Bypassing Capital Interventions: Carry Trades via Commodity Futures Market

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December 30, 2024

Preliminary Version, click here for latest update

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†I would like to thank Tomas Williams, Roberto Samaniego and Rafael Lopez-Monti for useful comments and discussions. I extend our appreciation to George Washington University for granting access to WRDS, including the Refinitiv commodity contracts and Bloomberg carry trade data. I affirm that all funding sources had no involvement in study design, data collection, and analysis, or the decision to publish the manuscript. I have no relevant or material financial interests or affiliations that could be perceived as constituting a potential conflict of interest. Any opinions, findings, conclusions, or recommendations expressed in this work are solely those of the authors and do not necessarily reflect the views of the supporting organizations.

Abstract

This study proposes a "Gamma Model" to examine commodity-collateral-based arbitrage, leveraging the arbitrage motives of commodity producers and traders in developing countries. From an imperfect market perspective, we explore how exchange rate mechanisms interact with commodity-driven arbitrage. Our findings reveal that non-financial institutions bypassing capital controls use international financing at lower interest rates through commodity trading, capturing higher returns in domestic markets. These activities amplify the impact of liquidity shocks in the commodity futures market on exchange rates, especially in countries with stricter capital controls.

Using data from 25,035 commodity contracts (extracted via an LLM) in the Refinitiv database and daily carry trade returns from Bloomberg, we test two key hypotheses: (1) liquidity risk in the commodity market significantly reduces arbitrage returns (coefficient: -0.226); and (2) stricter capital controls amplify this effect. The results further indicate that liquidity risk varies across commodity types, with Precious Metals and Raw Metals being the most commonly used commodities for arbitrage activities. Additionally, liquidity risk contributes more significantly to carry trade returns under medium-level capital controls, particularly in the bond market and money market capital interventions. This research offers new insights into the linkage between commodity markets and exchange rate volatility, providing policymakers with a new channel to reconsider about the effectiveness of capital control.

Keywords: Carry Trade, Commodity Financing, Liquidity Risk, Capital Control
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.

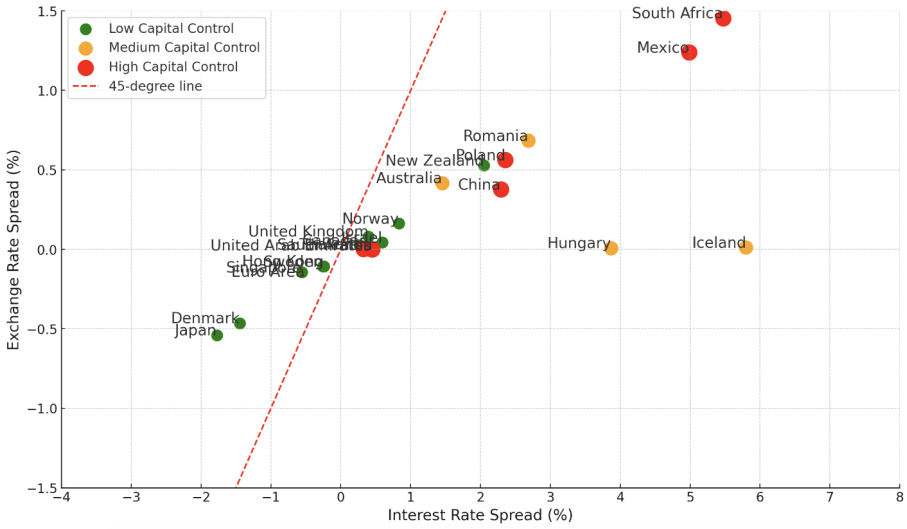


Figure 1. Capital Control and UIP Deviation

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 different groups do have different impact on UIP devi-

ation [12]: For those countries with low level capital control level, they do not have a significant correlation with the carry trade return, however, when the capital control group with median and high level, the deviation from the 45 degree line is more significant. This indicates that investors are increasingly adopting alternative methods for carry trade to bypass these controls.

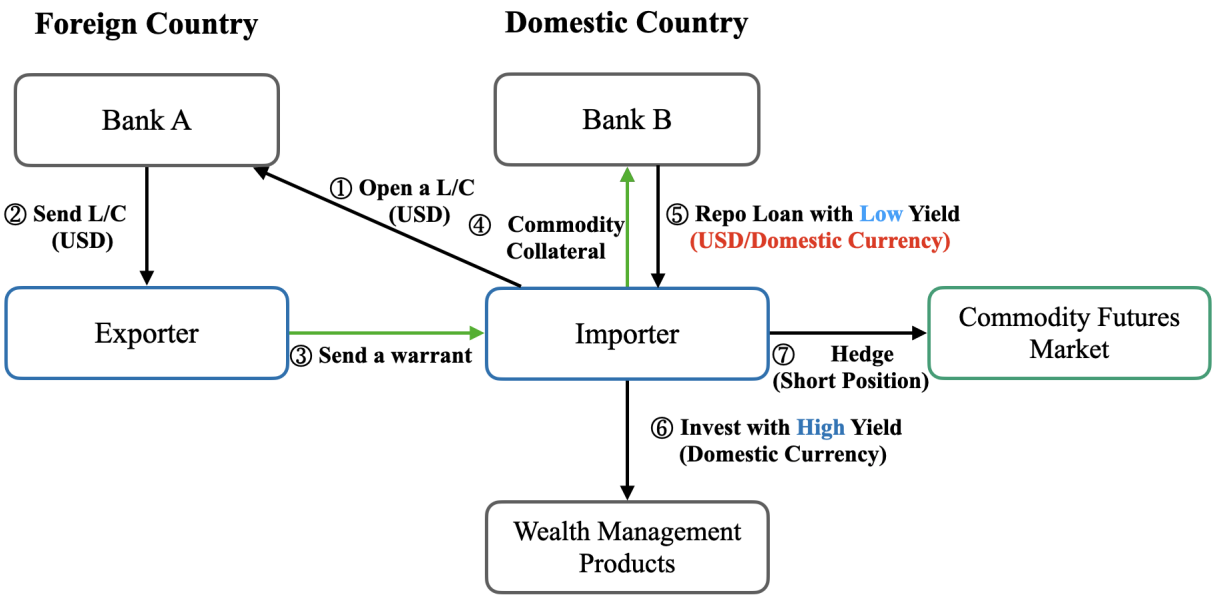
A new approach, known as the 'commodity-currencies' strategy, has been detailed by Ready et al. (2017a), highlighting the shift towards real trade strategies in carry trade practices. Beyond physically importing commodities from foreign markets, investors can utilize 'warehouse warrants' as financial 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.

