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Regulatory Changes in Commodity Futures Market, FPI Participation and Market Quality

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Abstract

We examine the impact of the Securities and Exchange Board of India's (SEBI) September 2022 regulation, which permitted Foreign Portfolio Investors (FPIs) to participate in selected commodity futures contracts traded on the Multi Commodity Exchange (MCX), one of India's leading commodity derivatives exchanges, on market quality. The natural experiment allows us to implement the difference-in-differences approach. We find that post-regulation, liquidity increases significantly, whereas volatility remains unaffected. Additionally, we find that post-regulation futures markets play a more significant role in price discovery and lead the spot markets on the arrival of new information. Our findings also suggest an improvement in price efficiency post-regulation. Our results are robust after controlling for lagged volume, contract value, market volatility, time to maturity, and spot volatility. Furthermore, the placebo test also confirms the robustness of the findings.

Keywords: Foreign Portfolio Investors; Regulation; Emerging Markets; Commodities; Market Quality

JEL classification: G10, G14, G18, G28

1 Introduction

Commodity derivative markets around the world have witnessed remarkable growth and an increased investor base in the past decade (Hamilton and Wu, 2015). Due to diversification benefits and favorable risk-return trade-offs, commodity derivatives are emerging as a separate asset class similar to other financial assets (Cheng and Xiong, 2014). Although the commodity market in India has a history spanning over a century, it gained formal recognition through a legal trading mechanism in 2003. Commodity derivatives are designed to help market participants mitigate their price risk in the underlying commodities. Therefore, regulators try to ensure broader participation, efficient price discovery mechanisms, low transaction costs, and low volatility in these markets.

Anecdotal evidence suggests that institutional investors are better informed and have the skills to analyze information more quickly than retail investors. The emergence of high-frequency trading

(HFT) has also opened up the debate about whether institutional investors can exploit emerging markets, especially given the challenges posed by weak institutional infrastructure and high levels of information asymmetry (Yan and Zhang, 2009; Kauffman et al., 2015). Prasanna and Bansal (2014) find that the involvement of Foreign Institutional Investors (FIIs) in emerging markets often results in excess market volatility and lower liquidity. Therefore, regulators in emerging markets vigilantly monitor market quality and take measures to improve it further. To improve market quality and better risk management, the Securities Exchange Board of India (SEBI), the regulator of commodity derivatives in India (SEBI regulation, dated 29th September 2022), allowed foreign portfolio investors (FPIs) to participate in selected non-agricultural commodity futures contracts. This move is viewed by market activists and participants as a response to the negative consequences of the Commodity Transaction Tax (CTT), which has been imposed on India's commodity derivatives trading since 2009. Although the CTT's introduction aimed to limit speculation and raise government revenues, it has significantly decreased trading volumes by 2018 at the Multi Commodity Exchange.[1,2]

The FPIs' participation is expected to improve the market quality. However, there are concerns that FPIs may exploit the market due to the presence of inefficiencies in emerging markets. Earlier studies suggest that the presence of FPIs can increase the efficiency of markets (Kacperczyk et al., 2021; Vo, 2019). However, their presence beyond a certain level can negatively impact the price efficiency (Lim et al., 2016). Indian Commodity market has, on several occasions, witnessed bans in some of the commodity derivatives due to the expectation of high speculations and its negative impact on the underlying commodities (Sobti, 2020). It is crucial to note that Foreign Portfolio Investors were allowed to participate in the Indian equity market and not in exchange-traded commodity futures until the SEBI Sept 2022 regulation. In the past few years, there has been a significant increase in the number of foreign investors registered in India, showing a keen interest in investing in Indian markets. Currently, more than 10,000 FPIs are registered in India, highlighting their growing presence in the Indian market.[3]

Examining the impact of the participation of FPIs in the Indian commodity derivatives market is important for several reasons. First, it is expected to provide evidence and contribute towards settling the ongoing debate on whether FPI participation increases volatility and destabilizes prices in the futures and spot markets in emerging countries such as India. Second, this study attempts to address an important research question: Does greater participation of FPIs' improve market quality? This has implications for policymakers who must ensure that the market stays resilient and reliable (Bernstein, 1987; Harris, 2003). The findings are expected to provide detailed analysis to help policymakers decide whether to open Indian commodities/other markets further. This study revolves around three central research questions: First, does the internationalization of the commodities futures market enhance liquidity? Second, does including FPIs in the commodities futures market markets contribute to reducing volatility? Third, how does opening up the commodity futures market for FPIs facilitate price discovery and better price efficiency?

In a natural experiment setting, the SEBI regulation implemented in September 2022 allows us to implement a difference-in-differences methodology to assess the impact of the regulation on market quality in the Indian commodity futures market. Two liquidity measures, Amihud and Microstructure Noise measures, show significant improvement in liquidity post-regulation. However, there is no tangible improvement in volatility as measured by two well-established volatility measures, Garman Klass and the Meilijson Volatility measure. Additionally, our findings indicate an improvement in the information share and component share captured by the futures market compared to the spot market following the regulation, alongside enhanced price efficiency. Specifically, our analysis reveals a variance ratio approaching 1 for treated commodities than non-treated commodities, indicating increased efficiency. Furthermore, our placebo test conducted one year before the regulation supports our findings.

Our study differs from previous research as it focuses on studying the impact of FPI participation on volatility and liquidity. Fan et al. (2020) concentrate on evaluating the effects of internationalization on the volatility of Chinese iron ore and PTA futures markets, whereas Xu and Zhang (2019) examine only the gold futures contracts. Similarly, Ding et al. (2017) explore the relationship between oil and stock market price movements after financialization. Xu and Zhang (2019)) investigate the impact of the opening of the Shanghai Gold Exchange International Board (SGEI) on gold trading on volatility. In contrast, our study analyzes a wide range of commodity futures: crude oil and natural gas from the energy sector, gold and silver from precious metals, copper, aluminum, and lead from metals, and mentha oil and cotton from the agriculture sector. Furthermore, rigorous studies on the Indian Commodity market on financialization are very few. Shamsher (2021) examines the financialization of the Indian commodities market, emphasizing return co-movements and volatility spillovers between commodity and stock markets, while Lauter and Prokopczuk (2022) analyze the correlation between liquidity and price efficiency measures. Our study further explores the influence of FPI participation on price discovery and commodities market efficiency, employing metrics such as Information Share, Component Share, and variance ratio.

The rest of this paper is structured as follows: Section 2 provides an overview of the extant literature. Section 3 outlines the research questions and the development of hypotheses. Section 4 elaborates on the data and methodology employed, while Section 5 presents the Results and Discussions. To ensure the soundness of our findings, Section 6 offers robustness tests. In Section 7, we discuss both the contributions and implications of our study, and the paper culminates in Section 8 with a conclusive summary.

2 Literature Review

The literature addressing the impact of internationalization on commodity futures markets is sparse, as studies primarily examine the impact of foreign ownership on price stability and market quality in the equity market. Research articles mainly investigate the impact on improved risk-sharing mechanisms (Lee and Chung, 2018) and reductions in equity capital costs (Henry, 2000; Bekaert and Harvey, 2000). The studies examining the impact of foreign investors' participation on liquidity and price discovery (He and Shen, 2014; Lee and Chung, 2018) find a positive impact on market quality. However, a few studies express reservations and underscore concerns regarding the potential aggressive demand for liquidity by foreign investors in the short term (Bae et al., 2004) and the perceived role of foreign speculative capital as a significant contributor to financial crises (Stiglitz, 1999). Our study addresses a research gap focused on an emerging commodity derivative market.

Market liquidity is a critical factor influencing both market volatility (Brunnermeier and Pedersen, 2009) and the process of price discovery (Chordia et al., 2008). Bessembinder and Seguin (1993) observed a strong correlation between trading volume and price volatility, underscoring the substantial role of liquidity in influencing market dynamics. The relationship between commodity market volatility and liquidity has been extensively examined in previous studies such as Feng et al. (2014) and Fan et al. (2020), which document a significant enhancement in both the trading volume and the number of trades in the PTA futures market in China, following a period of internationalization.

Studies in Indian markets provide mixed evidence of the participation of foreign institutions. Garg and Bodla (2011) find that foreign institutions play a stabilizing role, contributing positively to market efficiency, whereas Joo and Mir (2014) assert that ownership by foreign institutions tends to increase the volatility of firm-level stock returns. Baral and Patra (2019) in their study find that the participation of foreign investors enhances the liquidity of stocks by stimulating trading activities and enhancing price discovery. On the other hand, Batra et al. (2023) find that foreign institutional investors destabilize the Indian stock market. Prasanna and Bansal (2014) find that the involvement of Foreign Institutional Investors (FIIs) in emerging markets often results in excess market volatility and lower liquidity. The contrasting nature of empirical studies underscores the intricate relationship between internationalization and the various dimensions of stock market dynamics. These insights lay the groundwork for examining similar implications within the domain of the commodity futures market.

