Carry Trade with Commodity Trading

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Abstract

This study presents a Commodity-based Gamma Model, which is an imperfect market theory of exchange rate determination through the commodity-colletral carry trading. As a major component of arbitrage capital flows, the commodity-based carry trade significantly influences exchange rate dynamics based our quantitative model and empirical findings. Theoretically, many non-financial institutions in developing countries, such as commodity production and trading companies, have incentive to engage in commodity trading primarily for arbitraging purposes rather than consumption. To circumvent capital control constraints, these firms borrow abroad at lower costs in foreign currencies, leveraging their commodity trading activities, and invest these funds at higher domestic rates. By integrating these commodity-based arbitraging incentive into financiers' liquidity constraints, we find that exchange rates exhibit high sensitivity to liquidity shocks in the commodity futures market. Our empirical findings also highlight the crucial role of commodity-based carry trade in shaping exchange rate movements and underscore the importance of monitoring liquidity conditions in the commodity futures market.

Keywords: Carry Trade, Commodity Financing, Liquidity Risk

JEL Codes: F30, F31, E44

1 Introduction

Carry trade is a trading strategy that capitalizes on the failure of uncovered interest parity (UIP). Based on research from Cumby and Obstfeld (1980), Meese and Rogoff (1981), Hodrick (1987), and Fama (1984), empirical evidence shows that exchange rate determination theories often suffer from deviations when assuming a perfect financial market. This deviation, known as the UIP puzzle, indicates that changes in exchange rates do not correspond to the interest rate differentials between countries. Consequently, investors tend to borrow in currencies with low interest rates and invest in currencies with high interest rates. By the end of the maturity period, they can profit from the interest rate spread that is not offset by the exchange rate movements.

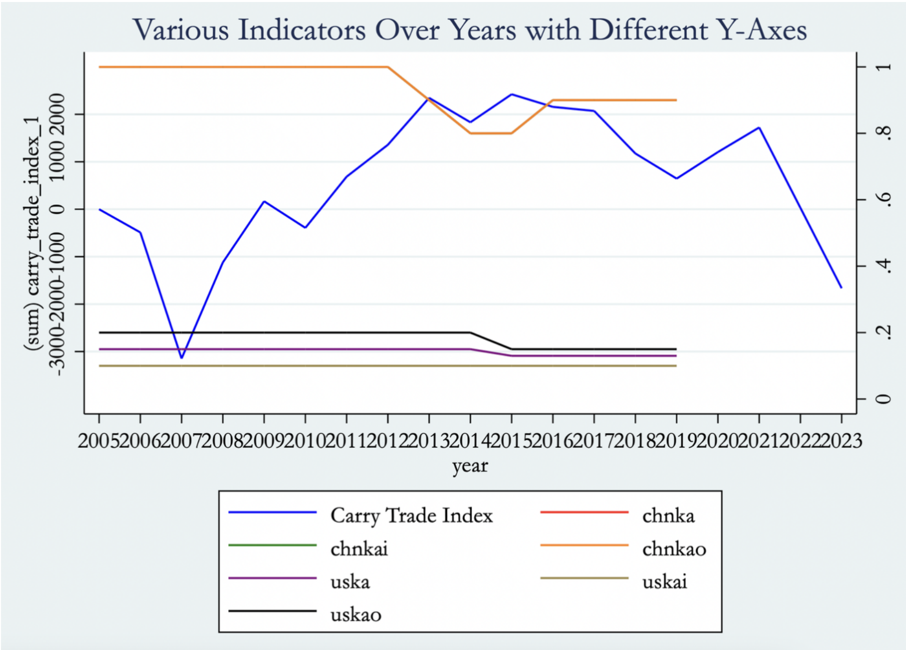


Figure 1. Capital Contorl and Carry Trade Reutrn between China and the US

The flow of carry trade brings about large capital inflows and outflows in the international capital market, particularly during financial crises (Boonman, 2023). This can significantly disrupt the monetary policies of developing countries. Consequently, many of these nations have implemented capital control policies to stabilize international capital flows. However, the effectiveness of these capital control policies in developing countries on the carry trade is questionable. For example, Figure 1 illustrates that capital control policies in China do not have a significant negative correlation with the carry trade return between CHY-USD.[1] This indicates that investors are increasingly adopting alternative methods for carry trade to bypass these controls.

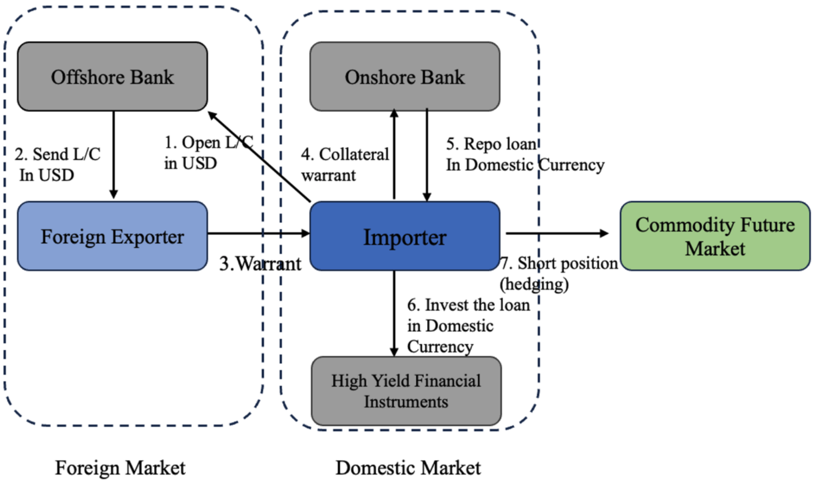
A new approach, known as the 'commodity-currencies' strategy, has been detailed by Ready et al. (2017a), highlighting the shift towards real trade strategies in carry trade practices. Beyond physically importing commodities from foreign markets, investors can utilize 'warehouse warrants' as financial instruments. This method facilitates importation with minimal or no transaction costs (Jo et al., 2022a) and can circumvent the issue of capital market segmentation.

The carry trade process using commodities as collateral, as depicted in Figure 2, involves a 12-step sequence. Initially, domestic firms, acting as investors, open a Letter of Credit (L/C) in foreign currency and obtain warehouse warrants from exporters. After securing these warrants (step 3), they use them as collateral to secure a repo loan in the domestic currency. Instead of immediately repaying the L/C, these importers invest the loan in high-yield financial instruments, such as Wealth Management Products (WMPs), and take short positions in commodity futures markets. At maturity, the firms reap returns from their investments, repay the repo loan in domestic currency and the L/C in foreign currency, and simultaneously sell the warehouse warrants in the futures markets.

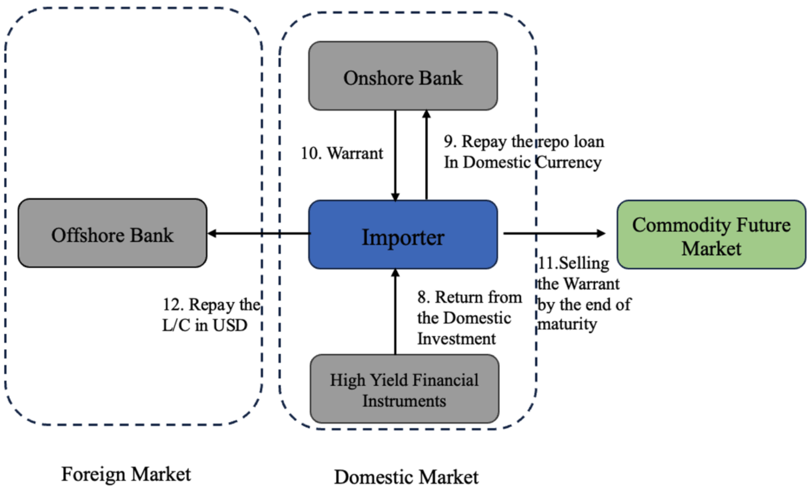
By analyzing commodity-based carry trade strategies in developing countries, we argue that exchange rate determination theory should account for commodity-based carry trade capital flows. Building on the general Gamma model introduced by Gabaix and Maggiori (2015), our model integrates financiers and households within an imperfect financial market framework. However, in this paper, we extend the financial creditors' balance sheet positions to include commodity-trading positions and update the limited risk-bearing capacity to incorporate commodity-based loans. This adjustment provides a more comprehensive understanding of the interactions between commodity markets and exchange rate dynamics.

