashed line is the net interest rate spread reflecting the investment return rate.**
(middle) The net investment returns and the inventory level for aluminum in China, for year 2010-2018.
(bottom) The net investment returns and the inventory level for zinc in China, for year 2010-2018.

rate change ($eerc$) by taking the difference between USDCNY 3-month forwards and the spot rate below.

$$eerc_t = usdcnyndf_t - exchangerate_t \tag{7}$$

For the industrial demand, we use the Industrial Value Added (IVA), the Purchasing Managers Index (PMI), and the monthly electricity production. IVA is used to measure the output of the industrial sector of the economy. The industrial sector includes manufacturing, mining, and utilities typically. Although these sectors contribute only a small portion of the gross domestic product (GDP), they are highly sensitive to the lending rates and consumer demand. The activity of industrial production also consume the raw materials, such as the metal commodity inventory under discussion here.

PMI is an indicator of economic activity based on surveys collected from purchasing managers in the entire manufacturing sector. It is a reflection of purchasing managers assessment of better, same or worse business conditions in any given month. Therefore, it is an important sentiment reading for the manufacturing sector and the economy. Specifically, an index reading of 50.0 means that the variable is unchanged, a number over 50.0 indicates an improvement, while anything below 50.0 suggests a decline.

Electricity production (ep) is a monthly macro-indicator measuring the amount of electricity generated from all the power generators in the country. According to China Daily[8], manufacturing and service sectors consume the most electricity in the country. Since the economic output is related to the electricity consumed, electricity production is also an early indicator of quarterly GDP. We use log electricity production ($lgep$) in the regression.

For the economic uncertainty, we construct a proxy for the stock market sentiment by calculating the rolling 120-day daily volatility of the Shanghai Composite Index returns ($szstd$) below.

$$szstd_t = \sqrt{\frac{1}{120}(\sum_{T=t-119}^{t} sz_T^2) - \frac{1}{120}(\sum_{T=t-119}^{t} sz_T)^2} \tag{8}$$

We also contruct a proxy for the investment return uncertanty by calculating the rolling 120-day daily volatility of the interest rate spread ($irsstd$) below.

$$irsstd_t = \sqrt{\frac{1}{120}(\sum_{T=t-119}^{t} irs_T^2) - \frac{1}{120}(\sum_{T=t-119}^{t} irs_T)^2} \tag{9}$$

Table 3 reports the summary statistics for all variables defined above. In particular, the standard deviation of the net investment returns ($nirs$) range between 4.10% to 6.85%, which we will later use to assess the economic importance of the net investment returns for the inventory level.

[8] `http://www.chinadaily.com.cn/a/201901/31/WS5c525240a3106c65c34e7791.html`

Table 3 Summary Statistics for Commodity & Macro Variables

Variable	N	mean	sd	p25	p50	p75	min	max
lginv.cu	377	11.97	0.369	11.73	12.0	12.2	10.96	12.89
lginv.al	377	12.63	0.525	12.31	12.67	12.95	11.19	13.81
lginv.zn	377	12.24	0.51	11.97	12.32	12.65	11.07	12.95
nirs.cu	377	-0.0161	0.0410	-0.0384	-0.0122	0.0151	-0.171	0.0812
nirs.al	377	0.00848	0.0685	-0.0141	0.0305	0.0535	-0.295	0.118
nirs.zn	377	0.00595	0.0589	-0.020	0.0121	0.039	-0.322	0.124
pg.cu	377	-0.0040	0.0804	-0.0556	-0.0094	0.0616	-0.275	0.186
pg.al	377	0.0150	0.0341	-0.0034	0.0229	0.0395	-0.117	0.077
pg.zn	377	0.00844	0.0439	-0.0088	0.0121	0.0274	-0.195	0.104
spot.cu	377	0.506	0.0931	0.452	0.507	0.557	0.345	0.743
spot.al	377	0.142	0.0168	0.131	0.142	0.155	0.101	0.183
spot.zn	377	0.173	0.0369	0.148	0.157	0.181	0.125	0.269
eerc	377	0.0301	0.0452	-0.0076	0.0418	0.0619	-0.069	0.179
pmi	377	50.81	0.924	50.1	50.6	51.4	49	53.4
iva	377	1.487	0.267	1.271	1.477	1.686	0.846	2.084
lgep	377	6.115	0.135	6.018	6.115	6.212	5.737	6.405
irsstd	377	0.0033	0.00226	0.00151	0.0027	0.00469	0.00013	0.00974
szstd	377	0.0124	0.00601	0.00888	0.011	0.0134	0.00483	0.031

4.3. Estimation Results

In this subsection, we test the hypothesis that the inventory levels of major metal commodities are related to the net investment returns after controlling for classical factors in inventory theory.

We run each metal commodity log inventory level on net interest rate spread (*nirs*), controlled by expected exchange rate change (*eerc*), spot-futures price change (*pg*), spot price (*spot*), industrial demand measured by PMI (*pmi*), IVA (*iva*), and the electricity production (*lgep*), as well as economic uncertainty measured by stock market volatility (*szstd*) as well as interest rate spread volatility (*irsstd*) using the below specification.

$$\begin{aligned} lginv_{it} &= \beta_0 + \beta_1 nirs_{it} + \beta_2 eerc_t + \beta_3 pg_{it} + \beta_4 spot_{it} \\ &+ \beta_5 pmi_t + \beta_6 iva_t + \beta_7 lgep_t + \beta_8 irsstd_t + \beta_9 szstd_t + \epsilon_{it} \end{aligned} \tag{10}$$

where $lginv_{it}$ is measured at weekly frequency, pmi_t, iva_t, and $lgep_t$ are updated at monthly frequency, and other variables, available for all trading days, are taken weekly moving average in the regression.