Our study is expected to contribute significantly for several reasons. In the unique regulatory landscape of India's commodity futures market, characterized by excessive speculation and behavioral biases, the entry of foreign investors with enhanced experience and rational decision-making expected to improve market quality. However, this may also present a potential downside, as foreign investors seek short-term liquidity (Bae et al., 2004). Our study provides crucial first-hand evidence for assessing the impact of internationalization on market quality. This study has policy implications as the impact of FPIs participation on market quality is expected to provide evidence to help in shaping future decisions about the further opening of the Indian derivative markets.

3 Research questions and Hypotheses development

The regulatory shift allowing Foreign Portfolio Investors to engage in Exchange-Traded Commodity Futures is expected to enhance liquidity in eligible commodity futures due to several factors, including the broader investor base facilitated by increased participation of FPIs. Furthermore, this move is also expected to lead to greater market integration due to cross-market arbitrage and diversification opportunities, potentially attracting even more foreign investors (Ding et al., 2017). Furthermore, traditional market microstructure models indicate that foreign investors enhance the information environment (Bohl et al., 2011). As foreign participation increases, it leads to a more transparent information landscape, enhancing informational efficiency within the market. Increased transparency not only increases market confidence but also attracts more participants to participate in trading activities (Agudelo, 2010). In light of these expectations, we propose the following hypothesis on the impact of new regulations on the liquidity of commodity futures.

H1: FPIs inclusion in the Non-Agricultural Exchange-Traded Commodity Futures market is anticipated to increase liquidity.

Volatility is the foundation for derivative pricing, determining an efficient hedge ratio, and risk management. In emerging markets, persistent concerns among regulators revolve around increased volatility, which escalates investor risk and subsequently increases the cost of equity (Eldomiaty et al., 2016). The regulatory intent behind allowing FPI involvement is to enhance the quality of the commodity market, anticipating a decrease in volatility (Li et al., 2011). Disruptions in commodity demand and supply during geopolitical upheavals or crises can exacerbate uncertainty and amplify price volatility. In such instances, FPI involvement is envisaged to expedite the dissemination of information from international commodity markets to their Indian counterparts. This enhanced flow of information is expected to empower other market participants to make better-informed decisions, anticipate changes in supply and demand, and adjust their trading strategies accordingly. Consequently, the level of uncertainty is expected to decrease, which could lead to a decrease in volatility within Indian commodity derivatives, thereby improving market efficiency and transparency (Hoang and Mateus, 2023). In this context, we propose the following hypothesis.

H2: FPI inclusion in the Non-Agricultural Exchange-Traded Commodity Futures market reduce Volatility.

Price discovery is a process that discovers the consensus price of all participants. Speculators, hedgers, and arbitragers prefer the derivative markets over the spot market due to lower transaction costs and better price discovery (Chen et al., 2016). FPIs' direct participation in Commodity Futures is expected to significantly enhance the price discovery process for the following reasons. Firstly, FPIs' higher exposure to global markets would help disseminate information across other international markets, reducing information asymmetry (Cai et al., 2022). Secondly, FPIs' investment in research and advanced analytical tools is expected to restrict market manipulation practices (Bae et al., 2004). Furthermore, the risk management practices employed by FPIs contribute to market stability leading to better price efficiency (Hoang and Mateus, 2023). Overall, the participation of FPIs in the trading of commodity derivatives presents unique advantages for better market quality; hence, it is expected to be reflected in the efficiency of the market as well. So, it is essential to test the following hypotheses.

H3a: FPI inclusion in the Non-Agricultural Exchange-Traded Commodity Futures market improves Price discovery.

H3b: Inclusion of FPIs in Non-Agricultural Exchange Traded Commodity Futures will elevate degree of market efficiency.

4 Data and Methodology

4.1 Data Description

Our study relies on data from the Multi Commodity Exchange of India Limited (MCX), a leading commodity derivatives exchange in the world operating under the regulatory framework of the Securities and Exchange Board of India (SEBI). In this study, we obtained daily data from the MCX covering open, high, low, closing prices, volume, open interest, and expiry dates of futures contracts and spot prices of the commodities. Specifically, we concentrate on seven non-agricultural commodities, as a Treatment group — Gold, Silver, Crude Oil, Natural Gas, Aluminium, Copper, Lead, for which FPIs participation is allowed by the September 2022 regulation and two agricultural commodities — Cotton and Mentha Oil as the control group where FPIs participation is still restricted. These commodities are selected based on data availability for sufficient trading days around regulation, liquidity and representation of a broad spectrum, encompassing precious metals, energy sector, base metals, and agricultural commodities.

Our analysis encompasses the construction of market quality metrics, specifically focusing on liquidity, volatility, price discovery, and price efficiency. To gauge liquidity, we employ the Amihud Price Impact (Amihud, 2002) and Microstructure Noise measures(Jain et al., 2024), while volatility is assessed using the Garman and Klass (Garman and Klass, 1980) and Meilijson Volatility estimator (Meilijson, 2011). Additionally, we delve into price discovery mechanisms by utilizing Information Share (Hasbrouck, 1995) and Component Share measures (Booth et al., 1999). Furthermore, we employ the variance ratio, a widely used measure to assess a market's efficiency by comparing the variability of returns over different periods (Lo and MacKinlay, 1988).

We employ a difference-in-differences methodology to evaluate the impact of the regulatory change permitting Foreign Portfolio Investors in Non-Agricultural Exchange-Traded Commodity Futures. We use liquidity and volatility measures in three distinct settings: 1) over a 90-trading-day period before and after the event to see the immediate impact of the regulation; 2) over a 180-trading-day period before and after the event to test whether the impact is permanent, and 3) introducing a buffer of 90 trading days pre- and post-regulatory shift to assess the impact over 91 to 180-trading-days before and after the event to control for potential short-run overreactions. To understand the improvement in price discovery due to the change in regulation in the futures market, we test the lead/lag relationship in spot market and futures contracts for the three event windows discussed earlier. We apply variance ratios to assess whether the regulation improves price efficiency. We estimate the variance ratio as the ratio of the variance of the 5-day returns to the variance of the 1-day returns over the same period.

4.2 Empirical Models: Difference-in-Differences Approach (DiD)

This study examines how the participation of Foreign Portfolio Investors (FPI) in Commodity Futures affects the market quality. We divide the available liquid futures contracts into two groups: 1) Treatment group includes future contracts where FPI participation is allowed, i.e., Aluminium, Copper, Crude Oil, Gold, Lead, Natural Gas, and Silver. 2) Control group of futures contracts where FPI participation remains restricted, i.e., Cotton and Mentha Oil. This distinction enables us to conduct a difference-in-difference analysis, comparing the changes in the treatment and control groups over time. We standardized the variables to remove scale effects and ensure that coefficients reflect the impact of a one standard deviation change in the independent variable on the dependent variable.

We employ a saturated fixed-effects regression model to explore the impact of regulatory change on the liquidity and volatility of the commodity futures contracts.

$$\begin{aligned} \text{ILLQ}_{i,t} = {} & \beta_1 \cdot \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \cdot \text{Trade Volume}_{i,t-1} + \beta_3 \cdot \text{Contract Value}_{i,t} \\ & + \beta_4 \cdot \text{DTM}_{i,t} + \beta_5 \cdot \text{Spot Volatility}_{i,t} + \gamma_{Commodity} + \delta_t + \epsilon_{i,t} \end{aligned} \tag{1}$$

$$\begin{aligned} \text{VOLT}_{i,t} = {} & \beta_1 \cdot \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \cdot \text{Trade Volume}_{i,t} + \beta_3 \cdot \text{OpenInt}_{i,t} \\ & + \beta_4 \cdot \text{DTM}_{i,t} + \beta_5 \cdot \text{SpotVolatility}_{i,t} + \gamma_{Commodity} + \delta_t + \epsilon_{i,t} \end{aligned} \tag{2}$$

The variable "Post" serves as an indicator (taking the value of 1 for days post-Regulation and 0 for days before the event). "Treat" is a dummy variable assigned a value of 1 for commodity futures in the treatment group and 0 for the commodity futures in the control group. The interaction term ("Post" * "Treat") acts as the difference-in-difference estimator. $\gamma_{commodity}$ is used to capture the commodities-fixed effects. δ_t is employed to capture the time-fixed effects. Following Jain et al. (2024), Chakrabarti and Rajvanshi (2013), Kadioglu et al. (2016), we control for lagged Trade Volume, Contract Value, VIX (India VIX volatility index), Days Till Maturity, and Spot Volatility for the robustness of the results.[4] To substantiate our hypothesis positing increased liquidity post-regulatory change, the coefficient β_1 in the regression equation (1) should be negative and significant when either Amihud Illiquidity or Microstructure Noise is the dependent variable. To support our hypothesis suggesting decreased volatility post-regulatory change, the coefficient β_1 in the regression equation (2) should be negative and significant when the Garman and Klass Volatility Measure or the Meilijson Volatility Estimator is the dependent variable.