[1]We used the capital control index provided by Fernández et al. (2016), which only have yearly data for each countries. We will investigate more index later on.

[Beginning of the Carry trade]



[By the end of maturities]



Notes: The pictures are generated by the author. Referenced from the paper (citation needed).

Figure 2. Carry Trade using Commodity Future Market

Ideally, this type of commodity-based exchange rate theorem is significantly affected by risks in the commodity market through the carry trade, as evidenced by the risk triggers observed during the Nickel crisis. In March 2022, the global commodity market experienced an extraordinary event when the London Metal Exchange (LME) halted nickel trading and voided transactions following a swift and substantial price increase (see Figure 3). Nickel prices escalated to over \$ 100,000 per tonne within hours, a development that not only surprised market participants but also prompted vital inquiries into market mechanisms and regulatory measures. The LME's official report attributed this extreme price fluctuation primarily to a 'short squeeze' – a situation characterized by limited supply and heightened demand leading to soaring prices, particularly for nickel. A key contributor to this scenario was Tsingshan Holding Group Company Limited, a major market stakeholder struggling with substantial un-hedged short positions. Further exacerbating the situation was a general hesitance among traders to provide liquidity, resulting in increased margin requirements for metal producers and traders. This reluctance was partly driven by geopolitical factors, especially the impact of Russia's invasion of Ukraine on February 24, 2022, on global markets.

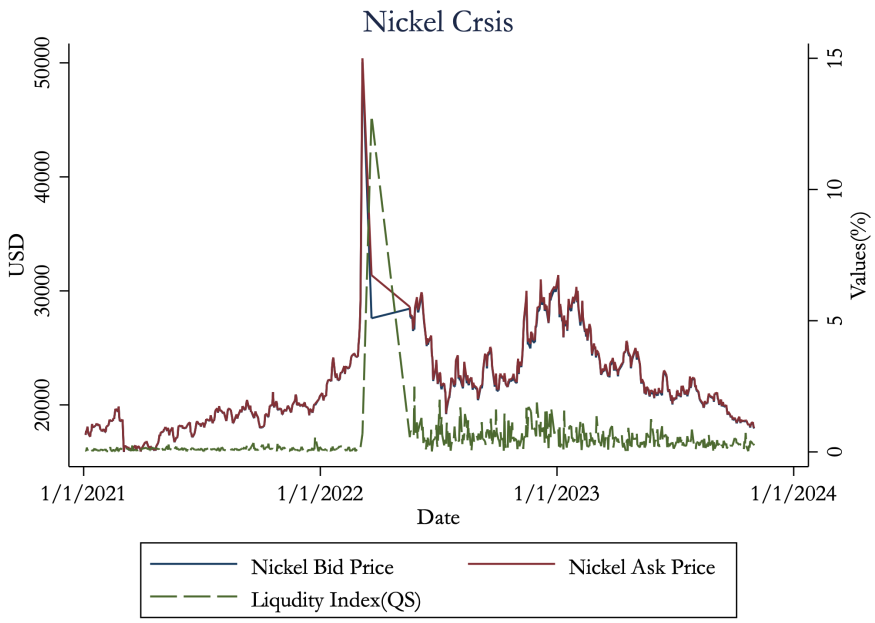


Figure 3. Nickel Crisis

To demonstrate the impact of liquidity risk in the commodity market on the exchange rate, our study build a quantitative model encoding the commodity-based lending position into financier' limited capacity constraints. In the meanwhile, we also adopt empirical method to evaluate the effects of the liquidity risk on the exchange rate through the carry trade channel. Initially, we focused on the CNY/USD pair as an example, employing an event study approach to investigate whether returns during the Nickel crisis were significantly abnormal compared to normal periods. Subsequently, a cross-sectional analysis is conducted to explore potential variations across different national settings, including differences between developing and developed countries, geographical disparities, and maturity variations. Futhermore, Our research also incorporates a series of robustness tests to substantiate our findings. Firstly, we plan to use the Bloomberg Carry Trade Index to assess the impact on liquidity across various countries, including those in the G10 and Asian regions. This analysis will compare carry trade activities between developing and developed nations, thereby shedding light on regional dynamics and disparities. Secondly, in order to ensure the thoroughness of our liquidity risk assessment, we will include additional proxies for liquidity risk. These will encompass measures like Effective Tick (Abankwa and Blenman (2021a)) and Price Impact (Goyenko et al. (2009)), providing a more comprehensive view of liquidity risk under different market conditions. Lastly, although our primary focus is on commodities with 3-month maturities, we acknowledge the potential insights to be gained from examining commodity carry trades across various maturities. This aspect, while not the central theme of our current paper, could provide valuable directions for future research, offering broader perspectives on the subject matter.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 updated the Commodity-based Gamma model, Section 4 provides the details on our data and empirical model. Section 5 then presents our main empirical results and robustness tests. Section 6 concludes the paper.

2 Literature Review

2.1 Exchange Rate Determination and Carry Trade

The foundation of exchange rate determination lies in various models, including the Monetary Model, the Portfolio Balance Model, and the Uncovered Interest Parity (UIP). The Monetary Model, links exchange rates to money supply and demand, inflation rates, and interest rates across countries. The Portfolio Balance Model, on the other hand, incorporates the role of asset markets and investor preferences in determining exchange rates. The UIP theory posits that the expected appreciation or depreciation of a currency is offset by the interest rate differential between two countries. However, empirical evidence often shows deviations from UIP, which are crucial for understanding carry trade strategies. These deviations suggest the existence of risk premia that investors demand for holding foreign currency-denominated assets (Fama, 1984). By testing the theory, empirical studies have provided mixed results regarding the profitability of carry trade and its relationship with exchange rate movements. Burnside (2011b) found that carry trades generally yield positive returns, contradicting the UIP theory. These returns are often attributed to market inefficiencies and risk factors that are not captured by traditional models. Further empirical analysis by Menkhoff et al. (2009) indicates that carry trade returns are associated with periods of low volatility and are susceptible to sudden reversals during financial crises. This highlights the importance of considering liquidity and funding risks when evaluating carry trade strategies.

More recent studies, such as Frankel (2008), explore the role of commodity prices and their influence on exchange rate dynamics, particularly in commodity-exporting countries. In this paper, the author also discussed how financial market structure and liquidity can impact exchange rates and carry trade profitability. The role of commodity markets and financial frictions in exchange rate determination is particularly relevant for developing countries with significant commodity exports. Financial frictions, such as capital controls, can affect the flow of funds and influence exchange rates.

Hausmann et al. (2001) discuss how these frictions can lead to misalignments in exchange rates, impacting the profitability of carry trades. Moreover, liquidity risk in the commodity futures market is a critical factor that influences households' preferences for commodity arbitraging. This risk can be measured using various indices that capture market volatility and trading volumes. Understanding these dynamics is essential for assessing the true risk-adjusted returns of carry trade strategies in commodity-exporting countries.

2.2 Carry Trade return and risk

Several studies have illuminated the role of financial institutions in arbitrage strategies within financial markets, with a particular emphasis on the excess returns and associated risks of carry trades. At its most basic, this strategy manifests as arbitrage in the currency market. Brunnermeier et al. (2009) investigated a method that entails investing in high-yield currencies and borrowing in low-yield ones, a practice known as the 'currency carry trade.' Building on this concept, Clarida et al. (2009) analyzed the strategy's return sensitivity to factors such as equity market volatility, yield curve levels, and slopes. In the context of financial crises, Lee and Wang (2020) underscored the risks of abrupt shifts in the currency market. Their findings of a strong linkage between these risks and carry trade returns led to the suggestion of an optimized strategy for enhanced returns. Extending this exploration, Lustig et al. (2014) formulated a no-arbitrage asset pricing model that explicates how the 'dollar carry trade' benefits from the dynamics between U.S. short-term interest rates and the volatility of the U.S. pricing kernel.