Table 4 reports the regression results for copper, aluminum and zinc. For each metal commodity, each table, column(1) reports the regression coefficients with price trajectory controls, exchange rate risk control, and year fixed effects. Column (2) adds industrial demand controls. Column (3) adds the economic uncertainty controls. All columns show a significantly positive coefficient for the net interest rate spread (*nirs*), suggesting that higher net investment returns are indeed associated with a higher metal inventory level.

Table 4 Relation between Metal Inventory and Net Investment Returns

Variable	**Copper** (*lginv.cu*)			**Aluminium** (*lginv.al*)			**Zinc** (*lginv.zn*)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
nirs	15.50***	15.56***	15.17***	4.16***	5.89***	3.51***	2.44**	2.64***	3.73***
	(11.235)	(11.124)	(11.272)	(3.614)	(4.337)	(2.766)	(2.373)	(2.632)	(3.515)
pg	-5.67***	-6.23***	-6.20***	0.70	-2.10	1.49	1.28	0.61	-0.80
	(-7.512)	(-8.428)	(-8.651)	(0.308)	(-0.809)	(0.608)	(0.919)	(0.424)	(-0.551)
spot	-1.71***	-1.96***	-1.19***	2.16	1.53	14.18***	-9.29***	-9.44***	-9.92***
	(-4.839)	(-5.967)	(-3.483)	(0.633)	(0.449)	(4.658)	(-11.326)	(-10.309)	(-8.396)
eerc	-1.11***	-0.80**	-1.35***	0.73	0.49	-0.87	-0.17	-0.02	0.45
	(-3.364)	(-2.295)	(-3.482)	(1.349)	(0.843)	(-1.447)	(-0.644)	(-0.054)	(1.431)
pmi		0.04**	0.03**		0.02	-0.01		0.02*	0.02
		(2.549)	(2.015)		(0.717)	(-0.326)		(1.852)	(1.300)
iva		-0.06	0.00		0.57***	0.54***		-0.06	0.02
		(-0.741)	(0.033)		(3.127)	(3.470)		(-0.581)	(0.171)
lgep		-0.91***	-0.86***		-0.37*	-0.12		-0.25*	-0.42***
		(-6.045)	(-6.229)		(-1.702)	(-0.680)		(-1.697)	(-2.749)
irsstd			4.26			-8.31			29.01***
			(0.749)			(-1.057)			(5.128)
szstd			20.97***			55.90***			-5.38
			(5.126)			(6.747)			(-1.029)
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	377	377	377	377	377	377	377	377	377
R-squared	0.690	0.727	0.753	0.653	0.673	0.732	0.882	0.885	0.893

Note: *** p<0.01, ** p<0.05, * p<0.1 using two-tailed tests.

Table 5 summarizes the economic impacts of those variables whose coefficients are significant. The economic importance of a particular variable is defined as the change of the log inventory level that responds to the value of that variable increased from its sample median to its 75th percentile. Specifically, the 25th percentile change of the net investment returns would increase the copper inventory by 41.4%, the aluminum inventory by 8.1%, and the zinc inventory by 10.0%. For all metal commodities examined, the net investment returns are significant with a substantial economic impact compared to other control variables. Taking copper inventory, for example, the economic impact of the net investment returns is one order of magnitude higher than those of the spot price, the exchange rate risk, the industrial demand proxied by PMI and the electricity production, as well as the economic uncertainty. The only one control variable that has the same magnitude in economic impact as the net investment returns is the price gap. This empirical evidence suggests that the financing role of metal inventory is not only a statistically significant factor but also a principal factor with economic impact compared to others. China's metal inventory cannot be comprehensively explained by domestic industrial demand alone, as the role of financing shown in Table 5 is rather substantial.

In unreported tables, we have checked the alternative specification using interest rate spread

Table 5 Economic Significance of Net Investment Returns & Control Variables

Variable	(75th-median)	Copper	Aluminium	Zinc
nirs.cu	0.0273	0.4141***		
nirs.al	0.023		0.0807***	
nirs.zn	0.0269			0.1003***
pg.cu	0.0710	-0.4406***		
pg.al	0.0166			
pg.zn	0.0153			
spot.cu	0.050	-0.0596***		
spot.al	0.013		0.184***	
spot.zn	0.024			-0.238***
eerc	0.0201	-0.0271***		
pmi	0.8	0.0218**		
iva	0.209		0.1135***	
lgep	0.097	-0.083***		-0.0404***
irsstd	0.002			0.0577***
szstd	0.0024	0.0503***	0.1342***	

constructed by Wenzhou index[9] instead of Shibor, as well as the alternative specifications using the detrended inventory level[10], our results remain the same qualitatively.

5. Firm-Level Inventory Empirical Analysis

The previous section establishes the empirical evidence using the country-level aggregated metal commodity inventory. In this section, we describe the firm-level variables, confirms that the country-level finding that the inventory level of metal is associated with the net investment returns also holds for firms in the manufacturing sector (particularly in the metal processing industry), and furthermore provides evidence for the financing mechanism using the firm-level short-term borrowing variable in financial statements.