Our empirical analysis employs two liquidity proxies: Amihud's Illiquidity (Amihud, 2002) and Microstructure Noise (Jain et al., 2024). The Amihud illiquidity measure, introduced by (Amihud, 2002), is the most widely used indicator to assess market liquidity and captures permanent price changes. This measure is widely used in the finance literature to compare liquidity across assets and markets (Amihud et al., 2006). This indicator is defined as the absolute price change per unit of trading volume.

$$Amihud\ Illiquidity_{i,t} = \frac{|PriceChange_{i,t}|}{DollarTradingVolume_{i,t}} \quad (3)$$

where $Price_{i,t}$ is the closing price on day 't', $DollarTradingVolume_{i,t}$ is calculated as the closing price multiplied by the shares traded of the commodity 'i' on day 't'.

[4] Following Cho et al. (2019), Contract Value is the product of the open interest, contract size, and the futures price

Microstructure Noise measure is based on high (H), low (L), open (O), and closing prices during the given period or interval. It is scaled by the closing price (C) of the commodity to allow comparison across commodity contracts. Microstructure Noise measure of liquidity is given by :

$$Microstructure\ Noise_{i,t} = \frac{(H_{i,t} - L_{i,t}) - |C_{i,t} - O_{i,t}|}{C_{i,t}} \tag{4}$$

It focuses on capturing transitory price pressures observed within a trading day, such as intra-day high and low prices that may reverse within the same day. This measure is used for high-frequency as well as low-frequency data. Both the Amihud Illiquidity and the Microstructure Noise Measure act as inverse proxies for liquidity, with higher values indicating lower levels of liquidity.

Previous studies such as Goyenko et al. (2009) and Marshall et al. (2012) find a robust correlation between the Amihud liquidity measure and other liquidity indicators such as effective spreads. However, this measure may be susceptible to being influenced by market volatility, which can cause price changes unrelated to liquidity factors. To address this concern, we employ Microstructure Noise as another measure of liquidity of the commodity futures, following the approach of Jain et al. (2024).

Furthermore, to examine the change in volatility due to the change in regulation, we use the Garman, Klass, and Meilijson volatility estimator. A robust measure of volatility is crucial for market participants as it helps them predict price changes and manage risks effectively. The Garman and Klass (1980) estimator is based on high, low, opening, and closing prices of the assets and, therefore, integrates more market information as compared to measures such as standard deviation and GARCH, which are based only on closing prices. The Garman Klass estimator is widely used to estimate asset volatility across assets and markets and is calculated as follows:

$$\sigma_{GK_i} = \sqrt{0.51(h_i - l_i)^2 - 0.02(c_i(h_i + l_i) - 2h_i l_i) - 0.38c_i^2} \quad (5)$$

where H_i, L_i, C_i, O_i are daily high, low, close, and open prices, respectively, during a day for each commodity 'i.' c_i, h_i, & l_i are the log difference of close, high, and low prices from the open price. However, the Garman-Klass estimator may yield a biased volatility estimate due to its discrete sampling method, which fails to account for opening price jumps and trend movements. To address this limitation, we employ an additional volatility measure.

The Meilijson (2011) volatility estimator is also based on high, low, opening, and closing prices. This measure improves the Garman and Klass volatility estimator by adjusting for opening jumps accurately, making the estimator more accurate (Meilijson, 2011). The Meilijson estimator is also adept at handling the effect of non-synchronous trading, a common issue in emerging markets, and therefore provides a more accurate estimation of volatility. Additionally, the Meilijson estimator is more robust regarding changes in the distribution of returns. The measure is denoted as:

$$\sigma_{M_i} = \sqrt{0.274\sigma_{1_i}^2 + 0.16{\sigma_2}_i^2 + 0.365{\sigma_3}_i^2 + 0.2 * {\sigma_4}_i^2} \quad (6)$$

where H_i, L_i, C_i, O_i are daily high, low, close, open prices respectively during a day for each commodity 'i'. c_i, h_i, & l_i are the log difference of close, high, and low prices from the open price. $c_i^{'} = c_i, h_i^{'} = h_i$ and $l_i^{'} = l_i \; if \; c_i > 0$, $c_i^{'} = -c_i, h_i^{'} = -h_i$ and $l_i^{'} = -l_i \; if \; c_i < 0$. ${\sigma_1}_i^2 = 2(h_i^{'} - c_i^{'})^2 + l_i^{'2}$, ${\sigma_2}_i^2 = c_i^{'2}$, ${\sigma_3}_i^2 = 2(h_i^{'} - c_i^{'} - l_i^{'})c_i^{'}$, ${\sigma_4}_i^2 = -\frac{(h_i^{'} - c_i^{'})l_i^{'}}{2ln2 - \frac{5}{4}}$

5 Results and Discussion

[INSERT TABLE 1. HERE]

Table 1 presents descriptive statistics for the commodity futures, both treatment and control group, trading on the MCX 180 days prior to and after the date of regulation, i.e., 29-Sep-2022. Amihud Illiquidity measure shows that Natural Gas exhibits the highest liquidity among commodity futures, with a median value of 0.385. Shifting our focus to the Microstructure Noise measure, Gold emerges as the most liquid commodity futures, reflecting a median value of 0.004, while Natural Gas emerges as the least liquid futures, registering a median value of 0.029. Regarding volatility, Natural Gas Futures emerge as the most volatile contracts, recording a median value of 3.720% according to the Garman & Klass Measure and 3.310% according to the Meilijson Volatility estimator. Kapas is the least volatile futures contract on the other end of the spectrum, with a Meilijson Volatility median value of 0.058% and a Garman & Klass Volatility median value of 0.148%.

[**INSERT TABLE 2. HERE**]

Table 2 provides the details of Amihud and Market Microstructure noise liquidity measures, Garman Klass and Meilijson volatility estimators, Information share, and component share pre- and post-90 days following the implementation of the September 2022 regulation. Amihud Illiquidity and Microstructure Noise Measures indicate a reduction in illiquidity, i.e., an increase in liquidity for most of the commodities where FPI participation is allowed (i.e., the treatment group) in the post-regulation period, as opposed to the control group. Garman Klass and Meilijson volatility estimator indicates a decrease in volatility for the commodity futures in the treatment group in the post-event period in contrast to commodity futures in the control group. Similarly, price discovery measures, such as Information Share and Component Share, indicate that the commodity futures in the treatment group capture more information as compared to the commodity futures in the control group relative to the spot market of the corresponding commodities.

The analysis of liquidity measures, volatility estimators, information share, and component share indicates an improvement in market quality due to FPI participation. Interestingly, a decline in market quality is observed in the control group after the regulatory change. This suggests a possible migration of participants from the control group commodities to the treatment group commodities following the regulatory adjustment, resulting in improved market quality for the treatment group and deteriorated quality for the control group.

We conducted a similar analysis for the event window spanning 180 days before and after the regulatory change, subdivided into periods: 180^{th} to 91^{st} day before the event and the 91^{st} to 180^{th}-day post-event. Our findings are similar to the results discussed for the event window of 90 days prior to and after the event. We have omitted the detailed results in this paper for brevity, but they are available upon request from the authors.

5.1 Impact of the Regulation on Liquidity

[INSERT TABLE 3. HERE]

Table 3 presents results from the difference-in-differences analysis. we run a panel regression model following equation (1), where the Amihud Illiquidity measure is the dependent variable. These results shed light on the impact of the regulatory change that permits Foreign Portfolio Investors to engage in Non-agricultural exchange-traded commodity futures on liquidity. Models (1), (2), and (3) correspond to the time windows of 90 Days, 180 Days, and 91 to 180 Days before and after the regulation, respectively.