Filipe et al. (2023) added a new dimension by integrating funding constraints into their model, showing a correlation between funding risk and carry trade. To amalgamate these risk factors and probe into maximizing returns from currency carry trade, Yamani (2019) devised a combined signal approach of carry, momentum, and value (CMV) to scrutinize directional trading strategies. Furthermore, Bekaert and Panayotov (2019) introduced a unique classification of currency carry trades as 'Good' or

'Bad,' based on the portfolios' Sharpe ratios and return skewness, offering a fresh perspective on the profitability of these strategies.

Collectively, this corpus of literature significantly enhances our comprehension of the intricacies and subtleties associated with carry trade strategies, illuminating both their potential returns and inherent risks. Additionally, Koijen et al. (2018) argued for the applicability of carry trade strategies across diverse asset classes, including global equities, bonds, currencies, commodities, US Treasuries, credit, and equity index options. Tackling the puzzle of unexplained excess returns in the stock market, Burnside (2011a) formulated a model that encompasses 'crisis risk.' In a similar vein, Acharya and Steffen (2015) explored the yield-chasing behavior of banks in the equity market, focusing on the sovereign bond holdings in the GIPSI countries (Greece, Ireland, Portugal, Spain, and Italy). Their study highlighted how European banks' quest for higher returns significantly amplified the Eurozone bank risks during 2007-2012.

In the wake of the recent Covid-19 crisis, which triggered unprecedented disturbances in financial markets, Mo et al. (2023) observed that carry trade strategies could be effectively executed through portfolio rebalancing. Another pivotal contribution was made by Lustig et al. (2019), who turned the lens towards the bond market. They found that the excess returns from carry trades in G10 countries, when applied to treasury bonds as opposed to bills, defy prediction by standard predictors due to the influence of the term risk premium. Building upon this, they introduced a preference-free, no-arbitrage model accounting for the term risk premium associated with long-term bond investments. Interestingly, they also noted that liquidity risk does not fully explain their findings, hinting that liquidity issues might challenge their conclusions.

Our study diverges from traditional non-arbitrage models that include liquidity constraints, focusing instead on the impact of liquidity risk on carry trade returns. This approach aligns with the 'liquidity-as-characteristic' model as described in Acharya and Pedersen (2005). Abankwa and Blenman (2021b) effectively showed that liquidity considerations are crucial in carry trade strategies across various markets. Supporting this view, Burnside et al. (2008) identified a connection between liquidity frictions and the profitability of carry trades, often due to liquidity spirals. Additionally, Bakshi and Panayotov (2013) established that variations in US dollar funding liquidity are predictive of carry trade outcomes, underscoring the critical nature of liquidity conditions.

More recent studies, such as the one by Ranaldo and Somogyi (2021), have found a substantial link between FX liquidity risk and carry trades, predominantly in static carry trade scenarios. The realm of liquidity risk research extends beyond just currency and FX markets, with investigations also encompassing commodity markets. For example, Acharya et al. (2013) explored the interplay between hedging supply and speculator demand within the commodity futures market. Further, Jo et al. (2022b) examined the influence of liquidity risk in the Chinese banking system, demonstrating that the interbank liquidity risk premium significantly affects the currency carry trade risk premium, both in Chinese and global markets.

While there is extensive literature on the impact of liquidity risk on carry trade returns, especially in currency and FX markets, the exploration of liquidity risk in other financial domains, such as the commodity futures market, is not as developed. Our paper aims to fill this gap, contributing to a broader understanding of liquidity risk across diverse financial arenas.

2.3 Carry trade with Non-Financial Institutions

The carry trade strategies we have discussed thus far predominantly involve financial institutions and focus on currencies or countries. In contrast, to regulate capital flows, developing countries often employ stringent capital control policies (Liu et al. (2023)). As a result, these countries tend to engage in carry trade or short-term capital flows within the non-financial sector, bypassing direct investment through the financial account. Despite the prevalence of "naive" carry trade (Berge et al. (2010)), there is a relative dearth of literature on firm-driven carry trade. Bruno and Shin (2017) conducted a firm-level balance sheet analysis and observed that emerging market firms with substantial cash reserves are more inclined to issue US dollar-denominated bonds, correlating positively with dollar carry trade. Hardy and Saffie (2023) documented that non-financial firms engage in carry trade through trade credit, using unique firm-level data from Mexico and 20 other emerging countries. They discovered that firms more active in carry trades tend to have higher trade credit, concurrently accumulating currency risk due to arbitrage strategies.

To circumvent capital controls, firms can also engage in arbitrage through current accounts. For example, firms in mainland China utilize round-trip reimports with Hong Kong to implement carry trade strategies (Liu et al. (2022)). These exporting (re-importing) firms act as carry traders, re-importing high value-to-weight ratio goods to minimize transportation costs, a strategy termed "Carry Trade by Trunk". However, the carry trade between mainland China and Hong Kong is unique due to the exceptionally low transaction costs, owing to geographical proximity between ports.

Similarly, Hsu and Wu (2023) and Pan et al. (2019) employed the Autoregressive Distributed Lag (ARDL) model to show how firms can leverage inventories of imported products (like aluminum, copper, and gold) as collateral assets. This strategy allows firms to import lower-cost capital into countries with tight capital controls, thereby realizing higher financial returns. However, these studies primarily focus on the real import activities of commodities, dependent on transaction costs between different countries' ports. An alternate approach involves using trade financing instruments to bypass the barriers of expensive transportation. Moreover, their model assumptions imply that commodities are sold solely based on price volatility at the maturity of high-yield investments, without considering hedging in the commodity futures market.

Addressing these gaps, our paper concentrates on carry trade strategies using commodities as collateral. A key contribution of this study is the investigation of carry trade strategies utilizing trade financing instruments, like Letters of Credit (L/C) and Warrants, while engaging in hedging in the futures market. Our research extends beyond discussing transportation costs to explore risks in commodity futures markets, particularly aiming to ascertain if there is a correlation between liquidity risk in these markets and the excess returns from carry trades.

3 Model Descriptions

In constructing a model to examine the dynamics of exchange rate, it is essential to consider the varying contexts of imperfect market setting up in developing countries. Ready et al. (2017b) developed a commodity carry trading model that assumes complete markets, focusing solely on the application within developed countries. This approach provides a solid foundation for understanding the interactions between commodity prices and currency values in stable, well-regulated financial environments. Conversely, Gabaix and Maggiori (2015) explore carry trade within the context of imperfect financial markets, highlighting the complexities and risks that arise when market imperfections are factored in. However, their analysis omits the commodity trading channel, which could play a significant role in influencing the outcomes of carry trades, particularly in countries heavily reliant on commodity exports or imports, and their loan capacity highly depends on the commodity trading volume. This gap suggests a need for a model that integrates the commodity trading related capacity constraints into considerations, offering a more comprehensive view of the exchange rate determination mechanism across different economic landscapes, which shows in Figure 4.

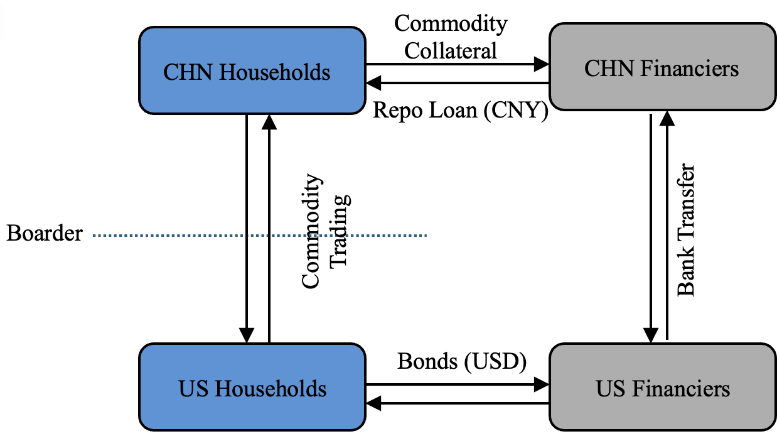


Figure 4. Gamma Model with commodity trading

In contrast to the Gamma model, we delve deeper into commodity-based repurchase agreements (repo loans) involving financiers and households in developing countries with capital controls. Financiers, starting without any initial capital, engage in trading bonds denominated in two different currencies. Their balance sheet is characterized by a holding of q_0 dollars, which is directly linked to the quantity of commodity collateral they possess, and they extend credit in the form of $-q_0 e_0$ RMB. This credit provision in RMB is influenced by both the underlying commodity warrants and the current spot exchange rate. These commodity-based liquidity constraints offer a new perspective on how shocks in the commodity market can affect exchange rates under imperfect market conditions. Detailed discussion on the model settings will follow to elucidate these dynamics.