5.1. Manufacturing Firm Data

Firms using metal commodity inventory for financing are primarily manufacturing firms. Therefore, we focus on China publicly listed firms (firms listed on China A-Share Market) in the manufacturing sector. We use the China Securities Regulatory Commission (CSRC) industry classification standard to determine the manufacturing sector. There are 82 industry groups, of which 29 industries belong to the manufacturing sector. We acquire the quarterly firm financial statement variables from Wind terminal ranging from January 1, 2010, to August 30, 2018. During this period, there

[9] We use Shibor as it provides similar time-series variation as the unsecured investment returns. Still, some unsecured lending rates are publicly available, with the most influential being the Wenzhou Private Finance Index showing that the recent interest rate on private borrowing is about 15.59% in the Wenzhou metropolitan area, which is an entrepreneurial hub in the southeast of China. See `http://www.wzmjjddj.com` (Chinese language website).

[10] From Figure 4 we can observe that inventories tend to have a time trend, which may be explained by the industrial demand. Still, we can detrend the inventory to eliminate the influence of time trend by removing the average inventory over the previous year from the present value, i.e., $inv_t - \frac{1}{52}\sum_{T=t-52}^{t-1} inv_T$.

are 3,276 publicly listed firms in the whole sample, of which 2,026 firms are in the manufacturing sector. Therefore, our firm sample of the manufacturing sector includes about 2/3 firms of all publicly listed firms in China A-Share universe. Table 6 describes the raw data variables.

Table 6 Firm Level Data Description

Variable	Description	Source
inv	firm quarterly inventory	Wind
$stborr$	firm quarterly short-term borrowing (quarterly)	Wind
$cogs$	firm quarterly cost of goods sold, proxy for margin-adjusted sales	Wind
$sales$	firm quarterly sales	Wind
ap	firm quarterly account payable	Wind
$fixedasset$	firm quarterly fixed asset, proxy for production capacity	Wind
$asset$	firm quarterly total asset	Wind

The dependent variable for the firm-level specification is the quarterly inventory (inv) a firm reports in its financial statement. As we cannot see the material details of the firm-level inventory, we use the inventory variable as a proxy for the actual inventory that may perform the financing role. To start with, we conduct the empirical test on the entire manufacturing sector first. Afterward, we check the granular industry groups within the whole manufacturing sector. In particular, one industry group within the manufacturing sector is the metal processing industry, which should mostly possess the metal inventory. For the main independent variable, we use the interest rate spread (irs) directly to proxy a firm's net investment opportunity. This proxy does not adjust the convenience yield as there is no reliable way to estimate it at the firm level without knowing the exact variety and quantity of the firm-level inventory.

We also pay particular attention to the short-term borrowing ($stborr$), an account shown in a firm's balance sheet indicating any debt obligation that is due within one year. This variable can be used to examine the inventory-induced financing mechanism in the empirical specification – if a firm uses its inventory for financing, its short-term borrowing should increase as suggested by the modeling analysis in Section 3. We normalize both the inventory and the short-term borrowing by the total asset, i.e., $INV = inv/asset$, $STB = stborr/asset$.

To consider for alternative explanations, we construct control variables on drivers of inventory such as demand level and its growth, lead-time, firm profitability, production capacity, and firm size following empirical literature in operations management.

The market demand is measured by sales. Specifically, we use cost of good sold variable ($cogs$) to proxy margin-adjusted sales as Cachon et al. (2007). COGS is a better measure of sales for our purpose as both inventory and COGS are recorded at the cost basis without profit. As a balance sheet item, it is normalized by asset, i.e., $COGS = cogs/asset$. Similar to Rumyantsev and Netessine (2007), besides COGS we further add sales growth variable (SG) by measuring the percentage growth in COGS from the current quarter to the next quarter, which explains a firm's inventory build-up in anticipation of future sales. Both $COGS$ and SG should be positively related to inventory.

$$SG_{i,t} = \frac{cogs_{i,t+1} - cogs_{i,t}}{cogs_{i,t+1}} \tag{11}$$

We use two measures for firm profitability, gross margin and return on assets (ROA). Gross margin (GM) follows the definition in Gaur et al. (2005). A higher gross margin is correlated with higher fill rate thus higher inventory level. Hence, inventory and gross margin should be positively correlated.

$$GM_{i,t} = (sales_{i,t} - cogs_{i,t})/sales_{i,t} \tag{12}$$

ROA is a different profitability measure, as it evaluates how efficient a firm's management is in generating earnings from its assets on the balance sheet. The higher the number, the more efficient a firm's management is at managing its assets to generate profits. Therefore as a component of asset, inventory should be negatively correlated with ROA.

$$ROA_{i,t} = (sales_{i,t} - cogs_{i,t})/asset_{i,t} \tag{13}$$

Production capacity is usually measured in the fixed assets variable ($fixedasset_{i,t}$), which includes plant, property, and equipment. If a firm has high capacity in its fixed asset composition, the inventory can be processed with low delay. Therefore, production capacity should be negatively related to inventory. It is normalized by the total asset for the regression specification.

$$FA_{i,t} = fixedasset_{i,t}/asset_{i,t} \tag{14}$$

Lead time (LDT) is another operational variable that explains inventory. A firm with a higher lead time requires more inventory. We measure lead time (LDT) following Rumyantsev and Netessine (2007), which is the average number of days of accounts payable outstanding. As the actual lead time data is not publicly available, the cash conversion cycle is a fair proxy for the lead time for the entire production cycle from buying inputs to selling outputs.

$$LDT_{i,t} = \frac{365}{4 * cogs_{i,t}/ap_{i,t}} \tag{15}$$

At last, firms with different sizes may have different inventory management policies. Rumyantsev and Netessine (2007) find large firms hold less inventory in general than small ones. In addition, size is a typical measurement for financial constraint (see Carpenter et al. 1998 and Hadlock and Pierce 2010). Large firms are less financially constrained in general, so they have easier access to short-term capital and hold less inventory in anticipation of the future demand shocks compared to small firms (Dasgupta et al. 2018). We take the natural log of the firm's total asset ($Size = log(asset)$) to proxy the firm size.