In column (1) of Table 3, the DiD model results for ±90 days around regulation, and the estimate for the interaction variable Treat * Post is -0.0917. This suggests that following the involvement of Foreign Portfolio Investors (FPIs) after the September 2022 regulation, the average illiquidity of treated commodities (i.e., non-agricultural, treatment group) decreases, i.e., liquidity increases by 0.09 standard deviation (SD) compared to non-treated commodities (i.e., agricultural, control group). Similarly, in column (2), DiD model results for ±180 days around regulation, the estimate for the Treat * Post interaction variable is -0.454, significant at the 1% level, indicating a 0.45 SD reduction in average illiquidity for treated commodities after FPI participation. In column (3), DiD model results for -180 to -91, and 91 - 180 days around regulation, the estimate for Treat * Post is -0.696, significant at the 0.1% level, indicating a 0.696 SD decrease in average illiquidity for treated commodities compared to the control group following FPI involvement. It is evident that post-regulation liquidity increases across all three-time windows; however, the effects are more pronounced during the 180-day periods immediately before and after the regulation, as well as between 91 and 180 days after the regulation. The findings are intuitive, as new investors need time to understand market dynamics before establishing positions. Furthermore, these results suggest that the impact of the regulation on liquidity improvement is permanent.

Overall, the beneficial effects of internationalization on commodity futures are consistent with previous studies indicating that increased participation of foreign investors enhances the liquidity of local markets (Ng et al., 2016; Ding et al., 2017). Our study aligns with the findings of Fan et al. (2020), indicating that the Commodity Futures Exchange (specifically MCX) becomes more active after opening up for FPI participation. Therefore, our study suggests that all else being equal, investors prefer trading in a more active market with higher liquidity.

[INSERT TABLE 4. HERE]

Table 4 presents results from the panel regression model following equation (1), using the Microstructure Noise measure as the dependent variable. Amihud liquidity focuses on returns on trade volume. In contrast, the Microstructure Noise measure refers to the deviations in observed prices from their fundamental values, which are often caused by market microstructure effects. As the liquidity may be affected by market microstructure issues. The results reveal a similar pattern of association to the Amihud Illiquidity measure. In column (3), of Table 4, the estimate for Treat * Post is -0.131, significant at the 0.1% level, indicating a 0.13 SD decrease in average illiquidity for treated commodities compared to the control group following FPI involvement in the trading window of -180 to -91, and 91 - 180 days. In general, the favorable outcomes of permitting FPI participation in non-agricultural commodity futures are consistent with findings from earlier research. This is supported by studies such as He and Shen (2014) and Ding et al. (2017). Thus, our study suggests that all else being equal, investors prefer trading in a market with reduced microstructure noise frictions.

The findings from Table 3 and Table 4 indicate a significant improvement in liquidity when we employ the Amihud Illiquidity as well as Microstructure Noise measure, particularly in the 91 to 180 days following the regulation. These results confirm the hypothesis that implementing regulatory changes, particularly permitting Foreign Portfolio Investors to participate in Non-agricultural commodity futures, has positively impacted the liquidity of eligible commodity futures.

5.2 Impact of the Regulation on Volatility

[INSERT TABLE 5. HERE]

The results illustrated in Table 5 come from the panel regression model following equation (2), using the Garman and Klass measure. These findings elucidate the impact of the September 2022 regulatory change on the volatility of commodity futures in any of the three time windows. We do not find any significant change in the GK Volatility of the non-agricultural commodities compared to the control group after the regulation. The interaction term remains statistically insignificant in all columns of Table 5. The results indicate that post FPIs involvement the volatility of the futures contracts has not increase, which was the primary concern of the regulator and market participants at the time of introduction of the regulation.

[INSERT TABLE 6. HERE]

Table 6 presents the outcomes from the panel regression model following equation (2) employing the Meilijson volatility measure, revealing a similar association pattern as in the Garman and Klass measure. Chen et al. (2013) demonstrate that foreign institutions' ownership increases asset returns' volatility, while Li et al. (2011) suggest that foreign ownership reduces the volatility of asset returns due to improved risk-sharing. In contrast, our findings diverge from these studies, as we observe no significant decrease in volatility following FPI participation in the non-agricultural ETCF market. Our results are consistent with the study by Xu and Zhang (2019) that finds no substantial decrease in volatility after the opening of gold markets in the Shanghai Gold Exchange International Board in 2014.

The findings from Table 5 and Table 6 indicate no significant reduction in volatility across all three scenarios (pre- and post-90 Days, pre- and post-180 Days, and pre-and post-91-180 Days) when we employ the Garman Klass as well as Meilijson Volatility measure.Hence, we do not find evidence in support of our hypothesis that implementing regulatory changes, permitting Foreign Portfolio Investors to participate in Non-agricultural commodity futures, has significantly stabilize the price of the eligible commodity futures.

5.3 Impact of Regulation on Price Discovery

Price discovery is a process by which new information is timely and efficiently incorporated into the market prices of the assets. When the same asset (or an asset with similar attributes) is traded in multiple markets, it is interesting to know which market leads the price discovery process. In this study, we employ two measures for price discovery: Information Share(IS) and Component share (CS).

Information Share(IS) was proposed by Hasbrouck (1995) to capture information content for an asset that trades in multiple markets. The Hasbrouck model relies on the assumption that all public and private information is initially priced into one market before spreading to other markets. This measure helps quantify the incremental price change permanently reflected in security prices, typically attributed to new information or innovation available to one or more markets.

Since the commodities in our analysis trade in both the futures and underlying spot markets, they are interlinked, and their price dynamics are a function of common factors. The expected increase in the average information share measure of the futures market compared to the spot market, particularly following the introduction of FPI participation in non-agricultural commodities futures, is directly linked to the September 2022 regulatory change. Allowing FPI participation in the futures market enables foreign investors to trade futures contracts for non-agricultural commodities, broadening the participant base to include those with potentially diverse information compared to domestic traders. In contrast, the spot market, where physical commodities are traded for immediate delivery, does not directly benefit from this regulatory alteration. Consequently, this innovation predominantly affects the futures market rather than the spot market. Consequently, we anticipate that the futures market will integrate this new information more efficiently than the spot market, resulting in a higher average information share compared to the spot market. Furthermore, in some commodities, futures may anticipate movements in the spot market even before any innovation or regulatory change occurs, mainly due to the inherent characteristics of these commodities, such as demand and supply dynamics. For example, if there is an expected increase in demand for a certain non-agricultural commodity, futures prices might rise in anticipation of this demand, leading the spot prices to follow suit. In such cases, it is anticipated that futures prices for non-agricultural commodities will lead their corresponding spot prices by an even larger margin than before the regulatory change, as the futures market is expected to absorb and reflect this information quickly.

The second measure, Component share (CS), proposed by Booth et al. (1999), measures the contribution of each market to the response of common factors. The contribution is a function of the market error correction coefficients obtained from the Vector Error Correction Models (VECM). Lucey et al. (2013) find that information share (IS) responds to both permanent and transitory shocks, while component share (CS) captures only transitory shocks.

Financial instruments such as Commodity futures are essential to the market participants for hedging and risk management. If FPIs' participation improves the quality of future markets, then these markets should capture more information than the spot market post the 2022 September regulation. Our hypothesis posits that in the post-event period, the prices in the Futures Market for treatment commodity futures should take the lead and capture more information over the Spot Market. Alternatively, we anticipate that in the post-period, Futures Market prices will contribute significantly more than Spot Market prices to price discovery.

[INSERT TABLE 7. HERE]

The results provided in Table 7 shed light on the price discovery measures for the commodities in the treatment and the control group. This table highlights the average IS and CS of the future prices for the ten commodities within the scope of our study. The results indicate that the average Information Share of Non-Agricultural commodity futures during the post-scenario exceeds that of the pre-scenario, suggesting an enhancement in the futures price discovery following the regulatory change. Additionally, the analysis reveals that the Component Share, representing the transitory part of the innovation in the futures market, exhibits a significantly higher magnitude in the post-scenarios compared to the pre-scenarios, particularly for non-agricultural commodities as opposed to agricultural commodities. In combination, these findings indicates that the regulatory change, allowing Foreign Portfolio Investors to participate in the Non-Agricultural Exchange Traded Commodity Futures Market, has notably improved price discovery for the eligible commodities.

5.4 Impact of Regulation on Price Efficiency

Variance ratios offer insights into the efficiency and dynamics of financial markets as they measure the relative variability of returns over different periods, thus gauging market efficiency by assessing the degree to which prices reflect all available information (Hasbrouck and Schwartz, 1988). A ratio close to 1 suggests that price changes are essentially random and that market participants are efficiently incorporating new information into asset prices.

Any deviations from 1 show potential inefficiencies within the market. A variance ratio significantly below one (above one) may suggest that market prices are slow (fast) to incorporate new information, leading to under-reaction (over-reaction) or sluggish adjustments in asset prices (De Bondt and Thaler, 1985)).