3.1 Households

We adopted the model established by Gabaix and Maggiori (2015). Instead of focusing on the developed countries, we cast light on the developing counties, such as China. The utility functions of Chinese households mainly from the consumption of a goods basket, which is:

$$\theta_0 \ln C_0 + \beta \mathbb{E}[\theta_1 \ln C_1], \tag{1}$$

where C is a consumption basket defined as:

$$C_t = \left[(C_{NT,t})^{X_t} (C_{H,t})^{a_t} (C_{F,t})^{l_t + k_t} \right]^{\frac{1}{\theta_t}}, \tag{2}$$

where $C_{NT,t}$ is the domestic consumption of its non-tradable goods, $C_{H,t}$ is the consumption of its domestic tradable goods, and $C_{F,t}$ is the consumption of foreign tradable goods. We use the notation $\{X_t, a_t, l_t, k_t\}$ for non-negative, potentially stochastic preference parameters. We developed the arbitrage incentive parameter k_t for households, to demonstrate their preference for trading which targeting the arbitrage opportunities by using the tradeble gooes as the collateral assets rather than the real consumption,s uch as commodity-collateral trading.

$$\theta_t = X_t + a_t + l_t + k_t.$$

The households' optimization problem is:

$$\max_{(C_{NT,t},C_{H,t},C_{F,t})_{t=0,1}} \theta_0 \ln C_0 + \beta\mathbb{E}[\theta_1 \ln C_1], \tag{3}$$

subject to

$$C_t = \left[(C_{NT,t})^{X_t}(C_{H,t})^{a_t}(C_{F,t})^{l_t+k_t}\right]^{\frac{1}{\theta_t}}, \tag{4}$$

and

$$\sum_{t=0}^{1} \frac{1}{R^t}(Y_{NT,t} + p_{H,t}C_{H,t} + p_{F,t}C_{F,t}) = \sum_{t=0}^{1} \frac{C_{NT,t} + p_{H,t}C_{H,t} + p_{F,t}C_{F,t}}{R^t}. \tag{5}$$

The first order condition of the equilibrium in household sector could be written as:

$$P_{F,t}C_{F,t} = l_t + k_t \tag{6}$$

In the domestic market, $P_{F,t}$ and $C_{F,t}$ represent the price and consumption, respectively, of foreign tradable goods. Meanwhile, l_t denotes the preference for consuming foreign goods, and k_t denotes the preference for arbitraging foreign goods. Concurrently, the utility function of the foreign country can be expressed as $\theta_0^* \ln C_0^* + \beta\mathbb{E}[\theta_1^* \ln C_1^*]$, which allows us to deduce the first-order conditions for the trade of goods. Specifically, the relationship for the foreign country's tradable goods is given by $P_{F,t}^* C_{F,t}^* = l_t^* + k_t^*$. If trade has to be balanced period by period, the equilibrium exchange rate between CNY and USD is $e_t = \frac{l_t+k_t}{l_t^*+k_t^*}$. This means the RMB depreciates ($\uparrow e$) whenever China becomes more demanding for foreign goods, either due to increased consumption preferences ($\uparrow l$) or greater arbitrage opportunities ($\uparrow k$). Conversely, the RMB appreciates when there is a decreased preference for Chinese goods ($\downarrow l_t^*$) or reduced arbitrage opportunities ($\downarrow k_t^*$).

3.2 Financial Intermediaries

In this revised version of the complete markets model, we integrate a financial sector by introducing the role of financiers. We acknowledge that global financial markets often exhibit an excess supply of various currencies due to trade or portfolio flows. This aspect is especially relevant in developing countries where carry trade activities incentivize financial intermediaries, whose operational capacities are largely dependent on the availability of commodity warrants. As a result, there exists a strong correlation between the risk of default and commodity market volatility.

Within our model, the amount of collateral lending by financiers is denoted by $q_0(k)$, which is contingent upon the arbitraging preference and the amount of commodity collateral loans lending to the households sector. The corresponding value of the repo loan, expressed in domestic currency, is given by $-\frac{q_0(k)}{e_0}$, where e_0 represents the exchange rate during the current period. The financiers aim to maximize the expected value of financial institutions, which is formally expressed as:

$$\max_{q_0} V_0 = \mathbb{E}\left[\beta\left(R - R^*\frac{e_1}{e_0}\right)q_0(k)\right],$$

where V_0 is the expected value of the financial institution, β is the discount factor, R denotes the return on investment, and R^* is the foreign return adjusted by the exchange rate changes between the current and subsequent periods, represented by $\frac{e_1}{e_0}$.

Additionally, we acknowledge the imperfections in the financial market, indicated by a constraint that limits financiers' risk-bearing capacity (Maggiori, 2017). This introduces the possibility of households defaulting on financial contracts, potentially resulting in significant losses for financiers. For example, during the Nickel crisis in 2022, the market price and liquidity conditions of the commodity changed sharply, inducing large defaults within Chinese import companies. Following the existing literature, we assume that in each period, after taking positions but before shocks are realized, the financier can divert a portion of the funds she intermediates.[2] If the financier diverts the funds, the households that had lent to her recover a portion $1-\Gamma\left|\frac{q_0(k_0)}{e_0(k_0,l_0)}\right|$ of their credit position $\left|\frac{q_0(k_0)}{e_0(k_0,l_0)}\right|$, where $\Gamma = \gamma\,\mathrm{var}(e_1(k_1,l_1))^\alpha$, with $\gamma \geq 0$ and $\alpha \geq 0$. Moreover, γ indicates that the sensitivities for adjusting or diverting funds decrease with the preference for arbitraging; in other words, financial intermediaries need time to adjust their funds

[2]We also argue that different financiers would have different response periods to shocks, meaning their sensitivities γ are also heterogeneous among the financiers, which will contribute to different adjustment costs of diverting and consequently affect the equilibrium of the exchange rate.

and will suffer higher losses if the γ is larger. Thus, the financier's optimal equations could be represented as the follows:

$$\max_{q_0} V_0 = \mathbb{E}\left[\beta\left(R - R^*\frac{e_1}{e_0}\right)q_0(k_0)\right] \tag{7}$$

$$\text{s.t.} \quad V_0 \geq \Gamma\frac{q_0(k_0)^2}{e_0(k_0, l_0)} \tag{8}$$

The maximization problem reflects the decision-making process of financiers, who weigh the returns on financial assets denominated in the two countries' currencies against the risks posed by exchange rate fluctuations. These fluctuations arise not only from the general bonds market but also from the goods trading market, including the commodity futures market. Incorporating these financial sector dynamics into the incomplete markets model provides a more robust depiction of exchange rate dynamics and fund flows. From the above financier's maximization problem, we could find out the demand equation of the collateral loans:

$$Q_0 = \frac{1}{\Gamma}\mathbb{E}\left[e_0(k_0, l_0) - e_1(k_1, l_1)\frac{R^*}{R}\right] \tag{9}$$

And the expectation of exchange rate in next period could be derived as:

$$\mathbb{E}(e_1) = \frac{R}{R^*}\left[e_0(k_0, l_0) - \Gamma Q_0\right] \tag{10}$$

Unlike the model presented by Maggiori (2017), this study highlights the significant role of arbitrage preferences in influencing the total volume of credit extended by financial intermediaries. Specifically, when the arbitrage incentive, denoted as k_0, is high in the domestic market during the current period, there tends to be an increase in the volume of outstanding collateralized loans. Furthermore, elevated expectations of future arbitrage opportunities, represented by an increase in k_1, can lead households to postpone their consumption of tradeable goods, anticipating more favorable conditions in the subsequent period.

Equilibrium Exchange Rate

From the setting up of both households sector and financial intermediaries sector, now we could find out the equilibrium exchange rate. The market clearing condition could be written as:

$$(l_0^* + k_0^*)e_0 - l_0 - k_0 + Q_0 = 0, \tag{11}$$

$$(l_1^* + k_1^*)e_1 - l_1 - k_1 - RQ_0 = 0. \tag{12}$$

In Equation 10, the first component $(l_0^* + k_0^*)e_0 - l_0 - k_0$ represents the net export demand of domestic countries in current period t_0, which includes both real trading requirements and arbitrage activities within the household sectors. The second component pertains to the demand from financiers. Similarly, Equation 11 delineates the trading demands in next peiord t_1, illustrating their impact on the overall market dynamics.