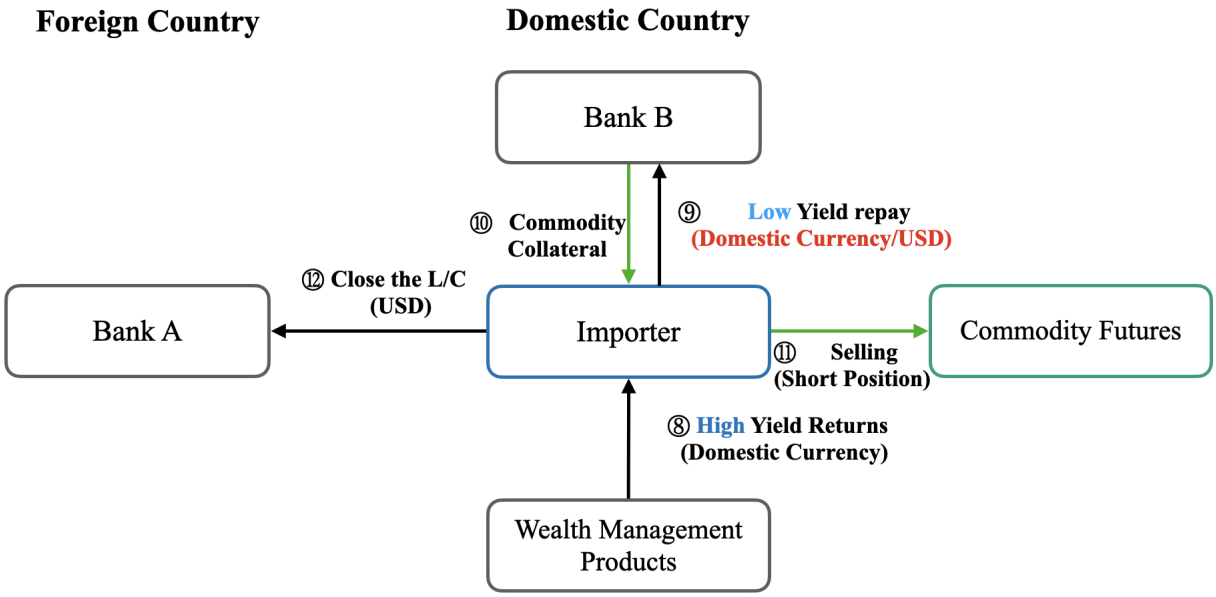
By analyzing commodity-based carry trade strategies in developing countries, we argue that exchange rate determination theory should account for commodity-based carry trade capital flows. Building on the general Gamma model introduced by Gabaix and Maggiori (2015), our model integrates financiers and households within an imper-

[1]We utilized the capital control index from Fernández et al. (2016c), which provides annual data for each country. To facilitate analysis, we categorized capital controls into three groups—low, medium, and high—based on their standard deviations from the mean. Specifically, the "low" category includes values below one standard deviation below the mean, the "medium" category spans values within one standard deviation of the mean, and the "high" category encompasses values above one standard deviation above the mean.

[2]The red line represents the 45-degree line, which corresponds to the Uncovered Interest Parity (UIP) line.



(a) Beginning of the Carry trade



(b) By the end of maturities

Notes: The pictures are generated by the author.

Figure 2. Carry Trade using Commodity Future Market

fect 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.

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 Tang and Zhu (2016). Further exacerbating the situation was a general hesitance among traders to provide liquidity, resulting in increased margin requirements for metal producers and traders.

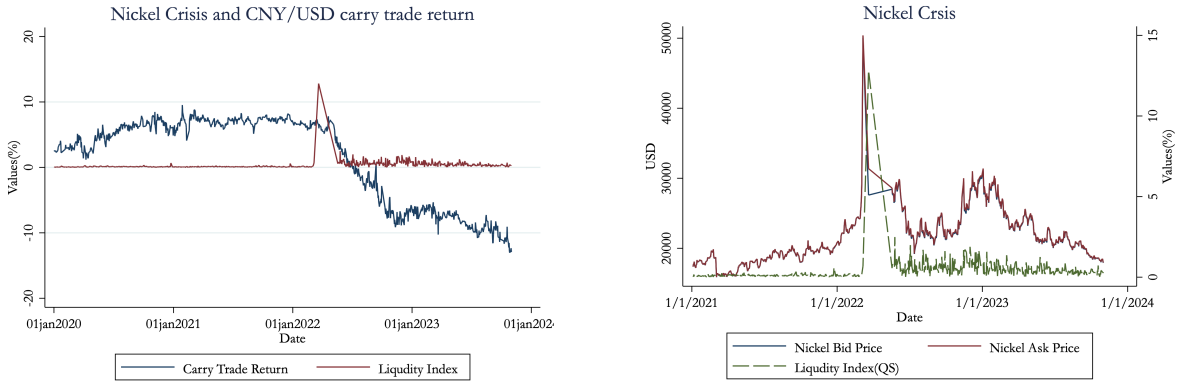


Figure 3. Dynamic Time Series and Simple Correlation Analysis of LME Nickel Crisis

To demonstrate the impact of liquidity risk in the commodity market on the ex-

change 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 Return (CTR) 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 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.