Table 7 reports the summary statistics of all firm-level variables. Table 8 presents the correlation coefficients for those variables. All measures are winsorized at 1% and 99% to avoid extreme outliers.

Table 7 Summary Statistics for Firm Variables in China Manufacturing Sector

Variable	Explanation	N	mean	sd	p25	p50	p75
INV	inventory	42995	0.156	0.0962	0.0897	0.136	0.197
STB	short-term borrowing	42995	0.140	0.114	0.0483	0.118	0.204
irs	interest rate-spread	41468	0.0328	0.0126	0.0245	0.032	0.0429
$COGS$	cost of good sold	33998	0.138	0.108	0.0691	0.111	0.172
SG	sales growth	28466	1.085	0.524	0.839	1.014	1.209
ROA	return on asset	42397	0.0375	0.0514	0.00792	0.0255	0.0575
GM	gross margin	33975	0.137	0.45	0.0257	0.218	0.381
FA	fixed asset	42983	0.246	0.142	0.138	0.22	0.332
LDT	lead-time	33949	88.63	89.44	41.03	68.72	104.6
$Size$	log asset	42995	21.79	1.238	20.94	21.68	22.5

Table 8 Correlation Matrix for Firm-level Variables in China Manufacturing Sector

	INV	STB	irs	$COGS$	SG	ROA	GM	FA	LDT	$Size$
INV	1	0.145	0.0182	0.17	0.057	-0.0525	0.0021	-0.184	0.0391	-0.01
STB	0.149	1	-0.0123	0.181	0.0062	-0.279	-0.0907	0.243	-0.0887	0.0698
irs	0.0435	-0.0018	1	0.0186	-0.0237	-0.0057	-0.0283	-0.0402	0.0012	0.0333
$COGS$	0.233	0.171	0.0203	1	-0.207	0.113	-0.203	0.105	-0.368	0.118
SG	0.0399	0.0012	-0.0223	-0.253	1	-0.179	0.112	-0.0421	0.366	-0.0099
ROA	-0.0647	-0.302	-0.0272	0.128	-0.257	1	0.153	-0.156	-0.202	-0.0337
GM	-0.0528	-0.148	-0.0404	-0.377	0.124	0.206	1	-0.0981	0.0402	-0.0834
FA	-0.117	0.271	-0.0245	0.17	-0.0235	-0.168	-0.128	1	-0.147	0.128
LDT	-0.0075	-0.164	-0.0091	-0.496	0.204	-0.188	0.0824	-0.191	1	-0.0079
$Size$	-0.0322	0.115	0.0178	0.117	0.0197	-0.0499	-0.121	0.103	0.009	1

Notes: Upper triangle reports Spearman correlaton. Bottom triangle reports Pearson correlation.

Besides the above control variables that may lead to alternative explanations to our hypothesis, we absorb other time-series and cross-sectional attributes that may affect the inventory decision using strong and comprehensive fixed effects in the empirical model specifications. Our fixed effects include the year, the quarterly season, the province[11], the ownership[12], and the industry.

[11] Provincial-level administrative divisions are the highest-level Chinese administrative divisions. There are 34 such divisions, classified as 23 provinces, four municipalities, five autonomous regions, and two Special Administrative Regions (Hong Kong and Macau). We construct the province fixed effects accordingly.

[12] In China A-Share market, ownership type includes central state-owned, public, foreign-capital, private, collective, locally-administered state-owned, and others. We construct the ownership fixed effects accordingly.

5.2. Mechanism Identification and Estimation Results

For the firm-level empirical analysis, as we have both the inventory (INV) and the short-term borrowing (STB) data, besides confirming the country-level hypothesis at the firm level, we can further investigate other supporting evidence to identify the mechanism for the financing role of inventory.

Specifically, an increase in the investment returns should incentivize a firm to increase its inventory, which at the same time to increase its short-term borrowing due to the financing role of the inventory. Therefore, we have the following three firm-level hypotheses.

Hypothesis F1: A manufacturing firm's inventory is positively associated with the investment returns.

This hypothesis verifies that the empirical evidence at the country-level also holds at the firm-level. Hypothesis F1 suggests a positive significant β_1 in the below specification.

$$\begin{aligned} INV_{it} =& \beta_0 + \beta_1 irs_t + \beta_2 COGS_{it} + \beta_3 SG_{it} + \beta_4 ROA_{it} + \beta_5 GM_{it} \\ &+ \beta_6 FA_{it} + \beta_7 LDT_{it} + \beta_8 Size_{it} + F.E. + \epsilon_{it} \end{aligned} \tag{16}$$

Hypothesis F2: A manufacturing firm's short-term borrowing is positively associated with the investment returns.