To generate the equilibrium exchange rates e_0 and e_1, we assume for now that $\beta = \beta^* = 1$, which implies $R = R^* = 1$. Additionally, we assume the foreign countries' trading preferences are such that $l_t^* + k_t^* = 1$ for $t = 0, 1$, allowing us to derive the equilibrium condition for the domestic countries. Incorporating these assumptions, we obtain the domestic (CHN) external intertemporal budget constraint:

$$e_1 + e_0 = l_0 + k_0 + l_1 + k_1. \tag{13}$$

Follwoing the same steps as Maggiori (2017), we take expectations on both sides: $\mathbb{E}[e_1] = l_0 + k_0 + \mathbb{E}[l_1 + k_1] - e_0$. From the financiers' demand equation we have:

$$\mathbb{E}[e_1] = e_0 - \Gamma Q_0 = e_0 - \Gamma(l_0 + k_0 - e_0) = (1 + \Gamma)e_0 - \Gamma(l_0 + k_0), \tag{14}$$

By combining the market clearing conditions, we can derive a system of equations related to the determination of the current period exchange rate and the next period exchange rate, which can be expressed as follows:

$$\mathbb{E}[e_1] = l_0 + k_0 + \mathbb{E}[l_1 + k_1] - e_0 \tag{15}$$

$$\mathbb{E}[e_1] = (1 + \Gamma)e_0 - \Gamma(l_0 + k_0) \tag{16}$$

By solving those equations, we could generate the liner equation for the exchange rate at both t_0 and t_1, where the $\Gamma = \gamma \operatorname{var}(e_1(k_1, l_1))^{\alpha}$.

$$e_0 = \frac{(1 + \Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]}{2 + \Gamma}, \tag{17}$$

$$e_1 = l_0 + k_0 + l_1 + k_1 - \left[\frac{(1 + \Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]}{2 + \Gamma}\right] \tag{18}$$

By combining the function of e_0 and e_1 from equation 17 and 18, we could also derive the RMB expected appreciation in this Updated Gamma-model with commodity arbitrating needs is:

$$\mathbb{E}[\frac{e_0 - e_1}{e_0}] = \mathbb{E}\left[\frac{2\frac{(1+\Gamma)(l_0+k_0)+\mathbb{E}[l_1+k_1]}{2+\Gamma} - (l_0 + k_0 + l_1 + k_1)}{\frac{(1+\Gamma)(l_0+k_0)+\mathbb{E}[l_1+k_1]}{2+\Gamma}}\right], \tag{19}$$

$$\mathbb{E}[\frac{e_0 - e_1}{e_0}] = \mathbb{E}\left[\frac{2[(1 + \Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]] - (2 + \Gamma)(l_0 + k_0 + l_1 + k_1)}{(1 + \Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]}\right] \tag{20}$$

$$= \mathbb{E}\left[\frac{\Gamma(l_0 + k_0) + 2\mathbb{E}[l_1 + k_1] - (2 + \Gamma)(l_1 + k_1)}{(1 + \Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]}\right]. \tag{21}$$

Equation 21 illustrates the expected value of future exchange rate fluctuations. It is evident from the Gamma Model that the future exchange rate for countries with arbitrage needs is determined not only by the current period's real goods trade requirements and arbitrage activities but also by future preferences. Additionally, the exchange rate is influenced by the level of financial friction, Γ, which is determined by the sensitivity of the financiers and their expectations of future exchange rate variation. If there is no financial friction, i.e., $\Gamma = 0$, the expected value of appreciation is zero and the UIP holds. Meanwhile, we observe that the fluctuation of the exchange rate is influenced by changes in future commodity arbitrage preferences in the domestic country: when k_1 increases ($\uparrow k_1$), the future exchange rate deviation decreases ($\downarrow \frac{e_0 - e_1}{e_0}$). Thus, this model demonstrates that fluctuations in the commodity trading market influence exchange rate determination through both the real trading needs channel and the arbitrage channel. If we consider about the carry trade between those two countries, the return could be written as:

$$\text{Carry Trade Return}_t = R_t - R_t^* - \mathbb{E}_t[\Delta e_{t+1}] = \mathbb{E}[\frac{e_0 - e_1}{e_0}] \tag{22}$$

$$= \mathbb{E}\left[\frac{\Gamma(l_0 + k_0) + 2\mathbb{E}[l_1 + k_1] - (2+\Gamma)(l_1 + k_1)}{(1+\Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]}\right], \tag{23}$$

$$= \frac{\Gamma(l_0 + k_0)}{(1+\Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]} - \frac{\Gamma\mathbb{E}[l_1 + k_1]}{(1+\Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]} \tag{24}$$

We also find that the carry trade return is influenced by the commodity-based arbitrage needs in the current period k_0 and the expected future commodity carry trading preferences $\mathbb{E}(k_1)$. By taking the derivative, we observe that the carry trade return has a positive relationship with the current period arbitrage preference, expressed as $\frac{d\text{Carry Trade Return}_0}{dk_0} \geq 0$.[3] As the current period arbitrage needs increase through the commodity market ($\uparrow k_0$), the carry trade return also increases. Similarly, we find that when the future expectation of arbitrage opportunities increases, the current period carry trade return decreases. This outcome is rational, as households might defer their investment opportunities to the next period, anticipating higher arbitrage possibilities in the future. However, we have not considered the interest rate differentials between countries.[4] Incorporating interest rate differentials into our model would enhance its accuracy and predictive power.

[3]The dereviation result is $\frac{d\text{Carry Trade Return}_0}{dk_0} = \frac{\Gamma[(1+\Gamma)(l_0+k_0)+\mathbb{E}[l_1+k_1]] - \Gamma[l_0+k_0-\mathbb{E}[l_1+k_1]](1+\Gamma)}{[(1+\Gamma)(l_0+k_0)+\mathbb{E}[l_1+k_1]]^2} \geq 0$.

[4]We assume the interest rate difference $R_t - R_t^*$ equals zero in the previous setup of this basic commodity-based Gamma model.

$$\text{Carry Trade Return}_t = R_t - R_t^* - \frac{\Gamma(l_0 + k_0)}{(1+\Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]} - \frac{\Gamma\mathbb{E}[l_1 + k_1]}{(1+\Gamma)(l_0 + k_0) + \mathbb{E}[l_1 + k_1]} \tag{25}$$

Thus, in general cases, the interest rate spread between the two countries and the expected changes in the exchange rate simultaneously determine the carry trade returns. Specifically, the exchange rate is influenced by trading needs, which consist of real trading preferences and commodity arbitrage needs, particularly in many developing countries facing financial frictions such as capital control policies. Hence, from our quantitative model, we conclude that risks in the commodity market also contribute to the carry trade returns. To substantiate this, we employed several empirical methods to examine whether carry trade returns are affected by risks in the commodity market and to further test the Uncovered Interest Parity (UIP) deviation by considering the risk premia in the commodity futures market.

4 Empirical Analysis

In this section, we engage in empirical examinations to evaluate the influence of commodity market risks on exchange rates, particularly through the mechanism of commodity-based carry trade. Our analysis commences with an exploration of the correlation between carry trade returns and commodity market risks, with a focused investigation on the ramifications of the Nickel Crisis of 2022. Utilizing data from both China and the United States, we concentrate on the risks associated with the nickel commodity futures market.

Initially, employing the CNY-USD currency pair, we implement an event study methodology to scrutinize the effects of Nickle market risk on carry trade returns in the periods preceding and succeeding the crisis. Concurrently, we utilize a comprehensive dataset encompassing daily data across the entire commodity futures market. This dataset includes a variety of future production metrics, enabling us to apply multiple analytical techniques to validate the forecasts of our quantitative models across different product categories.

Further, we expand our analysis to incorporate various currency pairs, aiming to uncover regional variations in the impact of these risks. Subsequently, we revisit the classical framework proposed by Fama (1984) to delve deeper into how commodity market risks influence exchange rate determinations. This multifaceted approach allows us to provide a nuanced understanding of the interplay between commodity market conditions and currency value fluctuations.