[INSERT TABLE 8. HERE]

Table 8 presents the average variance ratios for the treated as well as the untreated commodities before and after September 29, 2022. This analysis aims to assess the pricing efficiency for these commodities surrounding the regulatory event. The pre-event variance ratios serve as a benchmark to gauge market efficiency for the treated commodities leading up to the event date. Our observations reveal a consistent trend across all three scenarios involving Non-agricultural Commodities. The variance ratios for these treated commodities have notably increased and approached a value of 1 during the post-period compared to the pre-period. Conversely, for the untreated agricultural commodities, i.e., Cotton and Mentha Oil, the variance ratio has diverged further from 1.

Overall, our findings suggest that the presence of FPIs in the exchange-traded commodity Futures market has improved the flow of information. Specifically, information appears to be assimilated into prices more swiftly during the post-period for the treated commodities than untreated ones. Foreign investors positively impact the liquidity and price discovery of commodities, as supported by various studies (He and Shen, 2014; Ng et al., 2016; Lee and Chung, 2018). Our findings are based on the idea that there will be fewer arbitrage opportunities when the market is opened to foreign investors with more information. This aligns with existing research that has shown arbitrage opportunities in emerging markets with trade barriers (Ansotegui et al., 2013) and that markets are less connected when there are barriers to foreign investment (Gagnon and Karolyi, 2006). When trading barriers are removed, foreign investors are likely to act as sophisticated arbitrageurs, reducing existing mispricing (He and Shen, 2014), which results in less mispricing and improved price discovery.

6 Robustness Tests

Indian commodity market is an emerging market and its quality is improving over time. Although we have used a robust methodology to ensure that our results are reliable, we also employ further robustness tests to avoid spurious results. We apply a placebo test to confirm whether the observed effects are specific to the treatment of interest or can be attributed to other factors. We shift the placebo test one year before the actual event date, i.e., from 29 September 2022 to 29 September 2021.

[INSERT TABLE 9. HERE]

[INSERT TABLE 10. HERE]

The findings presented in Table 9 and Table 10 reveal that the coefficient β_1 (coefficient of interaction between post-regulation dummy and treatment group dummy) of the difference-in-differences estimator employed in this placebo (falsification test) is insignificant for both the liquidity (see Table 9) and volatility measures (see Table 10) across all three-time windows, namely ± 90 Days, ± 180 Days, and $\pm$ 91 to 180 Days around the hypothetical event date of **29 September 2021**. These findings provide strong empirical evidence indicating that the observed increase in liquidity levels of commodity futures can be attributed to the actual implementation of the regulatory change.

7 Contributions and Implications of the study

Our research contributes to the literature by examining the effects of Foreign Portfolio Investors' participation on both volatility and liquidity aspects after SEBI's September 2022 regulation. While Fan et al. (2020) primarily examined the impact of internationalization on commodity market volatility, our study extends this investigation to encompass liquidity considerations as well. Similarly, Ding et al. (2017) examine the relationship between oil as a commodity and stock market price movements post-financialization, whereas our research specifically investigates the internationalization aspect within the commodity segment. Our study examines hypotheses across multiple non-agricultural commodity futures traded in the Indian market, including seven commodities, differing from the study by Xu and Zhang (2019) that focuses solely on gold futures and found no increase in volatility with the opening of the Shanghai Gold Exchange International Board (SGEI). Furthermore, Lauter and Prokopczuk (2022) explore the correlation between liquidity and price efficiency measures; however, our study delves deeper into the influence of participation of FPI on price discovery and market efficiency, utilizing metrics such as Information Share, Component Share, and variance ratio.

The significance of our study is highlighted by the historical segmentation of the Indian commodity futures market until September 29, 2022. Additionally, within India's distinct and evolving regulatory landscape for commodities, the involvement of foreign investors holds promise for improving market quality. Our research stands out by offering first-hand empirical evidence on the impact of internationalization on market quality, with implications for market regulators and participants. We suggest extending FPI participation to agricultural commodity derivatives, accompanied by robust monitoring mechanisms, based on the observed empirical evidence of a positive association between FPI inclusion and enhanced liquidity, and improved price discovery. Market players can derive valuable insights from our study to make informed investment and risk management decisions amidst evolving market conditions and regulatory landscape. We emphasize the importance of leveraging the increased liquidity and decreased volatility associated with FPI engagement in non-agricultural Exchange-Traded Commodity Futures. From a governmental standpoint, policymakers may see these positive outcomes as beneficial for economic growth and global market integration. While continued policy support for FPI participation initiatives may be considered, caution is advised to address potential risks linked to heightened global integration. Policymakers must remain vigilant, monitoring any adverse effects on the stability of the domestic market and implementing responsive measures to ensure sustained development and resilience in the commodity futures market.

8 Conclusion

Our study examines the impact of SEBI's September 2022 regulation, which allows Foreign Portfolio Investors (FPIs) to trade in exchange-traded Commodity Futures in India, on market quality attributes such as liquidity, volatility, price discovery, and price efficiency. We apply the difference-in-differences (DiD) method to asses the impact of the regulation on market quality. Our findings indicates that post-regulation there is an improvement in liquidity, whereas there is no significant change in volatility. DiD model results for -180 to -91, and 91 - 180 days pre and post regulation indicate a 0.696 Standard Deviation decrease in average illiquidity for treated commodities compared to the control group following FPI involvement. Our results are robust after controlling for Trade volume, Open interest, Days till maturity, spot volatility, and fixed time and commodity effects. Furthermore, the research explores the influence of the inclusion of FPI on price discovery. Our empirical analysis finds that the commodity futures prices capture more information share and component share post-regulation, leading the spot market prices. Also, the variance ratio test shows that post-regulation FPI participation improves price efficiency. Further, Placebo test confirm the robustness of our results. It seems that the improvement in liquidity would attract more institutional investors which will further improve the quality of the market. Our findings have significant policy implications as it may contribute to resolving the ongoing debate within the Indian commodity market on the potentially destabilizing effect of FPI participation.

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Table 1: **Descriptive Statistics ± 180 Days from Regulatory Change : 29-Sep-2022**

		TREATMENT							CONTROL	
Statistics	Measures	ALUMINIUM	COPPER	CRUDEOIL	GOLD	LEAD	NATURALGAS	SILVER	MENTHAOIL	COTTON
P25	Amihud Price Impact	0.997	0.419	0.175	0.437	1.970	0.185	0.288	17.800	5.340
	Microstructure Noise	0.006	0.005	0.010	0.003	0.003	0.017	0.006	0.004	0.006
	GK Volatility	0.806%	0.743%	1.590%	0.416%	0.453%	2.910%	0.827%	0.550%	0.924%
	Meilijson Volatility	0.557%	0.506%	1.090%	0.259%	0.317%	2.060%	0.531%	0.403%	0.537%
Mean	Amihud Price Impact	2.60	1.06	0.47	1.48	5.50	0.53	0.66	43.00	36.70
	Microstructure Noise	0.011	0.009	0.019	0.005	0.006	0.030	0.010	0.007	0.011
	GK Volatility	1.280%	1.040%	2.300%	0.617%	0.704%	3.830%	1.180%	0.888%	1.370%
	Meilijson Volatility	1.330%	1.040%	2.350%	0.597%	0.710%	4.280%	1.150%	0.926%	1.380%
Median	Amihud Price Impact	1.960	0.791	0.395	0.952	4.270	0.385	0.601	36.800	14.600
	Microstructure Noise	0.009	0.008	0.017	0.004	0.005	0.029	0.009	0.006	0.009
	GK Volatility	1.090%	0.943%	2.090%	0.557%	0.606%	3.720%	1.080%	0.801%	1.190%
	Meilijson Volatility	0.981%	0.787%	1.740%	0.441%	0.554%	3.310%	0.855%	0.738%	1.050%
p75	Amihud Price Impact	3.420	1.490	0.666	1.690	8.050	0.726	0.861	61.300	38.100
	Microstructure Noise	0.0136	0.0111	0.0253	0.00603	0.00739	0.0401	0.0129	0.00942	0.0155
	GK Volatility	1.490%	1.200%	2.800%	0.715%	0.852%	4.460%	1.420%	1.110%	1.730%
	Meilijson Volatility	1.700%	1.300%	3.020%	0.755%	0.890%	5.340%	1.510%	1.160%	1.790%

Table 1. reports summary statistics for commodity-wise liquidity and volatility measures for 180 Days pre-and post the regulatory change date of September 29th, 2022. We employ two liquidity measures - the Microstructure Noise measure to estimate bid-ask spreads and the Amihud Illiquidity measure to proxy transaction costs. Similarly, we use the Garman & Klass Estimator and Meilijson Volatility estimator to estimate the price volatility of commodity futures using high, low, opening, and closing prices.