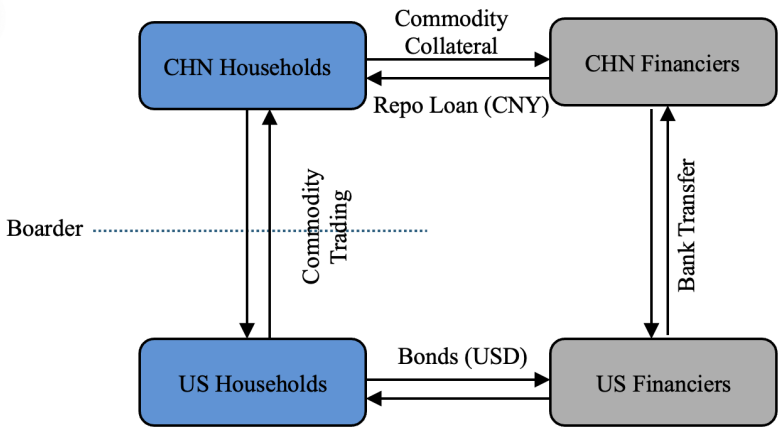


Figure 4. Gamma Model with commodity trading

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.[3] 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

[3]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 $\frac{d\text{Carry Trade Return}_0}{dk_0} \geq 0$.[4] 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.[5] Incorporating interest rate differentials into our model would enhance its accuracy and predictive power.

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

[5]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 Data and 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 mul-

tiple 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 Data

4.1.1 Carry Trade Returns (CTR)

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:

$$CTR_{i,t} = (r^f_{i,t} - r^f_{US,t}) - \frac{NDF_{i,t}}{e^{Spot}_{i,t}} \tag{26}$$

Specifically, $r^f_{i,t}$ represents the 3-month interbank offered rate for country i, serving as the foreign interest rate in our framework. Similarly, $r^f_{US,t}$ denotes the 3-month LIBOR in USD, which acts as the domestic interest rate. Moreover, $NDF_{i,t}$ represents the 3-month non-deliverable forward (NDF) rate for currency i against the USD, capturing market expectations of future exchange rates. Lastly, $e^{Spot}_{i,t}$ is the spot exchange rate for currency i against the USD, reflecting the prevailing market rate. The dataset spans from January 3, 2000, to September 13, 2024, providing a robust temporal scope for the analysis.

We collected 25 countries and regions' interest rate spread and exchange rate spread to generate the daily carry trade returns data. The distribution of the carry trade returns in different countries are listed in the figure 5.

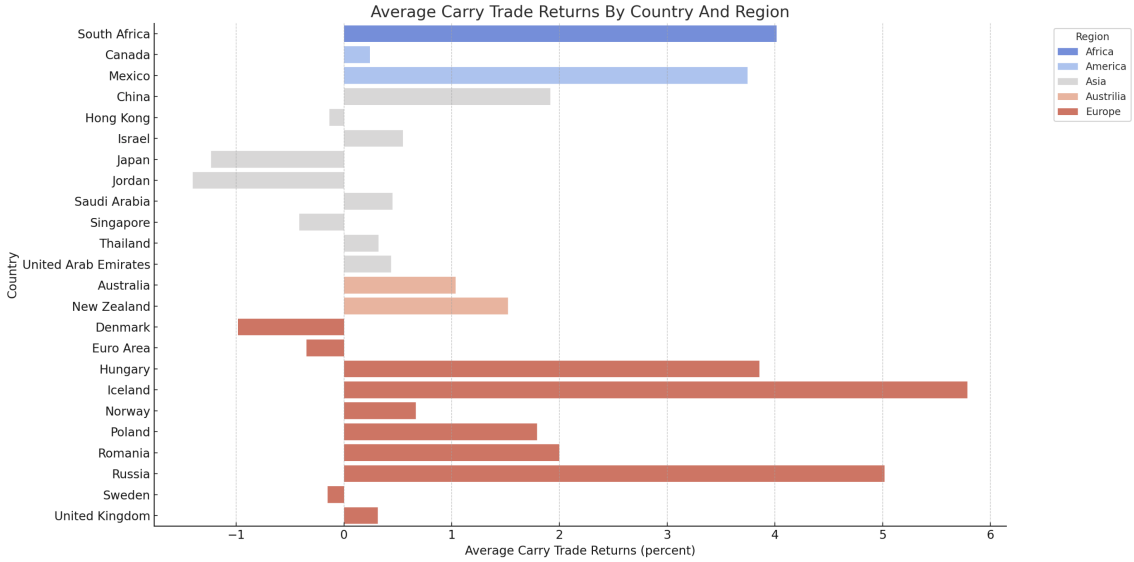


Figure 5. Distribution of Carry Trade Returns

4.1.2 Liquidity Risk Index (LRI)

To facilitate a comprehensive and rigorous evaluation, the other key variable is the liquidity risk measurement in the commodity futures market. We have meticulously curated and processed a detailed dataset from the Refinitiv dataset, which encompasses 25,035 commodity futures contracts globally. This dataset features daily bid and ask prices, as well as trading volumes for each contract. To identify the country associated with each contract, we employ a Large Language Model (LLM) powered by ChatGPT and adhere to several principles to distinguish the country and location. The principles are formatted as follows:

1. If any country name, abbreviation, or code appears in the name, use that country name.

2. If there is no explicit country name in it, find the company or foreign exchange name or abbreviation in it. First infer which country the company or foreign exchange is located in and use that location as the country name.