4.1 Carry Trade Returns and the Risk of Commodity Future Market

4.1.1 Data

In general, carry trade returns are conceptualized as the aggregate of the interest rate differential and the subsequent change in the exchange rate. Mathematically, this can be represented as:

$$\text{Carry Trade Return}_t = R_t - R_t^* - \mathbb{E}[\Delta e_{t+1}] \tag{26}$$

where R_t represents the Shanghai Interbank Offered Rate (3M) (SHIBOR(3M)), which is the foreign interest rate in our analysis. R_t^* is the 3 Month London Interbank Offered Rate in USD (LIBOR), serving as the domestic interest rate.What's more, $\mathbb{E}[\Delta e_{t+1}]$ denotes the expected change in exchange rate, operationalized as the USD CNY Forward Rates (NDF 3M)denotes the expected change in exchange rate, operationalized as the USD CNY Forward Rates (NDF 3M).

To facilitate a comprehensive and rigorous evaluation, our research leverages daily data spanning from October 6, 2006, to November 1, 2023. This extensive dataset includes 4,253 data points, which allows for an in-depth analysis of carry trade returns across diverse market scenarios and economic cycles. Furthermore, we have meticulously curated and processed a detailed dataset from Bloomberg Terminal, which encompasses various futures contracts. This dataset features daily bid and ask prices, as well as trading volumes for each contract. Comprising a total of 18,468 daily records, our dataset forms a substantial empirical basis for dissecting the complexities and dynamics of carry trade returns. This rich repository of data provides invaluable insights into the evolution of these returns amidst fluctuating global financial conditions and significant economic events.

To measure the preference for commodity arbitraging, we use the risk index as a proxy to identify fluctuations in households' preferences. Meanwhile, in the realm of the Commodity Futures Market, liquidity risk is the most crucial risk to quantify. To this end, we adopt the methodology introduced by Marshall et al. (2012) for measuring liquidity risk, utilizing the Quoted Spread as a liquidity index. [5] This measure provides an insightful gauge of market liquidity by capturing the cost incurred by traders due to lack of immediate trade execution.

The Quoted Spread is calculated as follows:

$$\text{Quoted Spread}_t = (A_t - B_t)/M_t$$

where A_t represents the Ask price for each commodity future (3M), which is the price a seller is willing to accept for a commodity. B_t denotes the Bid price for every commodity future (3M), reflecting the price a buyer is willing to pay for the commodity. And M_t is the Midpoint price for every commodity future (3M), calculated as the average of the Ask and Bid prices. This serves as a reference point for the current market price of the commodity.

[5] We are going to using different risk factors in commodity future market later on.

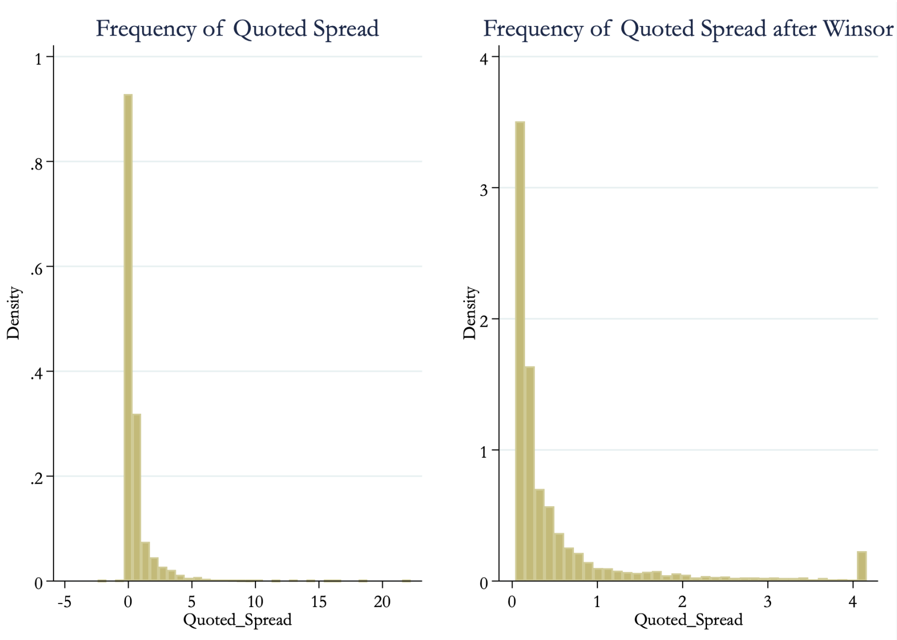


Figure 5. Discard some extreme value

By calculating the Quoted Spread, we can effectively assess the liquidity of commodity futures. A smaller spread indicates higher liquidity, implying that the commodity can be bought or sold near its market price with relative ease. Conversely, a wider spread suggests lower liquidity, entailing potentially higher costs for trading due to price discrepancies between buyers and sellers. This measure is integral to our analysis, as it allows for a nuanced understanding of the liquidity dynamics in the Commodity Futures Market.

4.1.2 Nickle Market Analysis

Firstly, we run the simple OLS model between the CNY/USD carry trade returns and the liquidity risk index of the Nickle future market, the model is:

$$\text{Carry Trade Return}_t = \beta_1 + \beta_2 \,\text{Nickle market risk}_t + \sigma_t \tag{27}$$

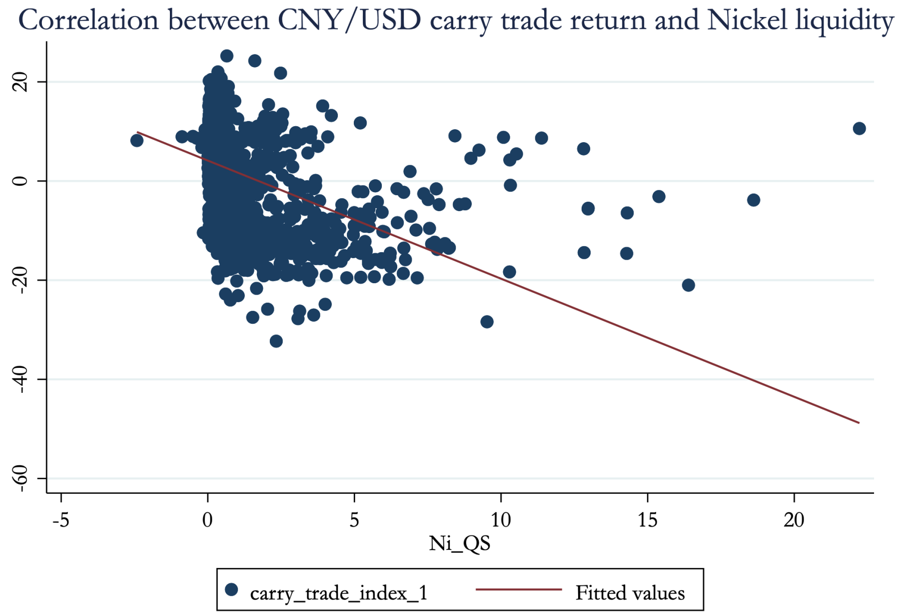


Figure 6. Simple correlation

The graph presented in Figure 6 illustrates that the relationship between the liquidity risk of the commodity futures market and the carry trade return is negatively significant. This finding is further substantiated by our regression analysis showed in Table **??**, which indicates a significant negative correlation between the liquidity risk of the nickel futures market and the carry trade returns between China and the US. This negative association underscores the impact of market liquidity risks on carry trade strategies, particularly in the context of volatile commodity markets like that of nickel. These results contribute to a deeper understanding of financial interactions within international trading frameworks, highlighting the sensitivity of carry trade returns to changes in market liquidity.

Secondly, a significant focus is placed on conducting a Time Series Analysis and an Event Study to assess the impact of the nickel crisis that unfolded on March 8, 2022. This event represents a pivotal moment in the commodities market, particularly for the nickel trade, and its analysis is crucial for understanding the broader market dynamics and responses.