Table 2: **Commodity Wise Measures: pre and post ± 90 Days from Regulatory Change : 29-Sep-2022**

		TREATMENT							CONTROL	
MEASURES		ALUMINIUM	COPPER	CRUDE OIL	GOLD	LEAD	NATURAL GAS	SILVER	MENTHAOIL	COTTON
AMIHUD LIQUIDITY	PRE	1.736	0.784	0.331	0.94	4.870	0.513	0.581	34.272	34.100
	POST	1.292	0.689	0.426	0.793	4.080	0.431	0.558	34.106	25.700
	DIFF.	-25.55%	-12.10%	22.40%	-15.64%	-16.22%	-15.98%	-3.96%	-0.48%	32.68%
MICROSTRUCTURE NOISE	PRE	9.604	8.897	19.998	4.430	6.450	33.600	9.150	6.949	10.2
	POST	9.564	7.173	16.552	4.060	4.890	29.600	9.140	5.515	7.85
	DIFF.	-0.42%	-19.38%	-17.23%	-8.35%	-24.19%	-11.90%	-0.11%	26.00%	29.94%
GARMAN AND KLASS	PRE	1.154%	1.149%	2.384%	0.527%	0.739%	4.000%	1.130%	0.837%	1.410%
	POST	1.181%	0.925%	1.959%	0.494%	0.581%	3.960%	1.120%	0.683%	1.350%
	DIFF.	2.29%	-19.47%	-17.84%	-6.26%	-21.38%	-1.00%	-0.88%	-22.56%	-4.26%
MEILIJSON EXTIMATOR	PRE	1.080%	1.061%	1.935%	0.470%	0.668%	3.360%	0.952%	0.760%	1.270%
	POST	1.100%	0.742%	1.704%	0.364%	0.466%	3.670%	0.840%	0.641%	1.280%
	DIFF.	-1.83%	-30.03%	-11.94%	-22.55%	-30.24%	9.23%	-11.76%	-18.69%	0.79%
INFORMATION SHARE	PRE	0.896	0.595	0.878	62.06%	72.03%	78.49%	77.62%	30.81%	43.29%
	POST	0.999	0.781	0.944	77.38%	77.19%	84.96%	89.51%	23.78%	37.02%
	DIFF.	11.60%	31.14%	7.42%	24.69%	7.16%	8.24%	15.32%	-22.82%	-14.48%
COMPONENT SHARE	PRE	0.900	0.608	0.620	71.13%	78.44%	64.32%	79.97%	32.40%	39.82%
	POST	0.961	0.734	0.792	83.96%	82.36%	68.91%	82.50%	22.11%	26.83%
	DIFF.	6.74%	20.80%	27.84%	18.04%	5.00%	7.14%	3.16%	-31.76%	-32.62%

Table 2. illustrates the liquidity, volatility, and price discovery metrics for each of the ten commodities corresponding to Scenario 1 that encompasses both pre- and post-90 days following the regulatory change. Additionally, the table presents the results for the difference between the pre- and post-period. Specifically, the table provides results for liquidity metrics: Amihud Illiquidity and Microstructure Noise, as well as volatility measures: Garman and Klass and the Meilijson volatility estimator. Furthermore, the analysis includes price discovery measures: Information Share and Component Share.

Table 3: **Difference-in-Differences Analysis: Amihud Illiquidity measure**

	Dep. variable: Amihud Illiquidity		
	(1)	(2)	(3)
Treat * POST	-0.0917	-0.454*	-0.696***
	(0.267)	(0.155)	(0.0105)
Lagged Trade volume	0.099	0.0305	-0.0072
	(0.081)	(0.0384)	(0.0124)
Contract Value	-0.213	-0.354	-0.059
	(0.252)	(0.261)	(0.043)
Days Till Maturity	0.133	0.097	0.00437
	(0.108)	(0.0795)	(0.0259)
Spot Volatility	0.0236	0.0229	0.0047
	(0.0165)	(0.013)	(0.0055)
Observations	1591	3,112	1,521
Commodity FE	YES	YES	YES
Time FE	YES	YES	YES
R^2	0.422	0.447	0.626
Adjusted R^2	0.343	0.373	0.572
F-Statistic	5.325***	5.967***	11.6***

Table 3. presents the outcomes of the applied difference-in-differences model for the three scenarios, i.e., ± 90 Days, ± 180 Days, and ± 91-180 Days, when considering the Amihud Illiquidity measure. The results offer valuable insights into the impact of the treatment on the change in liquidity.

$$\text{ILLQ}_{i,t} = \beta_1 \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \text{TradeVolume}_{i,t-1} + \beta_3 \text{ContractValue}_{i,t} + \beta_4 \text{DTM}_{i,t} + \beta_5 \text{SpotVolt}_{i,t} + \gamma_{commodity} + \delta_t + \epsilon_{i,t}$$

"Post" is an indicator variable taking the value of 1 for days following the regulatory change and 0 for days preceding the regulatory change, while"Treat" is a dummy variable assigned the value of 1 for Non-Agricultural Commodities and 0 for Agricultural Commodities. $\gamma_{commodity}$ is used to capture the commodities-fixed effects. δ_t is used to capture the time-fixed effects. The interaction term ("Post" * "Treat") acts as the difference-in-differences estimator. Control variables encompass lagged Trade Volume, Contract Value, VIX, Days Till Maturity, and Spot Volatility. The standard errors are double-clustered and are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01

Table 4: **Difference-in-Differences Analysis: Microstructure Noise measure**

	Dep. variable: Microstr. Noise		
	(1)	(2)	(3)
Treat * POST	0.0114	-0.061	-0.131***
	(0.072)	(0.069)	(0.0104)
Lagged Trade volume	-0.118***	-0.0003	0.094
	(0.019)	(0.0601)	(0.072)
Contract Value	-0.033	0.0043	0.106*
	(0.043)	(0.0399)	(0.0452)
Days Till Maturity	0.0113	0.011	0.018
	(0.023)	(0.0095)	(0.018)
Spot volatility	0.077***	0.152***	0.214**
	(0.011)	(0.026)	(0.042)
Observations	1,591	3,112	1,521
Commodity FE	YES	YES	YES
Time FE	YES	YES	YES
R^2	0.594	0.576	0.581
Adjusted R^2	0.538	0.519	0.521
F-Statistic	10.66***	8.201***	9.601***

Table 4. presents the outcomes of the difference-in-differences model for three scenarios, i.e., ± 90 Days, ± 180 Days, and ± 91-180 Days, when considering the Microstructure Noise measure. The results offer insights into the association between the treatment and the liquidity changes.

$$\text{ILLQ}_{i,t} = \beta_1 \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \text{TradeVolume}_{i,t-1} + \beta_3 \text{ContractValue}_{i,t} + \beta_4 \text{DTM}_{i,t} + \beta_5 \text{SpotVolt}_{i,t} + \gamma_{commodity} + \delta_t + \epsilon_{i,t}$$

"Post" is an indicator variable taking the value of 1 for days following the regulatory change and 0 for days preceding the regulatory change, while"Treat" is a dummy variable assigned the value of 1 for Non-Agricultural Commodities and 0 for Agricultural Commodities. $\gamma_{commmodity}$ is used to capture the commodities-fixed effects. δ_t is used to capture the time-fixed effects. The interaction term ("Post" * "Treat") acts as the difference-in-differences estimator. Control variables encompass lagged Trade Volume, Contract Value, VIX, Days Till Maturity, and Spot Volatility. The standard errors are double-clustered and are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01

Table 5: **Difference-in-Differences Analysis: Garman and Klass measure**

	Dep. variable: GK Volatility		
	(1)	(2)	(3)
Treat * POST	-0.018	-0.056	-0.087
	(0.053)	(0.08)	(0.109)
Trade Volume	0.828***	0.312**	0.31*
	(0.099)	(0.0812)	(0.093)
Open Interest	0.011	-0.0815**	-0.01
	(0.029)	(0.023)	(0.024)
Days Till Maturity	0.006	0.0226	0.033
	(0.0197)	(0.0117)	(0.02)
Spot volatility	0.023	0.122***	0.213***
	(0.015	(0.018)	(0.026)
Observations	1,591	3,112	1,521
Commodity FE	YES	YES	YES
Time FE	YES	YES	YES
R^2	0.777	0.748	0.768
Adjusted R^2	0.747	0.714	0.735
F-Statistic	25.45***	21.86***	22.91***

Table 5. presents the outcomes of the difference-in-differences model for the three scenarios, i.e., ± 90 Days, ± 180 Days, and ± 91-180 Days, when considering the Garman and Klass Volatility measure. The results offer insights into the relationship between the treatment and volatility changes.