This hypothesis supports the explanation that an increase in investment returns will increase the short-term borrowing, as firms have a high incentive to raise overseas low-cost capital to invest in the domestic market. Hypothesis F2 suggests a positive significant β_1 in the below specification.

$$\begin{aligned} STB_{it} =& \beta_0 + \beta_1 irs_t + \beta_2 COGS_{it} + \beta_3 SG_{it} + \beta_4 ROA_{it} + \beta_5 GM_{it} \\ &+ \beta_6 FA_{it} + \beta_7 LDT_{it} + \beta_8 Size_{it} + F.E. + \epsilon_{it} \end{aligned} \tag{17}$$

Hypothesis F3: A manufacturing firm's inventory is positively associated with the interaction term of the investment returns and the short-term borrowing.

This hypothesis suggests when the interest rate gap increases, manufacturing firms increase their inventory level through the channel of increased short-term borrowing. It identifies the mechanism that it is through an increase in short-term borrowing that we see the true motivation of inventory build-up in response to a rise in the investment returns – to raise low-cost capital to chase the financial arbitrage opportunity. Therefore, for the financing role of inventory to be identified, we should expect to see hypothesis F3 holds. Specifically, hypothesis F3 suggests a positive significant β_1 for the interaction term, $STB_{it} * irs_t$, in the below specification.

$$\begin{aligned} INV_{it} =& \beta_0 + \beta_1 STB_{it} * irs_t + \beta_2 irs_t + \beta_3 COGS_{it} + \beta_4 SG_{it} + \beta_5 ROA_{it} \\ & + \beta_6 GM_{it} + \beta_7 FA_{it} + \beta_8 LDT_{it} + \beta_9 Size_{it} + F.E. + \epsilon_{it} \end{aligned} \tag{18}$$

Table 9 reports the result of the overall manufacturing sector. Column (1) through (3) report the results on hypothesis F1 through F3 with only time-series fixed effects (*F.E.*) on the year and the quarterly season. Column (4) through (6) report the results by further including cross-sectional F.E. on the province, the ownership, and the industry. Robust standard errors are clustered at the firm level. We find all the hypotheses are confirmed for the entire manufacturing sector.

The regression coefficients on the standalone term irs_t in column (3) and column (6) deserve further discussion. Note that after introducing the interaction term of the interest rate spread and short-term borrowing, i.e., $STB_{it} * irs_t$, the regression coefficients on irs_t change to slightly negative compared to column (1) and column (4). This precisely illustrates the role of the short-term debt channel: we can divide the manufacturing firms into two categories, one group of firms uses the financing of inventory to obtain investment returns, and the other does not participate in such practice. The interaction term ($STB_{it} * irs_t$) captures the incremental effect of the former group as only a joint increase in investment returns and the short-term borrowing can explain their rise in inventory. The standalone term, irs_t, capture the remaining firms who may not participate in such practice. Moreover, the negative coefficient suggests they may reduce their inventory in response to the investment returns. This is plausible because the investment returns also reflect the domestic cost of working capital, so those firms would manage their inventory more carefully when the cost of working capital increases.

Table 10 reports the coefficients and economic significance of variables when its value increases from the sample median to the 75th percentile for the entire manufacturing sector. For all manufacturing sector, a 25% increase in interest rate spread would increase the inventory ratio by 16.6% in its total asset composition. This impact as the same magnitude as the operational factors in the control variables. The economic significance of the control variables also matches our expectations. Specifically, current demand ($COGS$), demand growth (SG), gross margin (GM), and lead time (LDT) are positively related to inventory, while ROA and production capacity (FA) are negatively associated with inventory. Size, also as a proxy for financial constraint, does not have a material impact on inventory. The impact of interest rate spread is in the same magnitude as most significant control variables, showing that the impact of the financing role is a substantial factor in the firm-level inventory stock decision.

Furthermore, we are interested in examining each industry under the manufacturing sector breakdown. We categorize 29 industries under the manufacturing sector into ten industry groups due

Table 9 Firm-level Results in China Manufacturing Sector

VARIABLES	INV (1)	STB (2)	INV (3)	INV (4)	STB (5)	INV (6)
$STB*irs$			3.19***			2.85***
			(6.886)			(6.973)
irs	0.13*	0.42***	-0.39***	0.15**	0.40***	-0.31***
	(1.835)	(4.601)	(-3.924)	(2.298)	(4.515)	(-3.377)
$COGS$	0.20***	0.17***	0.18***	0.18***	0.15***	0.16***
	(9.807)	(6.456)	(9.296)	(9.842)	(6.019)	(9.178)
SG	0.01***	0.01***	0.01***	0.01***	0.00	0.01***
	(4.245)	(2.742)	(4.037)	(3.828)	(0.949)	(3.746)
ROA	-0.22***	-0.81***	-0.14***	-0.15***	-0.79***	-0.08***
	(-6.664)	(-19.184)	(-4.326)	(-4.846)	(-20.907)	(-2.686)
GM	0.01***	0.00	0.01***	0.00*	-0.00	0.00*
	(2.791)	(0.723)	(2.693)	(1.928)	(-0.378)	(1.941)
FA	-0.14***	0.13***	-0.16***	-0.13***	0.10***	-0.14***
	(-10.685)	(8.701)	(-11.489)	(-9.661)	(6.668)	(-10.391)
LDT	0.00*	-0.00***	0.00**	0.00**	-0.00	0.00**
	(1.870)	(-2.952)	(2.117)	(2.046)	(-1.019)	(2.120)
$Size$	0.00	0.00*	0.00	-0.00	0.00**	-0.00
	(0.451)	(1.702)	(0.167)	(-0.521)	(2.259)	(-0.832)
Year F.E.	Y	Y	Y	Y	Y	Y
Season F.E.	Y	Y	Y	Y	Y	Y
Province F.E.	N	N	N	Y	Y	Y
Ownership F.E.	N	N	N	Y	Y	Y
Industry F.E.	N	N	N	Y	Y	Y
Observations	28,429	28,429	28,429	28,007	28,007	28,007
R-squared	0.105	0.172	0.121	0.245	0.233	0.257

Note: OLS estimation with robust standard errors clustered by firm. *** p<0.01, ** p<0.05, * p<0.1 using two-tailed tests.