To effectively capture the effects of this crisis, we have selected an event window that extends from two days prior to the onset of the crisis (starting March 6, 2022) to

Table 1. Regression Results

	Carry Trade Return	
	(1)	(2)
Quoted Spread Daily	-2.383***	
	(-29.54)	
Quoted Spread Weekly		-4.673***
		(-41.29)
Constant	4.134***	5.223***
	(34.15)	(43.80)
Observations	3913	3913

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

May 16, 2022. This timeframe is particularly relevant as it concludes with the release of a comprehensive report from the London Metal Exchange (LME) concerning the crisis. This extended event window allows for an in-depth examination of the crisis's immediate impact, as well as its short-term ramifications in the market.

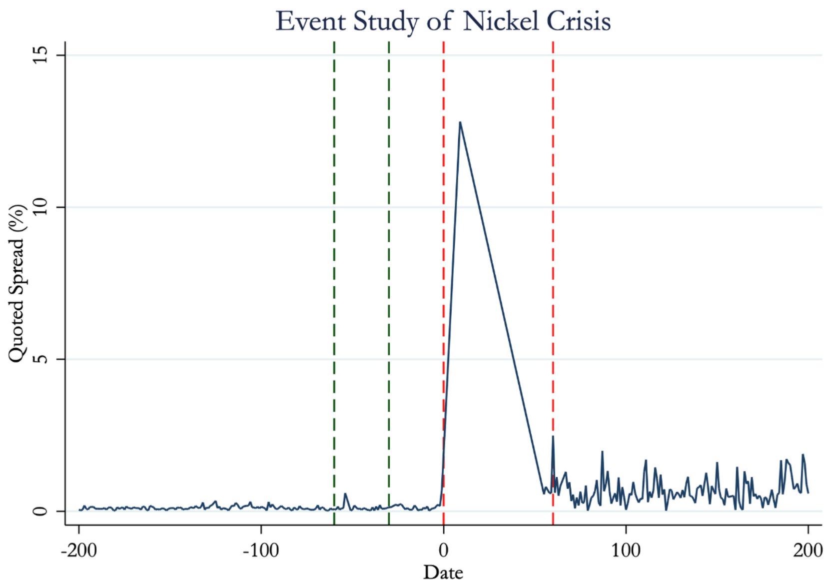


Figure 7. Event study

Our Time Series Analysis within this period will involve a detailed investigation of relevant market data, including price movements, trading volumes, and liquidity measures, to quantify the extent of the crisis's impact. The Event Study methodology will enable us to isolate the effects of the nickel crisis from other concurrent market factors, thereby providing a clearer picture of the crisis's direct consequences.

By examining data within this meticulously selected timeframe, our study aims to shed light on the market's response to unprecedented events and the efficacy of regulatory interventions. This analysis enriches the existing body of literature concerning commodity market crises and offers valuable insights for market participants and regulators. However, given that the nickel futures market is relatively small compared to the broader commodity trading market, we seek to ensure the robustness of our findings. Additionally, to explore heterogeneity across different futures contracts, including metals, agriculture, and energy, we delve further into the complexities presented by each futures product. This comprehensive approach allows us to more accurately assess the broader implications of market dynamics and regulatory strategies.

4.1.3 Futures Level Analysis

In this section, we utilized a high-frequency dataset at the futures contract level. This dataset comprehensively includes each commodity futures product, equipped with their respective bid and ask prices, and categorized according to Bloomberg Terminal's classifications: Metal, Energy, and Agriculture. Leveraging this rich dataset, we calculated the product-level Quoted Spread ($product\_QS$) and analyzed the relationship between the carry trade index and product quoted spread employing fixed effects. To facilitate our analysis, we employ the following regression model:

$$\text{CarryTradeIndex}_{it} = \beta_0 + \beta_1 \text{Product\_QS}_{it} + \mu_i + \gamma_t + \epsilon_{ijt} \tag{28}$$

In this analysis, the $\text{CarryTradeIndex}_{it}$ quantifies the carry trade returns for each commodity product i at time t, reflecting potential profit from trading futures contracts. Concurrently, Product_QS_{it} measures the quoted spread for the same product and time, representing the bid-ask spread which serves as a proxy for transaction costs and market liquidity. To address the unobserved heterogeneity inherent to each type of commodity, we introduce fixed effects μ_i for each product. These fixed effects capture unique, static characteristics of each commodity that might affect their market behavior.

Table 2. Futures Level Analysis Regression Results

	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
product_QS	**-13.97*****		-1.242	
	(0.918)		(0.811)	
product_QS_metal		**299.9*****		**224.0*****
		(6.331)		(6.856)
product_QS_energy		**-16.46*****		**-4.521*****
		(0.894)		(0.808)
product_QS_agriculture		**-68.35*****		**33.26*****
		(3.398)		(2.769)
Constant	**0.976*****	**1.477*****	**1.252*****	**1.872*****
	(0.0549)	(0.0536)	(0.0583)	(0.0591)
Time F.E.	Yes	Yes	No	No
Industry F.E.	Yes	No	Yes	No
HD F.E.	No	No	Yes	Yes
Observations	18468	18468	18468	18468

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Additionally, time-specific fixed effects, γ_t, are included to adjust for temporal macroeconomic or systemic financial variations that influence all commodities in a uniform manner. The model also accounts for random, unexplained variations through the idiosyncratic error term ϵ_{it}. Moreover, our study delves into the correlations within each product category to discern patterns that may influence trading strategies and risk assessments across similar commodities.

The empirical analysis results summarized in Table 2, we investigate the effects of quoted spreads on the carry trade index across different commodity categories. Model 1 shows a significant negative relationship between product quoted spreads and carry trade returns, with a coefficient of -13.97, indicating that higher liquidity risk in the commodity futures market is associated with lower returns. Futhermore, we look at in details about different categories in model 2. Model 2 disaggregates the effects by commodity type, revealing a substantial positive impact of quoted spreads on metal commodities, standard error = 6.331, contrasted by negative impacts on energy and agriculture. This model only includes time fixed effects, highlighting differential impacts across commodities. The last two columns, models 3 and 4 introduce High-Dimensional Fixed Effects (HD F.E.), enhancing the robustness of our findings by controlling for more granular unobserved heterogeneity. Model 3 retains the product quoted spread without disaggregation and shows a muted negative effect, -1.242, which is no longer significant. This suggests that once comprehensive fixed effects are controlled, the overall impact of quoted spreads on carry trade returns may be more nuanced. Model 4, similar to Model 2, disaggregates the quoted spreads by commodity type but under the HDFE framework. Here, the positive effect for metals persists but at a reduced magnitude of 224.0, while the negative impacts for energy and agriculture commodities are attenuated to -4.521 and 33.26 respectively, with both remaining significant.

Overall, the models underscore the complex and varied interactions between market liquidity—as proxied by quoted spreads—and carry trade returns across different commodity categories. The inclusion of HDFE models provides a more nuanced understanding, revealing that once a broader array of fixed effects is controlled, the direct impacts of quoted spreads can exhibit significant variations, both across and within commodity types. These findings not only contribute to the literature on financial markets and commodity trading but also have practical implications for traders and risk managers who must navigate these market dynamics.

4.1.4 Cross-Section Analysis

$$CarryTradeReturn_{j,t} = \beta_0 + \beta_1 LiquidityIndex_t^i + \beta_2 Price_t^i + \beta_3 VIX_t + \gamma X + \sigma_t^i$$

$$i \in \{nickel, aluminum, copper, corn, soybeans, wheat, cotton, rubber, sugar, heatingoil\}$$

$$j \in countries$$

4.2 Country level Analysis

This analysis aims to explore the relationship between carry trade returns, represented by `carry_trade_index_2`, and the liquidity risks of three key commodities: Aluminum (`Ah_QS`), Nickel (`Ni_QS`), and Copper (`Cu_QS`).

4.2.1 ARIMAX Model

The ARIMAX model is specified as:

$$\text{carry\_trade\_index\_2}_t = \alpha + \sum_{i=1}^{p} \phi_i \text{carry\_trade\_index\_2}_{t-i} + \sum_{j=1}^{q} \theta_j \epsilon_{t-j} + \sum_{k=1}^{n} \beta_k X_{kt} + \epsilon_t$$

Where:

- X_{kt} are the exogenous variables: `Ah_QS`, `Ni_QS`, and `Cu_QS`.

Results

The ARIMAX model was fitted with an ARIMA order of $(1, 1, 1)$ and the following exogenous variables: `Ah_QS`, `Ni_QS`, `Cu_QS`. The table below summarizes the results of the regression analysis.