3. If none of the above appears, infer based on the major type of commodities that the foreign exchange is most likely transacting. Then use the country where the

foreign exchange is located as the country name. For example: Input: `Acrylonitrile, Cont.Price U$/MT`. Reasoning: It suggests that it is likely traded on a major commodity exchange in the United States, such as the Chicago Mercantile Exchange (CME).

4. Do not refer to any currency symbol or unit in the name, as it may mislead the answer.

5. If none of the above conditions apply, use `UNK` to indicate the country is unknown.

After refining the commodity contract dataset, the final data covers 16 countries, as illustrated in Figure 6. Of the total contracts, 50.8% were identified using the Type 1 principle, while 27.1% were classified based on the second rule. This distribution highlights the high robustness and reliability of the inferred country locations within the dataset.

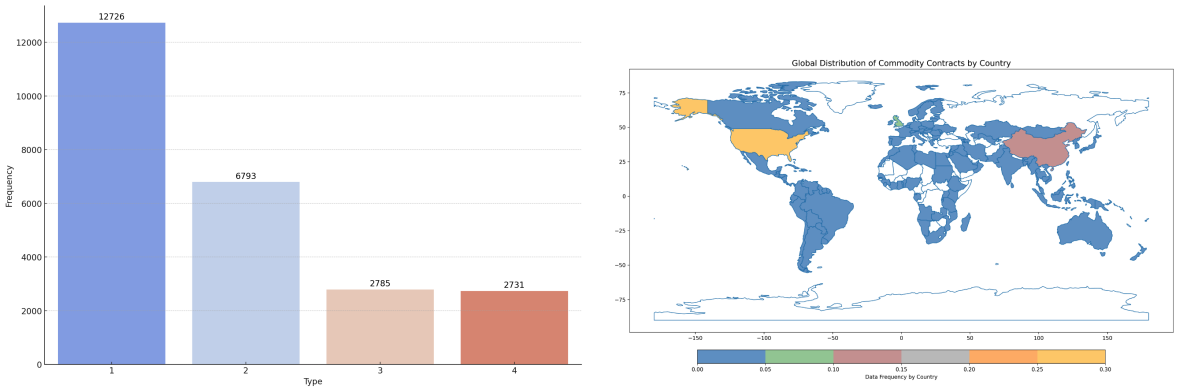


Figure 6. Distribution of Commodity Contracts

To measure the preference for commodity financing, 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. [6] This measure provides an insightful gauge of market liquidity by capturing the cost incurred by traders due to lack of immediate trade execution.

[6] We also use different risk factors in the commodity future market in the empirical analysis part.

The Liquidity Risk Index (LRI) is calculated as follows:

$$LRI_{i,t}^{j} = \frac{PA_{i,t}^{j} - PB_{i,t}^{j}}{PM_{i,t}^{j}} \tag{27}$$

where $PA_{i,t}^{j}$ represents the Average Ask price for commodity futures contracts of type j, in country i, at time t, which is the price a seller is willing to accept for the commodity. $PB_{i,t}^{j}$ denotes the Bid price for commodity futures contracts of type j, in country i, at time t, reflecting the price a buyer is willing to pay for the commodity. Finally, $PM_{i,t}^{j}$ is the Midpoint price for commodity futures contracts of type j, in country i, at time t, calculated as the average of the Ask and Bid prices. This serves as a reference point for the current market price of the commodity.

By calculating the LRI, 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.

4.1.3 Capital Control Index

Another essential variable used in this paper is the capital control index, which is derived from the Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). This index provides a comprehensive measure of controls on capital inflows and outflows across various categories, making it a crucial factor in the analysis. Specifically, we utilize the dataset provided by Fernández et al. (2016b), which includes annual indicators of controls on inflows and outflows across 10 categories of assets for 100 countries, spanning the years 1995 to 2021. This detailed classification allows for a more granular analysis of the impact of different types of capital controls.

4.2 Empirical Analysis

4.2.1 Case Study: US and China

OLS analysis Firstly, we estimate a simple OLS model to examine the relationship between the CNY/USD carry trade returns and the liquidity risk index of the nickel futures market. This analysis is motivated by a significant event in the nickel market involving a Chinese trading company, which serves as a representative case. the model is:

$$\text{CRT}_t = \beta_1 + \beta_2 \,\text{Nickle market LRI}_t + \sigma_t \tag{28}$$

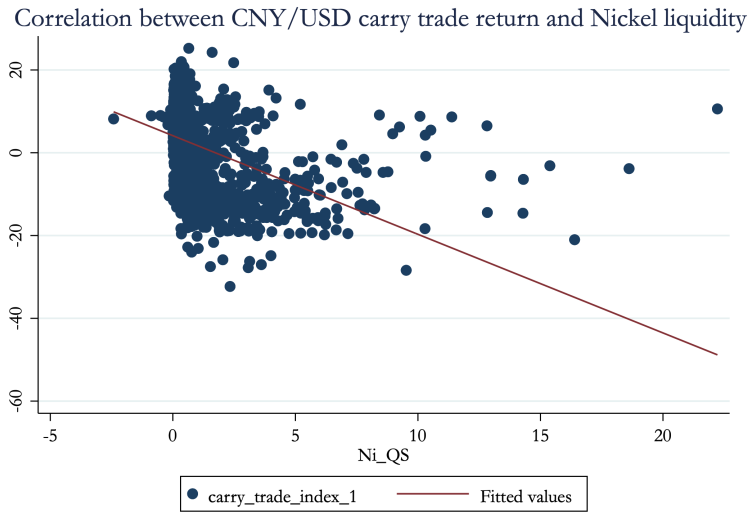


Figure 7. Simple correlation

The graph presented in Figure 7 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 1, 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.