Table 10 Economic Significance of Firm-level Variables for Manufacturing Sector (75th-median)

Variables	(75th-median)	All Manufacturing Sector		
		INV	STB	INV
$STB*irs$	0.003			0.916***
irs	0.011	0.166**	0.437***	-0.337***
$COGS$	0.061	1.098***	0.946***	1***
SG	0.195	0.151***		0.148***
ROA	0.032	-0.486***	-2.512***	-0.257***
GM	0.163	0.074*		0.075*
FA	0.112	-1.478***	1.154***	-1.602***
LDT	35.88	0.236**		0.246**
$Size$	0.82		0.374**	

to their relevance and the firm sample size consideration, i.e., food, textile, wood & paper, petrochemical, medicine & plastics, metal processing, equipment manufacturing, vehicle manufacturing, electrical & electronics, and other manufacturing. Table 11 shows the industry group classification.

Table 11 Firm Industry Group Definition in China Manufacturing Sector

Industry Group	Industry	Firm Count
1. Food		
	Agricultural processing industry	44
	Food manufacturing	38
	Wine, beverage, and tea	37
2. Textile		
	Textile manufacturing	39
	Apparel manufacturing	32
	Leather and fur manufacturing	11
3. Wood & Paper		
	Wood processing	8
	Furniture manufacturing	15
	Paper product manufacturing	28
	Printing and recording media manufacturing	10
	Cultural and entertainment manufacturing	12
4. Petrochemical		
	Petroleum and fuel processing	16
	Raw chemical materials processing	213
5. Medicine & Plastics		
	Pharmaceutical manufacturing	194
	Chemical fiber manufacturing	22
	Rubber and plastic products	70
	Non-metallic products	77
6. Metal Processing		
	Ferrous metal processing	30
	Non-ferrous metal processing	67
	Metal products manufacturing	55
7. Equipment Manufacturing		
	General equipment manufacturing	114
	Special equipment manufacturing	174
8. Vehicle Manufacturing		
	Automobile industry	120
	Railway, shipping, aerospace and other vehicles	41
9. Electrical & Electronics		
	Electrical machinery and equipment	204
	Computer and communication equipment	298
	Precision meter and instrument	35
10. Others		
	Other manufacturing	17
	Waste utilization industry	5
Total Manufacturing		2026

Table 12 reports the industry group breakdown results. Only the metal processing and the equipment manufacturing industries can survive hypothesis F1 at 1% statistical significance, verifying a positive association between the inventory and the investment opportunity holds for firms in those two particular industries. Further, both the metal processing and the equipment manufacturing firms support hypothesis F2, suggesting a positive relationship between short-term borrowing and the investment opportunity, and hypothesis F3, indicating that a joint increase in the investment returns and the short-term borrowing can explain an increase in their inventory. However, the equipment manufacturing industry only weakly supports F2 and F3 at 10% significance level, while the metal processing industry strongly supports all hypotheses at 1% significance level. To sum up, among all manufacturing industry groups, only the metal processing industry provides the strongest evidence supporting all firm-level hypotheses on the financing role of inventory.

By comparing hypothesis F1 and F3 for the metal processing group, the significance on the interest rate spread term (irs) disappear when the interaction term of the interest rate spread and short-term borrowing ($STB * irs$) is introduced. This conveys a similar message as the manufacturing sector result, that when the interest rate gap increases, we see an increase in inventory only for firms whose short-term borrowing also increase. This observation suggests that a rise in the investment returns only affect the inventory through a joint channel with short-term borrowing. Therefore, the firm-level empirical analysis not only verifies the finding on the country-level but also provide further evidence to establish the mechanism of the inventory's financing role, as we see the firm-level short-term borrowing indeed increases.

Table 13 reports the coefficients and economic significance of variables when its value increases from the sample median to the 75th percentile for the metal processing industry. A 25% increase in interest rate spread would increase the inventory ratio by 64.7% in its total asset. The economic impact of interest rate spread is much stronger for the metal processing industry compared to that for the manufacturing sector result in Table 10, which is only 16.6%. This result shows that the impact of the financing role is especially important as a deciding factor for the metal processing industry, which drives the result for the entire manufacturing sector.

6. Conclusion

This paper investigates and establishes the financing role of inventory, both theoretically and empirically. Such practice is especially prevalent in markets with high investment returns and financial frictions such as capital control. The financing role serves as an essential and complementary factor to various operational factors examined in classical inventory theory. To our knowledge, we are the first to show strong empirical evidence on the financing role of inventory. This finding suggests that traditional inventory theory should incorporate the financing role in making the optimal stocking decision.