$\text{VOLT}_{i,t} = \beta_1 \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \text{TradeVolume}_{i,t} + \beta_3 \text{OpenInterest}_{i,t} + \beta_4 \text{DTM}_{i,t} + \beta_5 \text{SpotVolt}_{i,t} + \gamma_{commodity} + \delta_t + \epsilon_{i,t}$

"Post" is an indicator variable taking the value of 1 for days following the regulatory change and 0 for days preceding the regulatory change, while "Treat" is a dummy variable assigned the value of 1 for Non-Agricultural Commodities and 0 for Agricultural Commodities. $\gamma_{commodity}$ is employed to capture the commodities-fixed effects. δ_t is used to capture the time-fixed effects. The interaction term ("Post" * "Treat") acts as the difference-in-differences estimator. Control variables include Trade Volume, Open Interest, Days Till Maturity of the futures contract, and Spot Volatility. The standard errors are double-clustered and are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01

Table 6: **Difference-in-Differences Analysis: Meilijson Volatility measure**

	Dependent variable: Meilijson Volatility		
	(1)	(2)	(3)
Treat * POST	-0.069	0.078	-0.057
	(0.04)	(0.077)	(0.006)
Trade Volume	0.818***	0.120	0.089
	(0.093)	(0.078)	(0.086)
Open Interest	-0.202**	0.014	-0.060**
	(0.057)	(0.017)	(0.021)
Days Till Maturity	-0.0004	0.01	0.011
	(0.016)	(0.013)	(0.02)
Spot volatility	0.019	0.132***	0.235***
	(0.027)	(0.019)	(0.046)
Observations	1,591	3,112	1,521
Commodity FE	YES	YES	YES
Time FE	YES	YES	YES
R^2	0.516	0.480	0.508
Adjusted R^2	0.45	0.409	0.437
F-Statistic	7.78***	6.774***	7.14***

Table 6. presents the outcomes of the difference-in-differences model for the three scenarios, i.e., ± 90 Days, ± 180 Days, and ± 91-180 Days, when considering the Meilijson Volatility measure. The results offer insights into the association between the treatment and the volatility changes.

$$\text{VOLT}_{i,t} = \beta_1 \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \text{TradeVolume}_{i,t} + \beta_3 \text{OpenInterest}_{i,t} + \beta_4 \text{DTM}_{i,t} + \beta_5 \text{SpotVolt}_{i,t} + \gamma_{commodity} + \delta_t + \epsilon_{i,t}$$

"Post" is an indicator variable taking the value of 1 for days following the regulatory change and 0 for days preceding the regulatory change, while "Treat" is a dummy variable assigned the value of 1 for Non-Agricultural Commodities and 0 for Agricultural Commodities. $\gamma_{commodity}$ is employed to capture the commodities-fixed effects. δ_t is used to capture the time-fixed effects. The interaction term ("Post" * "Treat") acts as the difference-in-differences estimator. Control variables include Trade Volume, Open Interest, Days Till Maturity of the futures contract, and Spot Volatility. The standard errors are double-clustered and are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01

Table 7: **Price Discovery Measures**

			TREATMENT							CONTROL	
SCENARIOS	MEASURES		ALUMINIUM	COPPER	CRUDE OIL	GOLD	LEAD	NATURAL GAS	SILVER	MENTHAOIL	COTTON
± 90 Days	INFORMATION SHARE	PRE	0.896%	0.595%	0.878%	62.06%	72.03%	78.49%	77.62%	30.81%	43.29%
		POST	0.999%	0.781%	0.944%	77.38%	77.19%	84.96%	89.51%	23.78%	37.02%
		DIFF.	11.60%	31.14%	7.42%	24.69%	7.16%	8.24%	15.32%	-22.82%	-14.48%
	COMPONENT SHARE	PRE	0.900%	0.608%	0.620%	71.13%	78.44%	64.32%	79.97%	32.40%	39.82%
		POST	0.961%	0.734%	0.792%	83.96%	82.36%	68.91%	82.50%	22.11%	26.83%
		DIFF.	6.74%	20.80%	27.84%	18.04%	5.00%	7.14%	3.16%	-31.76%	-32.62%
± 180 days	INFORMATION SHARE	PRE	86.575%	58.026%	93.151%	83.750%	81.930%	82.340%	78.320%	77.851%	18.980%
		POST	97.344%	97.344%	94.751%	91.840%	82.870%	97.700%	81.170%	66.639%	12.420%
		DIFF.	12.44%	67.76%	1.72%	9.66%	1.15%	18.65%	3.64%	-14.40%	-34.56%
	COMPONENT SHARE	PRE	87.010%	54.215%	63.307%	79.040%	89.390%	76.040%	64.280%	78.454%	37.560%
		POST	94.506%	94.506%	93.060%	88.940%	95.250%	87.510%	69.270%	63.149%	32.350%
		DIFF.	8.62%	74.32%	47.00%	12.53%	6.56%	15.08%	7.76%	-19.51%	-13.87%
± 91 to 180 Days	INFORMATION SHARE	PRE	80.624%	87.451%	79.461%	84.020%	69.390%	86.300%	68.972%	79.461%	67.990%
		POST	85.023%	74.762%	94.752%	95.890%	87.720%	99.920%	78.251%	46.260%	49.380%
		DIFF.	5.46%	-14.51%	19.24%	14.13%	26.42%	15.78%	13.45%	-41.78%	-27.37%
	COMPONENT SHARE	PRE	77.259%	81.816%	54.866%	81.110%	89.430%	91.830%	71.090%	54.866%	48.294%
		POST	92.408%	86.683%	87.117%	94.320%	94.340%	99.470%	83.490%	12.883%	52.397%
		DIFF.	19.61%	5.95%	58.78%	16.29%	5.49%	8.32%	17.44%	-76.52%	8.50%

Table 7. presents the average price discovery measures for the examined commodities examined across the three scenarios, i.e., ± 90 Days, ± 180 Days, and ± 91-180 Days. It provides the average Information Share and Component Share of Futures prices for seven treated commodities and three non-treated commodities. The Information Share measure assesses the variance of efficient price innovation and identifies the proportion attributed to innovations from different markets, encompassing both permanent and temporary shocks. Conversely, the Component Share measure evaluates each market's contribution to the common factor, predominantly reflecting the impact of temporary shocks.

Table 8: **Price Efficiency - variance ratio analysis**

	± 90 Days		± 180 Days		± 91 - 180 Days	
COMMODITIES	PRE	POST	PRE	POST	PRE	POST
ALUMINIUM	0.627	0.729	0.793	1.141	0.869	0.934
COPPER	0.972	0.996	0.909	1.084	1.053	1.033
CRUDE OIL	0.573	1.140	1.087	1.047	0.925	1.075
GOLD	0.568	0.776	0.751	0.852	0.700	0.808
LEAD	0.584	0.778	0.573	0.606	0.617	0.882
NATURAL GAS	0.887	1.110	0.897	1.013	0.913	1.091
SILVER	0.943	1.048	1.200	1.082	1.099	1.073
MENTHAOIL	0.711	0.640	0.844	0.629	0.944	1.162
COTTON	0.611	0.387	0.387	0.326	0.487	0.326

Table 8. provides the average variance ratios associated with treated and untreated commodities before and after September 29, 2022. The variance Ratio is given by:

$$\text{Variance Ratio} = \frac{\text{Variance of 5-Day Returns over pre-period}}{5 * \text{Variance of 1-Day Returns over post-period}}$$

This ratio is expected to be closer to one in more efficient markets. Prices of assets with low market efficiency may exhibit greater volatility, i.e., more transitory changes between the periods in which the equilibrium price is changing. Inaccurate Price Discovery is responsible for excessive volatility in a shorter period. The prices of assets with high market resilience are expected to exhibit lower volatility (less transitory changes) between periods in which the equilibrium price is changing.