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. 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_LRI*) and analyzed the relationship between the Carry Trade Return (CTR) and product LRI employing fixed effects. To facilitate our analysis, we employ the following regression model:

$$\text{CTR}_{it} = \beta_0 + \beta_1 \text{Product_LRI}_{it} + \mu_i + \gamma_t + \epsilon_{ijt} \tag{29}$$

In this analysis, the CTR_{it} quantifies the carry trade returns for each commodity product i at time t, reflecting potential profit from trading futures contracts. Concurrently, Product_LRI_{it} measures the LRI 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. 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 OLS empirical analysis results summarized in Table 1, we investigate the effects of LRI on the Carry Trade Return across different commodity categories. Model 1 shows a significant negative relationship between product LRI 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. Furthermore, 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 LRI 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 LRI 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 LRI on carry trade returns may be more nuanced. Model 4, similar to Model 2, disaggregates the LRI 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.

Event Study 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 May 16, 2022. This timeframe is particularly relevant as it concludes with the release

Table 1. Regression Results: OLS and Futures Level Analysis of CNY/USD

OLS Regression Results			Futures Level Analysis Regression Results				
	(1)	(2)		(1)	(2)	(3)	(4)
LRI Daily	-2.383***		product_LRI	**-13.97*****		-1.242	
	(-29.54)			(0.918)		(0.811)	
LRI Weekly		-4.673***	product_LRI_metal		**299.9*****		**224.0*****
		(-41.29)			(6.331)		(6.856)
Constant	4.134***	5.223***	product_LRI_energy		**-16.46*****		**-4.521*****
	(34.15)	(43.80)			(0.894)		(0.808)
			product_LRI_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.	No	No	Industry F.E.	Yes	No	Yes	No
HD F.E.	No	No		No	No	Yes	Yes
Observations	3913	3913		18468	18468	18468	18468

t statistics and standard errors in parentheses

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

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.

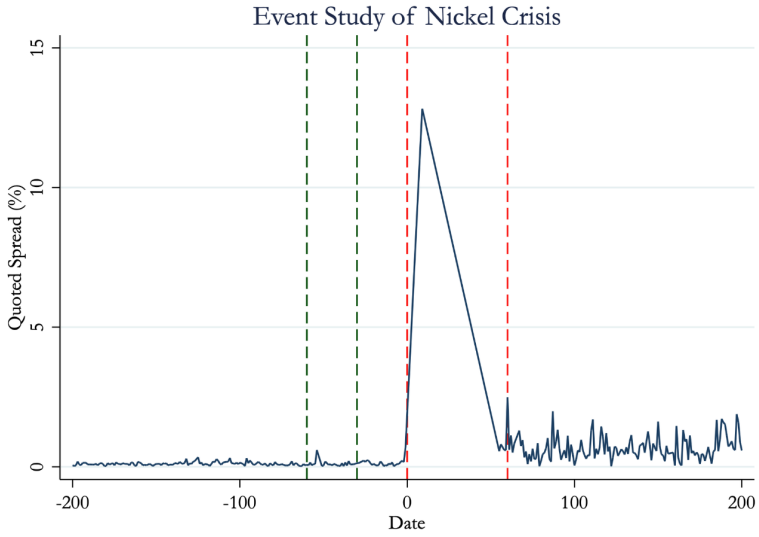


Figure 8. Event study

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.

GARCHX Model After estimating the OLS 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.

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[7]:

$$\text{CTR}_t = \mu + \beta_1 \text{Ah_LRI}_t + \beta_2 \text{Ni_LRI}_t + \beta_3 \text{Cu_LRI}_t + \epsilon_t, \tag{30}$$

where

$$\sigma_t^2 = \omega + \alpha_1 \epsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2, \tag{31}$$

[7]Notes: This table presents the results of the GARCHX model with the CTR 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.

Table 2. GARCHX Model Regression Results

Mean Equation	Coefficient	Std. Error	P-value
Const	667.4999	8.401	0.000
Ah_LRI	-114.7210	35.963	0.001
Ni_LRI	-44.7841	18.557	0.016
Cu_LRI	-245.8168	57.962	0.000

Volatility Equation	Coefficient	Std. Error	P-value
ω	1625.3813	346.263	0.000
α_1	0.5981	0.0356	0.000
β_1	0.4019	0.0375	0.000