We use a combination of modeling and empirical analysis. We first develop a 3-period inventory model with financing function and show that the optimal inventory level is positively associated with the net investment returns. Then, we collect commodity and macroeconomic data to confirm

Table 12 Firm-level Results for Industry Group Breakdown in China Manufacturing Sector

Variable	Food			Textile			Wood & Paper			Petrochemical			Medicine & Plastics		
	INV (1)	STB (2)	INV (3)	INV (4)	STB (5)	INV (6)	INV (7)	STB (8)	INV (9)	INV (10)	STB (11)	INV (12)	INV (13)	STB (14)	INV (15)
$STB*irs$			5.60*** (3.975)			7.02*** (2.929)			2.49 (1.359)			3.04*** (4.162)			1.88** (1.969)
irs	0.28 (0.909)	-0.36 (-1.118)	-0.49 (-1.312)	-0.15 (-0.483)	-0.00 (-0.006)	-1.28*** (-2.824)	-0.44 (-1.589)	0.61* (1.774)	-0.91* (-1.856)	0.11 (0.822)	0.11 (0.415)	-0.42** (-2.134)	0.14 (0.922)	0.48** (2.527)	-0.18 (-0.955)
$COGS$	0.12** (2.564)	0.01 (0.286)	0.11** (2.366)	0.34** (2.514)	0.20** (2.579)	0.29** (2.259)	0.22* (1.699)	-0.06 (-0.605)	0.22* (1.800)	0.18*** (5.346)	0.20*** (3.864)	0.16*** (4.634)	0.30*** (5.151)	0.18*** (3.290)	0.28*** (4.930)
SG	-0.00 (-0.326)	0.01* (1.827)	-0.00 (-0.517)	0.02 (1.449)	-0.01 (-1.189)	0.02* (1.789)	0.00 (0.191)	-0.01*** (-2.673)	0.00 (0.310)	0.01** (2.028)	-0.00 (-0.225)	0.01** (2.019)	0.01*** (2.675)	-0.01 (-1.301)	0.01*** (2.741)
ROA	-0.07 (-0.767)	-0.51*** (-4.112)	0.03 (0.395)	-0.57** (-2.290)	-0.82*** (-4.173)	-0.37 (-1.467)	-0.10 (-0.724)	-0.31 (-1.658)	-0.07 (-0.527)	-0.07 (-1.276)	-0.75*** (-8.410)	0.01 (0.106)	-0.13** (-2.036)	-0.67*** (-10.841)	-0.08 (-1.484)
GM	0.04* (1.737)	-0.07*** (-3.220)	0.05** (2.247)	0.01 (0.667)	-0.01 (-1.156)	0.01 (0.780)	0.00 (0.394)	-0.03*** (-2.989)	0.01 (0.637)	0.00 (0.019)	0.01 (1.078)	-0.00 (-0.231)	-0.00 (-0.567)	0.01 (0.924)	-0.00 (-0.652)
FA	-0.16*** (-2.736)	0.05 (0.766)	-0.16*** (-2.983)	-0.21** (-2.128)	0.05 (0.601)	-0.22** (-2.237)	0.02 (0.625)	0.02 (0.364)	0.02 (0.538)	-0.06*** (-2.817)	0.11** (2.445)	-0.08*** (-3.311)	-0.14*** (-5.039)	0.08*** (2.819)	-0.14*** (-5.168)
LDT	0.00** (2.020)	-0.00** (-2.415)	0.00** (2.191)	-0.00 (-0.601)	0.00 (0.614)	-0.00 (-0.643)	0.00 (0.646)	0.00 (0.214)	0.00 (0.588)	0.00* (1.721)	0.00 (0.011)	0.00* (1.838)	0.00** (2.291)	0.00* (1.704)	0.00** (2.052)
$Size$	0.00 (0.236)	0.00 (0.463)	0.00 (0.165)	0.02 (1.570)	0.02 (1.645)	0.02 (1.233)	-0.01 (-1.234)	0.02* (1.966)	-0.01 (-1.321)	-0.00 (-1.013)	0.02*** (2.645)	-0.01 (-1.470)	-0.00 (-0.162)	0.00 (0.281)	-0.00 (-0.170)
Observations	1,619	1,619	1,619	1,201	1,201	1,201	908	908	908	3,431	3,431	3,431	5,254	5,254	5,254
R-squared	0.466	0.302	0.493	0.396	0.546	0.429	0.468	0.464	0.475	0.268	0.265	0.298	0.228	0.279	0.234