Table 9: **Robustness Test for Liquidity measures**

	± 90 Days		± 180 Days		± 91 to 180 Days	
	Amihud	Microstr. Noise	Amihud	Microstr. Noise	Amihud	Microstr. Noise
	(1)	(2)	(3)	(4)	(5)	(6)
Treat * POST	0.083	0.115	0.802	0.0925	1.478	0.033
	(0.056)	(0.206)	(0.600)	(0.186)	(1.129)	(0.190)
Lagged Trade Volume	-0.0004	0.026	-0.012	-0.0254	0.0021	-0.064
	(0.0019)	(0.0348)	(0.012)	(0.037)	(0.0073)	(0.036)
Contract Value	-0.0117	-0.160*	0.05	-0.0102	0.078	0.096
	(0.007)	(0.065)	(0.037)	(0.074)	(0.087)	(0.068)
Days Till Maturity	0.016	-0.055	-0.038	-0.029*	-0.08	-0.008
	(0.014)	(0.03)	(0.037)	(0.0107)	(0.068)	(0.023)
Spot Volatility	0.0012	0.124****	-0.023	0.194***	-0.014	0.253***
	(0.00123)	(0.020)	(0.027)	(0.019)	(0.023)	(0.190)
Observations	1,579	1,579	3,185	3,185	1,606	1,606
Commodity FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
R^2	0.535	0.478	0.235	0.484	0.300	0.502
Adjusted R^2	0.471	0.407	0.135	0.416	0.200	0.435
F-Statistic	8.401***	6.699***	2.341***	7.134***	3.149***	7.424***

Table 9. presents the results of the difference-in-differences model across three-time windows pre- and post- a hypothetical date of regulatory change implementation, i.e, 29th September, 2021, as opposed to the actual implementation date of 29th September 2022. This analysis focuses on the liquidity measures, namely the Amihud Illiquidity and Microstructure Noise Measure.

$$\text{ILLQ}_{i,t} = \beta_1 \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \text{TradeVolume}_{i,t-1} + \beta_3 \text{ContractValue}_{i,t} + \beta_4 \text{DTM}_{i,t} + \beta_5 \text{SpotVolt}_{i,t} + \gamma_{commodity} + \delta_t + \epsilon_{i,t}$$

"Post" is an indicator variable taking the value of 1 for days following the regulatory change and 0 for days preceding the regulatory change), while "Treat" is a dummy variable assigned the value of 1 for Non-Agricultural Commodities and 0 for Agricultural Commodities. The interaction term ("Post" * "Treat") acts as the difference-in-differences estimator.$\gamma_{commodity}$ is employed to capture the commodities-fixed effects. δ_t is used to capture the time-fixed effects. Control variables include lagged Trade Volume, Contract Value, VIX, Days Till Maturity, and Spot Volatility. The standard errors are double-clustered and are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01

Table 10: **Robustness Test for Volatility measures**

	± 90 Days		± 180 Days		± 91 to 180 Days	
	Garman Klass	Meilijson	Garman Klass	Meilijson	Garman Klass	Meilijson
	(1)	(2)	(3)	(4)	(5)	(6)
Treat * POST	0.188	0.135	0.11	0.105	0.011	0.060
	(0.25)	(0.16)	(0.196)	(0.133)	(0.282)	(0.22)
Trade Volume	0.283***	0.079	0.167	0.077	0.102	0.08
	(0.048)	(0.07)	(0.06)	(0.053)	(0.065)	(0.058)
Open Interest	-0.343*	-0.276*	-0.240	-0.212	0.159	-0.158
	(0.13)	(0.115)	(0.152)	(0.128)	(0.208)	(0.151)
Days Till Maturity	-0.024	-0.012	-0.001	0.009	0.007	0.019
	(0.046)	(0.016)	(0.012)	(0.0088)	(0.033)	(0.020)
Spot Volatility	0.208	0.23**	0.254***	0.225***	0.28***	0.21
	(0.025)	(0.053)	(0.016)	(0.017)	(0.025)	(0.029)
Observations	1,579	1,579	3,185	3,185	1,606	1,606
Commodity FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
R^2	0.692	0.432	0.645	0.414	0.627	0.407
Adjusted R^2	0.649	0.354	0.599	0.337	0.577	0.326
F-Statistic	16.37***	5.56***	13,84***	5.38***	12.41***	5.049***

Table 10. presents the outcomes of the difference-in-differences model across three-time windows before and after a hypothetical date of regulatory change implementation, i.e., 29th September, 2021, as opposed to the actual implementation date of 29th September 2022. This analysis focuses on the volatility measures, namely Garman and Klass Volatility and Meilijson Volatility measures.

$$\text{VOLT}_{i,t} = \beta_1 \text{Treat}_{Commodity} \times \text{Post}_t + \beta_2 \text{TradeVolume}_{i,t} + \beta_3 \text{OpenInterest}_{i,t} + \beta_4 \text{DTM}_{i,t} + \beta_5 \text{SpotVolt}_{i,t} + \gamma_{commodity} + \delta_t + \epsilon_{i,t}$$

"Post" is an indicator variable taking the value of 1 for days following the regulatory change and 0 for days preceding the regulatory change, while "Treat" is a dummy variable assigned the value of 1 for Non-Agricultural Commodities and 0 for Agricultural Commodities. The interaction term ("Post" * "Treat") acts as the difference-in-difference estimator. $\gamma_{commodity}$ is employed to capture the commodities-fixed effects. δ_t is used to capture the time-fixed effects. Control variables include Trade Volume, Open Interest, Days Till Maturity, and Spot Volatility. The standard errors are double-clustered and are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01

Appendix

A.1 Number of observations for each commodity for each Scenario

	Observations		
Commodities	Scenario 1 (± 90 Days)	Scenario 2 (± 180 Days)	Scenario 3 (± 91-180 Days)
ALUMINIUM	180	360	180
COPPER	180	360	180
CRUDEOIL	180	360	180
GOLD	180	360	180
LEAD	180	360	180
NATURALGAS	180	360	180
SILVER	180	360	180
MENTHAOIL	175	346	171
COTTON	156	246	90
Total Obs.	1591	3112	1521

Table A. 1: Number of observations for each commodity

Table A. 2: Description of Variables

Variable	**Description**	**Formulation**
Amihud Illiquidity	It measures the illiquidity of a stock based on the price impact of trading activity.	Absolute return of futures i at time t scaled by the volume of futures contracts traded for that commodity at time t
Microstructure Noise	It captures the short-term price fluctuations of Futures seen during a trading day, including intra-day highs and lows that may reverse within the same day.	Numerator is the difference between the divergence between the highest (H) and the lowest prices (L) and the absolute difference between the closing (C) and opening prices (O) observed in a trading day, whereas the denominator is the closing Futures price.
Garman and Klass	It estimates the daily volatility of the futures based on their high, low, open, and close prices.	The first term is the squared difference between the high and low prices, multiplied by 0.511. The next term is 0.019 times the difference between - the product of the closing price and the sum of the high and low prices & twice the product of the high and low prices. The third term is 0.383 times the square of the closing futures price. Then we subtract the third and the second term from the first and find the square root of the result to arrive at the Garman-Klass volatility Measure.
Meilijson Volatility	It estimates the volatility of futures prices, incorporating the opening, closing, and lowest prices of each trading day.	It is calculated as the square root of the sum of four components: $\sigma^2_{1_i}$, $\sigma^2_{2_i}$, $\sigma^2_{3_i}$, and $\sigma^2_{4_i}$, each derived from the adjusted prices to estimate the volatility of the commodity. $\sigma_{1}{}_i^2 = 2(h_i^{'} - c_i^{'})^2 + l_i^{'2}, \quad \sigma_{2}{}_i^2 = c_i^{'2}, \quad \sigma_{3}{}_i^2 = 2(h_i^{'} - c_i^{'} - l_i^{'})c_i^{'}, \quad \sigma_{4}{}_i^2 = -\frac{(h_i^{'} - c_i^{'})l_i^{'}}{2ln2 - \frac{5}{4}}$ where, H_i, L_i, C_i, and O_i represent the daily high, low, close, and open prices, respectively, for each commodity i during a day. c_i, h_i, and l_i are the logarithmic differences of the close, high, and low prices from the open futures price. $c_i^{'}$, $h_i^{'}$, and $l_i^{'}$ are adjusted logarithmic differences: they equal c_i, h_i, and l_i if c_i is greater than 0; otherwise, they equal the negative of c_i, h_i, and l_i respectively. Refer to Equation 6 for the formula.
Information Share	The Information Share (IS) metric measures the information content for a commodity traded across futures and spot markets.	This can be achieved using the `pdshare` function in R software. The function takes a matrix of (log) prices of spot and futures prices as input and returns the IS measure. The `pdshare` function returns a list of five elements: 'is.original.ordering', 'is.reversed.ordering', 'component.share', 'var.covar.matrix', and 'lags used'. The IS measure is calculated by averaging the values of 'is.original.ordering' and 'is.reversed.ordering'
Component Share	This metric quantifies how much each market contributes to the response of common factors.	This can be implemented using the `pdshare` function in R software. The function consumes a matrix of (log) spot and futures prices and returns CS measure. The `pdshare` function returns a list of five elements: 'is.original.ordering', 'is.reversed.ordering', 'component.share', 'var.covar.matrix', and 'lags used'. The CS measure is given by the 'component.share' value
Variance Ratio	Variance ratios assess market efficiency by measuring the relative variability of returns over different periods.	The Variance Ratio is calculated as the ratio of the variance of 5-day returns over pre-period to five times the variance of 1-day returns over post-period.