The SARIMAX regression analysis reveals that liquidity risks associated with Aluminum (`Ah_QS`) and Copper (`Cu_QS`) have a statistically significant negative impact on carry trade returns, as measured by `carry_trade_index_2`. Specifically, increases in these liquidity risks are associated with a decrease in carry trade returns, underscoring the sensitivity of the carry trade strategy to fluctuations in commodity markets. In contrast, Nickel (`Ni_QS`) does not show a significant effect, suggesting that its liquidity risk is less relevant in this context.

The model's diagnostics demonstrate strong temporal dependencies, as evidenced by the significant autoregressive and moving average components. However, the presence of heteroskedasticity and non-normal residuals suggests that, while the model captures key relationships, there may be room for further refinement to address these issues. Overall, these findings highlight the importance of considering commodity

Table 3. SARIMAX Regression Results

Dep. Variable:	carry_trade_index_2
Model:	SARIMAX(1, 1, 1)
Date:	Wed, 14 Aug 2024
Time:	17:53:08
Sample:	0 to -3834
Covariance Type:	opg

	Coef.	**Std. Err.**	**z**	**P> |z|**	**[0.025**	**0.975]**
Ah_QS	-3.4780	1.636	-2.126	0.034	-6.685	-0.271
Ni_QS	-0.0678	0.679	-0.100	0.920	-1.398	1.262
Cu_QS	-4.5009	1.950	-2.308	0.021	-8.324	-0.678
ar.L1	0.6568	0.025	26.329	0.000	0.608	0.706
ma.L1	-0.7810	0.021	-36.836	0.000	-0.823	-0.739
sigma2	9661.6928	84.480	114.366	0.000	9496.115	9827.271

Ljung-Box (L1) (Q):	0.03
Prob(Q):	0.87
Heteroskedasticity (H):	0.46
Prob(H) (two-sided):	0.00

Notes: This table presents the results from a SARIMAX model with carry_trade_index_2 as the dependent variable. Coefficients, standard errors, z-values, and p-values are reported. The sample size is 3,834 observations.

market conditions when evaluating the performance and risks associated with carry trade strategies.

4.2.2 GARCHX Model

After estimating the ARIMAX model, which provided insights into the relationships between carry trade returns and commodity liquidity risks, it became evident that the residuals exhibited signs of heteroskedasticity. Specifically, the model diagnostics indicated non-constant variance in the residuals over time, a typical characteristic in financial time series data that can lead to inefficiencies in estimation if not properly accounted for.

To address this issue, we chose to extend our analysis by estimating a GARCHX model. The GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model is well-suited for capturing time-varying volatility, which is often observed in financial markets. By incorporating the same exogenous variables used in the ARIMAX model within the mean equation of the GARCHX model, we can simultaneously model the relationships between carry trade returns and commodity risks while also accurately capturing the dynamic volatility of the returns. This approach allows us to better understand the volatility patterns and improve the reliability of our parameter estimates.

Model Specification The GARCHX model consists of two key components: the mean equation, which models the conditional mean of the dependent variable, and the volatility equation, which models the conditional variance. The model can be represented as follows:

Mean Equation

$$\text{carry\_trade\_index\_2}_t = \mu + \beta_1 \text{Ah\_QS}_t + \beta_2 \text{Ni\_QS}_t + \beta_3 \text{Cu\_QS}_t + \epsilon_t, \tag{29}$$

where

Volatility Equation

$$\sigma_t^2 = \omega + \alpha_1 \epsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2, \tag{30}$$

Results

Table 4. GARCHX Model Regression Results

Mean Equation	**Coefficient**	**Std. Error**	**P-value**
Const	667.4999	8.401	0.000
Ah_QS	-114.7210	35.963	0.001
Ni_QS	-44.7841	18.557	0.016
Cu_QS	-245.8168	57.962	0.000

Volatility Equation	**Coefficient**	**Std. Error**	**P-value**
omega	1625.3813	346.263	0.000
alpha[1]	0.5981	0.0356	0.000
beta[1]	0.4019	0.0375	0.000

Notes: This table presents the results of the GARCHX model with the carry_trade_index_2 as the dependent variable. The mean equation is modeled using least squares with exogenous variables, while the volatility is modeled using a GARCH(1,1) process. The table reports the estimated coefficients, standard errors, and p-values. The sample consists of 3,834 observations.

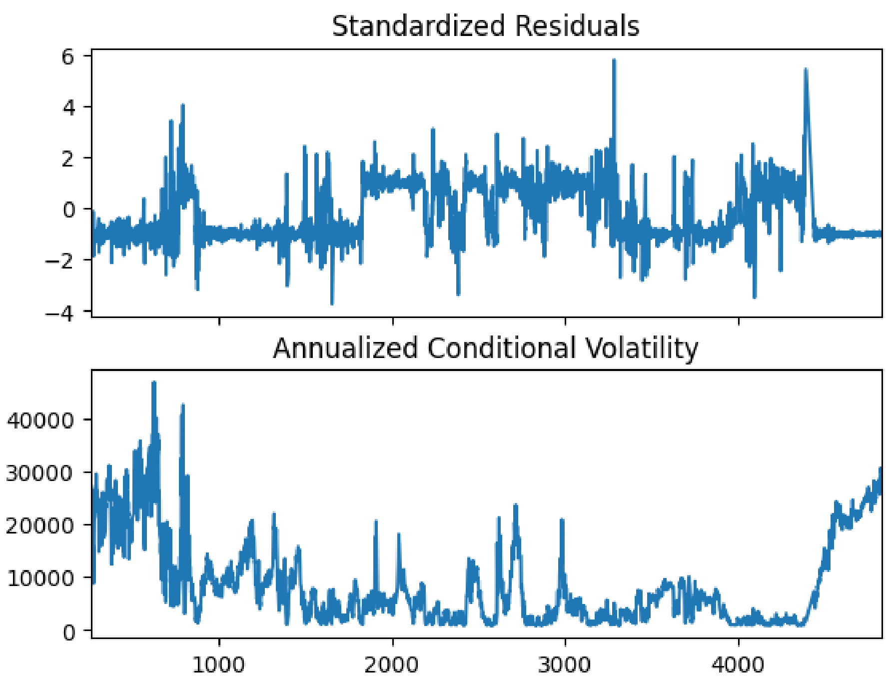


Figure 8. GARCHX Results

The results of the GARCHX model indicate that the liquidity risks associated with Aluminum (`Ah_QS`), Nickel (`Ni_QS`), and Copper (`Cu_QS`) have significant effects on carry trade returns, as measured by `carry_trade_index_2`. Specifically, the coefficients for all three commodities are negative, suggesting that increases in these liquidity risks are associated with decreases in carry trade returns. Among these, the impact of Copper is particularly strong, as indicated by the magnitude of its coefficient.

In the volatility equation, the significant coefficients for `omega`, `alpha[1]`, and `beta[1]` confirm the presence of time-varying volatility in the carry trade returns. The positive and significant `alpha[1]` and `beta[1]` coefficients suggest that both past shocks and past volatility contribute to the current level of volatility. This confirms the appropriateness of using a GARCH model to capture the conditional heteroskedasticity in the data.

The conditional volatility plot (Figure **??**) further illustrates how volatility evolves over time, highlighting periods of increased uncertainty in the carry trade strategy. These periods correspond to heightened sensitivity to commodity liquidity risks, reinforcing the importance of incorporating volatility modeling in the analysis. By modeling both the mean and volatility components, the GARCHX model provides a more comprehensive understanding of the dynamics affecting carry trade returns.

4.3 Product level Analysis

4.3.1

4.4 The Determination of Exchange Rate

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5 Conclusion

Firstly, this study embarks on an exploratory journey into the dynamics of carry trade, particularly between China and the U.S., through a comprehensive event study. Our primary analysis reveals a negative correlation between liquidity risk in the commodity futures market and carry trade returns. This inverse relationship underscores the nuanced interplay between market liquidity and profit opportunities in cross-border trades. Additionally, we extend our investigation by conducting a cross-sectional analysis, which facilitates a comparative assessment of the risk-return profiles across different countries. This two-pronged approach not only sheds light on the specific intricacies of the China-U.S. carry trade scenario but also provides broader insights into the varied market behaviors and their implications on global arbitraging strategies.

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Tables

Figures

Appendix