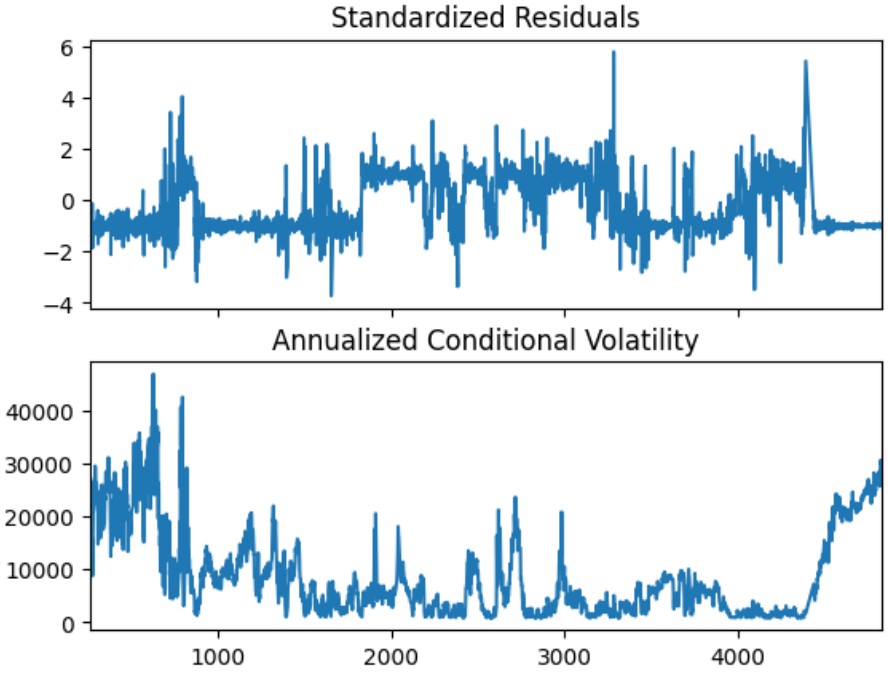


Figure 9. GARCHX Results

The results of the GARCHX model indicate that the liquidity risks associated with Aluminum (Ah_LRI), Nickel (Ni_LRI), and Copper (Cu_LRI) have significant effects on carry trade returns, as measured by CTR. 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 ω, α_1, and β_1 confirm the

presence of time-varying volatility in the carry trade returns. The positive and significant α_1 and β_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 9) 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.

Overall, the models underscore the complex and varied interactions between market liquidity—as proxied by LRI—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 LRI 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.

4.2.2 Panel Data Analysis

Carry Trade Returns and Commoidty Futures Market Liquidity Risk In this section, we use the whole sample data and analysing the variation cross differnet regions. The regression model in this part leverages panel data comprising daily observations from 24 countries over the period 2001 to 2024. The independent variable, $LRI^j_{i,t}$, represents various liquidity risk indices corresponding to different commodity types. To account for potential variations in liquidity risk determinants, we incorporate both regional and developmental status classifications as substitutes in different model specifications. This approach ensures a comprehensive examination of cross-country and cross-category dynamics, enabling robust insights into the factors influencing liquidity

risk across diverse economic contexts and commodity markets.

$$CTR_{i,t} = \beta_0 + \beta_1 LRI^j_{i,t} + \beta_2 Region + \beta_3 (LRI^j_{i,t} \times Region) + \alpha_i + \lambda_t + \epsilon_{i,t} \tag{32}$$

The regression results table 3 provides evidence of a significant relationship between carry trade returns ($CTR_{i,t}$) and the liquidity risk index ($LRI^j_{i,t}$) across regions and commodity types. In the baseline specification (Part a column 1), the coefficient for $LRI^j_{i,t}$ is negative and statistically significant (-0.226, $p < 0.01$), indicating that higher liquidity risk in commodity futures markets is associated with lower carry trade returns. This result aligns with theoretical predictions that liquidity risk imposes additional costs on arbitrage strategies.

The analysis incorporates both time and country fixed effects, which control for unobserved heterogeneity across time periods and countries, ensuring that the estimated relationships are not driven by omitted variable bias. The inclusion of these fixed effects enhances the robustness of the results by accounting for systematic differences in macroeconomic conditions and regional characteristics. Additionally, the regression model uses weighted averages, where the weights reflect the relative importance of observations in terms of commodity contracts amounts of the certain country.

The interaction terms between $LRI^j_{i,t}$ and regional dummies highlight notable heterogeneity in the impact of liquidity risk. For example, in column (2), the interaction term for Australia is both economically and statistically significant (-50.63, $p < 0.01$), suggesting that Australian markets experience a particularly strong negative effect of liquidity risk on carry trade returns. By contrast, the interaction terms for Europe and Asia, while negative, are not statistically significant, indicating weaker regional effects.

On the commodity side (b), columns (1) to (5) reveal that the relationship between $LRI^j_{i,t}$ and carry trade returns varies significantly by commodity type. Liquidity risk in the metals market has a positive and highly significant effect on returns (column 7, 10.88, $p < 0.001$), while liquidity risk in the precious metals market exhibits a strong negative relationship (column 4, -3.661, $p < 0.01$). These findings suggest that mar-

Table 3. Panel Regression Results: Region and Future Type Analysis

a. Region Analysis				b. Future Type Analysis					
	(1)	(2)	(3)		(1)	(2)	(3)	(4)	(5)
LRI	**-0.226****	6.653	**-0.262***	Prec LRI	**-3.661****				
	(-3.07)	(1.70)	(-2.21)		(-3.15)				
America × LRI		-7.258		Oilpro LRI		1.288			
		(-1.64)				(1.04)			
Asia × LRI		-6.003		Natgas LRI			0.508		
		(-1.52)					(0.63)		
Australia × LRI		**-50.63****		Metals LRI				10.88***	
		(-3.15)						(32.50)	
Europe × LRI		-6.939		Grains LRI					134.9
		(-1.77)							(0.96)
Developed × LRI			0.0499	Crude LRI					-0.0557
			(0.38)						(-0.71)
_cons	0.746***	0.746***	0.744***	_cons	0.808***	0.0139	0.616***	1.089***	0.924***
	(119.70)	(94.91)	(97.88)		(10.51)	(0.15)	(9.82)	(64.68)	(81.41)
Time F.E.	Yes	Yes	Yes	Time F.E.	Yes	Yes	Yes	Yes	Yes
Country F.E.	Yes	Yes	Yes	Country F.E.	Yes	Yes	Yes	Yes	Yes
Weighted Average	Yes	Yes	Yes	Weighted Average	Yes	Yes	Yes	Yes	Yes
R-square	0.828	0.828	0.828	R-square	0.914	0.830	0.956	0.786	0.728
Observations	43401	43401	43401	Observations	14490	21999	126	10733	29883
F	9.417	5.978	4.781	F	9.952	1.085	0.397	1056.457	0.508

t statistics and standard errors in parentheses

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

kets respond differently to liquidity risk depending on the characteristics of the commodities. The positive effect for metals markets is consistent with investor preferences for non-perishable, easy-to-store assets, whereas the negative relationship in the precious metals market may reflect heightened sensitivity to market liquidity conditions due to their distinct use cases and trading dynamics.