Variable	Metal Processing			Equipment Manufacturing			Vehicle Manufacturing			Electrical & Electronics			Other Manufacturing		
	INV (1)	STB (2)	INV (3)	INV (4)	STB (5)	INV (6)	INV (7)	STB (8)	INV (9)	INV (10)	STB (11)	INV (12)	INV (13)	STB (14)	INV (15)
$STB*irs$			3.09*** (2.874)			2.01* (1.722)			1.66 (1.626)			2.27*** (3.165)			2.38 (0.582)
irs	0.59*** (2.965)	0.97*** (2.914)	-0.16 (-0.507)	0.58*** (3.775)	0.43* (1.904)	0.30 (1.477)	0.03 (0.153)	0.16 (0.649)	-0.16 (-0.828)	-0.17 (-1.422)	0.41** (2.363)	-0.50*** (-3.312)	1.16 (1.476)	-0.11 (-0.080)	0.61 (0.573)
$COGS$	0.12*** (3.192)	0.12 (1.617)	0.11*** (3.022)	0.21*** (3.549)	0.13* (1.709)	0.20*** (3.409)	0.08 (1.387)	0.03 (0.489)	0.07 (1.361)	0.21*** (5.402)	0.25*** (5.010)	0.19*** (4.924)	0.29** (2.163)	0.06 (0.379)	0.27* (2.046)
SG	0.01** (2.604)	-0.00 (-0.369)	0.01*** (2.819)	0.00 (0.047)	-0.00 (-0.941)	0.00 (0.136)	-0.01 (-1.156)	-0.01 (-1.225)	-0.01 (-1.083)	0.00 (1.249)	0.01*** (2.665)	0.00 (1.060)	0.04*** (3.246)	0.03** (2.259)	0.04*** (3.068)
ROA	-0.15 (-1.646)	-1.09*** (-5.766)	-0.04 (-0.492)	-0.21** (-2.146)	-0.72*** (-6.882)	-0.17* (-1.766)	-0.07 (-0.863)	-0.78*** (-6.782)	-0.03 (-0.384)	-0.11** (-2.061)	-0.68*** (-8.619)	-0.06 (-1.156)	-0.34 (-1.037)	-0.46 (-1.288)	-0.32 (-1.001)
GM	0.01* (1.826)	0.01 (1.021)	0.01* (1.783)	0.01 (1.290)	-0.01 (-1.070)	0.01 (1.398)	-0.01** (-2.051)	-0.01** (-2.074)	-0.01* (-1.905)	0.01 (1.283)	-0.00 (-0.012)	0.01 (1.333)	0.04 (1.549)	-0.01 (-0.496)	0.03 (1.538)
FA	-0.17*** (-3.572)	0.12* (1.869)	-0.18*** (-3.884)	0.01 (0.092)	0.23*** (4.461)	-0.01 (-0.153)	-0.01 (-0.117)	0.13*** (3.069)	-0.01 (-0.277)	-0.14*** (-6.221)	0.08*** (2.599)	-0.14*** (-6.509)	-0.39** (-2.269)	0.17 (0.888)	-0.41** (-2.219)
LDT	-0.00 (-1.384)	-0.00 (-0.329)	-0.00 (-1.255)	0.00*** (3.131)	0.00 (0.615)	0.00*** (3.003)	0.00** (2.587)	0.00 (1.038)	0.00** (2.538)	0.00* (1.858)	-0.00 (-1.526)	0.00* (1.964)	-0.00** (-2.510)	-0.00* (-1.995)	-0.00** (-2.461)
$Size$	0.00 (0.538)	0.00 (0.426)	0.00 (0.429)	0.01** (2.039)	0.01 (1.322)	0.01* (1.882)	0.00 (0.192)	-0.02*** (-3.818)	0.00 (0.414)	-0.01*** (-2.899)	0.01* (1.830)	-0.01*** (-3.198)	0.03 (1.340)	0.01 (0.715)	0.03 (1.243)
Observations	2,538	2,538	2,538	3,756	3,756	3,756	2,127	2,127	2,127	6,859	6,859	6,859	314	314	314
R-squared	0.367	0.345	0.387	0.232	0.247	0.238	0.500	0.390	0.503	0.177	0.192	0.188	0.665	0.436	0.667

Note: OLS estimation with robust standard errors clustered by firm. All specifications have included fixed effects on year, quarterly season, province, ownership, and industry. *** p<0.01, ** p<0.05, * p<0.1 using two-tailed tests.

Table 13 Economic Significance of Firm-level Variables for Metal Processing (75th-median)

Variables	(75th-median)	Metal Processing Industry		
		INV	STB	INV
$STB * irs$	0.004			1.272***
irs	0.011	0.647***	1.073***	
$COGS$	0.097	1.174***		1.048***
SG	0.149	0.161**		0.167***
ROA	0.024		-2.626***	
GM	0.116	0.128*		0.116*
FA	0.106	-1.77***	1.283*	-1.95***

that the country-level metal commodity inventory levels are positively related to the net investment returns while controlling for other explanations including input price trajectory, currency risk, industrial demand, and economic uncertainty. The economic impact of the financing role is substantial compared to other factors.

Besides the evidence on the country-level metal inventory, we also conduct an empirical analysis on the firm-level by studying all public listed firms in China's manufacturing sector. We not only verify the country-level result to hold the same but also provide further evidence to support the financing mechanism using short-term borrowing in the financial statement. We find that when the investment returns increase, a firm will increase its inventory level if it also pursues more short-term borrowing. In the industry breakdown study, we find the most persuasive supporting evidence for the financing mechanism in the metal processing industry, which drives the result in the entire manufacturing sector. Common inventory factors such as demand, lead-time, profitability, and capacity are controlled in the firm-level identification.

Regarding the scope of this paper, we do not discuss trade credit in the study, as the metal industries can only use immediate payment ("sight" LC provided by the overseas bank) for the foreign suppliers without involving any trade credit. We do not consider the impact of the inventory's financing role on the input price as our analysis focuses on the operational decision process from the firm perspective, who treats the metal price as a given variable. Previous literature on the theory of storage such as Tang and Zhu (2016) have solved a general equilibrium including the input price, but do not discuss the operational details of the inventory financing process.

The implication of the financing role in inventory can be brought to the next level beyond the metal industries and beyond the China market. As long as some domestic financial market facing frictions in accessing credit and the interest rate arbitrage opportunities exist, financing activity using inventory is likely to persist in some form at a certain scale. Additional research opportunity exists in the area which we leave for future research. It would be interesting to study the model process from a bank's perspective: how to decide the financing terms based on different types of inventory and their operational consumption needs. It would also be interesting to study the view from the regulatory authorities: how to control the leverage in the inventory financing to prevent a major rush for the exit and widespread liquidation of inventory in a scramble for cash upon a systematic short circuit in the performance of the domestic investment. Both directions also allow for empirical analysis if relevant data can be obtained.

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