All in all, the regression results demonstrate that liquidity risk in commodity futures markets significantly impacts carry trade returns, with both regional and commodity-specific variations. Higher liquidity risk generally reduces carry trade returns, as evidenced by the negative and statistically significant coefficient for the liquidity risk index ($LRI^{j}_{i,t}$) in the baseline specification. On the commodity side, the influence of liquidity risk varies by type. The metals market shows a positive and highly significant relationship between liquidity risk and carry trade returns. Conversely, liquidity risk in the precious metals market has a negative impact on returns, reflecting its sensitivity to market liquidity conditions. These findings underscore the importance of considering both regional and commodity-specific characteristics when assessing the role of liquidity risk in carry trade dynamics.

Impact of the Bypass Mechanism In the second Panel data empirical model, we incorporated the capital control index to evaluate the bypass effect arising from capital controls on carry trade returns. The TWFE regression equation captures the interaction between the liquidity risk index ($LRI_{i,t}$) and the capital control index ($ka_{i,t}$), allowing us to assess how capital controls influence the relationship between liquidity risk and carry trade dynamics:

$$CTR_{i,t} = \beta_0 + \beta_1 LRI_{i,t} + \beta_2 ka_{i,t} + \beta_3 (LRI_{i,t} \times ka_{i,t}) + \alpha_i + \lambda_t + \epsilon_{i,t}$$

We utilize capital control indices to capture various aspects of regulatory intensity and policy design. The capital control dataset is sourced from Fernández et al. (2016a), which provides annual indicators of capital control measures across a wide

range of countries. This framework enables a comprehensive investigation into how capital controls, and their interaction with liquidity risks, influence carry trade returns across diverse economic contexts.

Table 4. Impact of Capital Controls on Carry Trade Returns

	(1) Carry Trade Returns	(2) Carry Trade Returns	(3) Carry Trade Returns
LRI	-4.413***	-1.820***	0.00752
	(-12.79)	(-4.60)	(0.02)
ka	-3.060***		
	(-23.78)		
ka × LRI	**-1.035**		
	(-1.65)		
kai		-5.094***	
		(-18.29)	
kai × LRI		**-43.75****	
		(-13.21)	
kao		1.807***	
		(7.01)	
kao × LRI		**39.91****	
		(12.73)	
bo			-6.562***
			(-30.40)
bo × LRI			**40.72****
			(18.13)
mm			-2.402***
			(-12.83)
mm × LRI			**-41.81****
			(-18.11)
Time F.E.	Yes	Yes	Yes
Country F.E.	Yes	Yes	Yes
Weighted Average	Yes	Yes	Yes
R-square	0.856	0.857	0.884
Observations	29,773	29,773	29,773

t statistics and standard errors in parentheses

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

The regression results presented in Table 4 explore the relationship between liquidity risk (LRI), capital control indices (ka, kai, kao, bo, mm), and carry trade returns. Model (1) includes LRI and a general capital control index (ka) along with their interaction term. The coefficient for LRI is negative and highly significant (-4.413, $p < 0.001$), suggesting that higher liquidity risk is associated with lower carry trade

returns. The interaction term $ka \times LRI$ is marginally significant (-1.035, $p = 0.10$), indicating that general capital controls may weakly amplify the negative effect of liquidity risk on carry trade returns. This implies that capital controls might introduce additional frictions that exacerbate the adverse impact of liquidity risks.

In Model (2), the capital control index is disaggregated into inward controls (kai) and outward controls (kao) to capture directional effects. The coefficient for kai is significantly negative (-5.094, $p < 0.001$), reflecting that stricter inflow controls reduce carry trade returns. Furthermore, the interaction term $kai \times LRI$ is strongly negative (-43.75, $p < 0.001$), showing that inflow controls intensify the sensitivity of carry trade returns to liquidity risk, potentially by restricting access to liquidity needed for stabilizing trades. Conversely, the coefficient for kao is significantly positive (1.807, $p < 0.001$), and its interaction with LRI ($kao \times LRI$) is also positive (39.91, $p < 0.001$). This indicates that outward controls mitigate the adverse effects of liquidity risk on carry trade returns, possibly by limiting capital flight and stabilizing market conditions.

Model (3) incorporates additional indices to examine the impact of capital controls in the bond market (bo) and money market (mm). The coefficient for bo is negative and significant (-6.562, $p < 0.001$), suggesting that stricter capital controls in the bond market reduce carry trade returns. However, the interaction term $bo \times LRI$ is positive and highly significant (40.72, $p < 0.001$), indicating that bond market controls may help mitigate the negative effects of liquidity risk by stabilizing capital flows and reducing volatility. In contrast, the coefficient for mm is also negative and significant (-2.402, $p < 0.001$), showing that capital controls in the money market reduce carry trade returns directly. Moreover, the interaction term $mm \times LRI$ is strongly negative (-41.81, $p < 0.001$), suggesting that money market controls may amplify the adverse effects of liquidity risk on carry trade returns, possibly by restricting short-term liquidity necessary for managing carry trade exposures.

The results highlight the multifaceted role of capital controls and the presence of bypass mechanisms in influencing the interplay between liquidity risk and carry trade returns. Stricter inflow controls exacerbate the sensitivity of carry trade returns to liq-

uidity risk, as market participants face heightened barriers to accessing liquidity, potentially driving them to seek alternative channels. Conversely, outward-oriented controls mitigate these effects by stabilizing markets and reducing capital flight, thereby dampening the adverse impacts of liquidity shocks. Bond market controls further demonstrate the ability to alleviate liquidity risk impacts, possibly by constraining long-term capital flows and encouraging stability. However, money market controls appear to inadvertently amplify the effects of liquidity risk, likely due to their influence on short-term liquidity needed for managing carry trade positions.

Except for the TWFE model, we also incorporate a Average Marginal Effect (AME) analysis in this paper to investigate whether different groups of capital control intensity exhibit varying marginal effects on the relationship between commodity liquidity risk and carry trade returns. We categorize the index into three distinct groups: "Weak Capital Control" for values between 0 and 0.33, "Medium Capital Control" for values between 0.33 and 0.66, and "Strong Capital Control" for values exceeding 0.66. Table 5 presents the regression results, while Figure 10 visualizes these effects.

Table 5. Average Marginal Effects of Liquidity Risk by Capital Control Levels

	dy/dx	Std. Err.	z	$P > \|z\|$	[95% Conf. Interval]
Weak Capital Control	-0.067	0.058	-1.16	0.246	[-0.180, 0.046]
Medium Capital Control	**-39.58*** **	0.845	-46.87	0.000	[-41.240, -37.929]
Strong Capital Control	0.073	0.071	1.03	0.301	[-0.065, 0.212]

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

The results highlight significant differences in how capital control levels moderate the relationship between liquidity risk and carry trade returns. For weak capital control regimes, the marginal effect of LRI is statistically insignificant, suggesting that liquidity risk has little impact on carry trade returns in such settings. However, under medium capital control regimes, the marginal effect is highly negative and significant (-39.58, $p < 0.001$), indicating that moderate levels of capital control amplify the adverse effects of liquidity risk on carry trade returns. This could reflect increased friction from partially restrictive policies that hinder liquidity while failing to stabilize markets effectively.

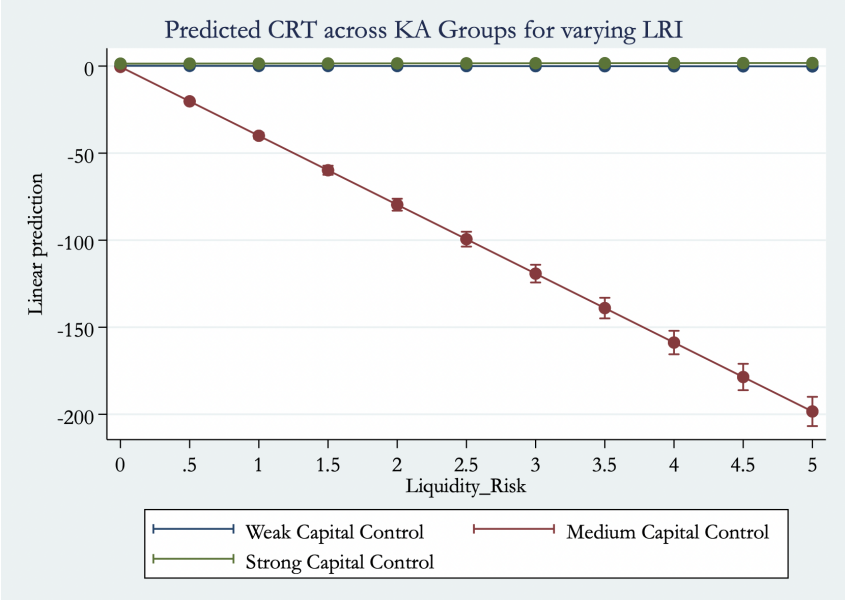


Figure 10. Marginal Effects of Liquidity Risk Across Capital Control Levels

For strong capital control regimes, the marginal effect of LRI is statistically insignificant, suggesting that stringent capital control measures neutralize the impact of liquidity risk. This stabilization might result from comprehensive restrictions that reduce market volatility and bypass activity, thereby mitigating the influence of liquidity shocks on carry trades. The visualization in Figure 10 further emphasizes the distinct behaviors of these regimes, illustrating how medium capital controls result in a pronounced negative marginal effect compared to weak or strong capital controls.

These findings underscore that medium capital controls, while partially restrictive, may inadvertently exacerbate liquidity risk's adverse effects, whereas strong controls appear to offer stabilization benefits without amplifying liquidity-related costs.

5 Conclusion

This paper examines how non-financial firms and investors leverage commodity futures to bypass traditional capital interventions, thus sustaining profitable carry trade returns. Our findings consistently indicate that liquidity risk in the commodity futures market exerts a significant, negative impact—around -0.226—on these cross-border arbitrage gains. Notably, commodities such as precious metals and raw metals emerge as

key instruments in this bypass mechanism, underscoring their liquidity and collateralizability in enabling firms to tap global capital at favorable rates. By shifting attention away from purely financial channels, our analysis highlights how these commodity-based strategies circumvent conventional policy measures designed to moderate sudden inflows or outflows of capital.

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.

Additionally, our cross-country analysis shows that medium-level capital controls bear an outsized influence on the interplay between liquidity risk and carry trade returns, especially in bond and money markets. Partial restrictions can unintentionally heighten the cost of liquidity, thus intensifying vulnerabilities in carry trades rather than curbing them. More stringent controls, on the other hand, appear to mitigate risk spillovers by limiting avenues for capital flight and stabilizing market conditions. Taken as a whole, the results emphasize the complex, multi-layered nature of cross-border capital regulation, and they suggest that policymakers may benefit from monitoring commodity-financing pathways if they wish to strengthen the effectiveness of capital controls in today's financially innovative landscape.

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