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RESEARCH

Effect of commodity transaction tax on the intraday liquidity of futures: emerging market scenario

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This paper examines intraday liquidity dynamics during the onset of commodity transaction tax (CTT) in the Indian futures market. The data analyzed comprises non-agricultural Indian commodity futures contracts from 2013 to 2014. From the analysis, we observe that changes associated with spread-based liquidity measures in commodity markets are significant post-CTT, but the direction of the impact is mixed. However, there is a distinct decline in market depth post-CTT uniformly across all commodities. Furthermore, a visual examination of the liquidity patterns before and after CTT shows that the "U shape" pattern common to intraday stock spread is absent in the commodity futures market. We conclude that spreads are unable to capture implicit transaction costs in the short term, while depth declines post-CTT, supporting Amihud's view that tax hinders market participation. Currently, studies examining emerging market liquidity, specifically in the context of intraday futures and taxation, are almost non-existent. Our study suggests policymakers exert caution while measuring the impact of transaction taxes using intraday liquidity measures.

Keywords: commodity markets, futures, liquidity, transaction tax, emerging markets, derivatives

JEL Classification Code: G18, G28, Q02, G12, G15

Introduction

Liquidity and its interplay with transaction costs have gained a prominent status in financial studies over the years. In developing economies, liquidity is a key component of the pricing structure of financial instruments as well as overall market quality. Liquidity reflects the level of market participation, while transaction cost aims at reducing excessive trades. Intraday measures of liquidity form an interesting topic; according to Meyer et al. (1), intraday measures often fail to capture higher implicit costs in the short term. Hence, it is interesting to examine distortion in intraday liquidity due to the introduction of transaction costs. Three main arguments illustrate the importance of examining movements in liquidity due to transaction costs. Firstly, increasing transaction costs in the commodity markets translates to investors demanding higher premiums for improving their net gains—recorded in the literature as the cost of illiquidity (2, 3). Secondly, market quality is regulated by liquidity, which in turn is governed by demand/supply dynamics. This tax-induced liquidity reduction in the markets can either improve the quality of the market because of lowered short-term speculative trades (4–6) or deteriorate the market quality by lowering participation in the markets, affecting the price-discovery process (7–10). The risk of illiquidity in the face of higher transaction costs increases volatility (11, 12), which adversely

affects the price discovery process, influencing the market quality. Thirdly, illiquidity impacts the investment horizon of portfolio managers. Increased illiquidity lengthens the holding period of an asset to realize gains as well as to offset higher transaction costs (13). It is clear from the aforementioned reasons that stabilizing liquidity in the market is relevant for regulatory authorities. Additionally, liquidity is a pertinent factor when conceiving financial policies. However, in 2013, India introduced a commodity transaction tax (CTT)—a type of transaction cost for non-agricultural futures into the market, visibly reducing the trading volumes in the markets as depicted in **Figure 1**. The case of the onset of transaction taxes in India provides the perfect opportunity to examine the consequences of a transaction tax on market liquidity.

Market microstructure researchers thoroughly debate studies analyzing the impact of transaction costs on market liquidity. Transaction taxes were first proposed by Keynes (14) to curb short-term speculative trades; however, the impact of transaction taxes in practice is quite complex. Extant literature predominantly focuses on two main inferences regarding the impact of taxation on prevailing market liquidity. One states that transaction tax hinders liquidity, while the other states that transaction costs have no impact on liquidity. However, the mechanism behind this impact varies.

There are several theories analyzing the adverse impact of transaction costs on liquidity levels in the market. Amihud's theory posits that any transaction cost is friction and hinders investor participation in the markets by increasing the cost of investment (13), leading to a reduction in overall trading volumes. Another view stated by Umlauf states that transaction costs lead to investor migration to tax-free markets or other alternatives (15, 16), leading to an increase in illiquidity. Advocates of transaction tax state that it is an effective method to reduce short-term speculative trades (5, 14, 17). Stiglitz's argument implicitly assumes that short-term speculative trades are destabilizing and must be reduced using a transaction tax to improve market quality. Thus, the cost associated with the loss of turnover due to the tax is offset by improved market quality. A few studies (18–20) also find that the tax has no impact on the overall liquidity of the market. According to Bloomfield, transaction tax has no significant impact on prevailing liquidity as efficient markets recover from shocks. Hence, post-taxation liquidity reduction is temporary, and the market bounces back to its original state. Alternatively, Galvani and Ackman (20) conclude that as noise traders exit the market, there is no impact on Amihud's liquidity. Apart from the theories examining the impact of transaction tax on liquidity, it is also pertinent to focus on the method of measuring liquidity, as this affects the nature of conclusions drawn from the studies.

Several studies measure liquidity using trading activity-based measures, i.e., trading volume and turnover ratios. We have provided a brief snapshot of empirical studies in **Table 1**. These studies conclude that liquidity has reduced post-taxation (7, 21). Meyer et al. (1) use intraday data and find a decline in depth and volume for 40 days before and after tax. In Euronext Paris, volume is found to decline by 18% and on Chi-X by 26%, whereas the traded contracts decline by 19% and 14%, respectively. A plethora of studies also use spread-based measures of liquidity. Colliard and Hoffmann (22) state that both quoted and effective spreads increase, whereas depth declines post-taxation for 109 trading days in France for intraday data. Gomber et al. (23) find similar results for daily data from France; they state that post-taxation depth declines and relative spreads increase. Their study covers different periods ranging from 10 days to 6 months before and after tax. The Italy-based study by Hvozdyk and Rustanov (24) finds evidence of reduced liquidity due to increased daily spreads two months before and after taxation. Similarly, results are recorded by Cappelletti et al. (25) concerning spreads using daily data for two time periods (6 and 12 months) before and after tax. Rühl and Stein (26) observe a 1.73% increase in spreads post-taxation in Italy, which indicates decreased liquidity levels. The US-based study by Pomeranets and Weaver (12) also records reduced liquidity post-taxation measures using Roll spread and Holden spread for one year before and after tax using daily data. The Taiwan-based studies in the context of stock futures find liquidity declines post-taxation using both intraday data (21) and daily data (27) for a maximum period

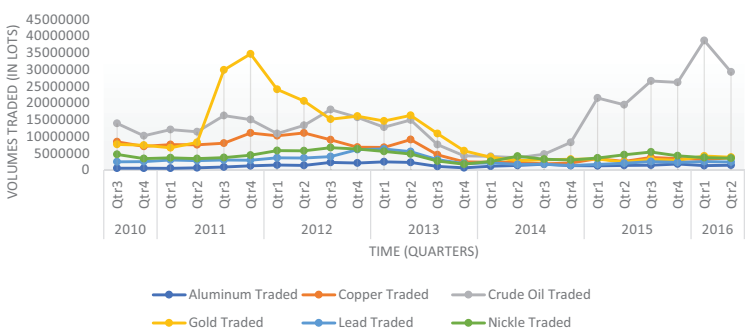

FIGURE 1 | This figure shows the changes in the volumes of aluminum, copper, crude oil, gold, lead, and nickel over time. There is a sharp decline in the traded volume in the year 2013 coinciding with the introduction of CTT.

TABLE 1 | An overview of literature on the effect of transaction cost/tax on market liquidity.

Author (year)	Sample country	Market	Type of cost	Effect of tax on liquidity measure
Pomeranets and Weaver (2018) (12)	France	Stock	Securities transaction tax	Bid-ask spread (+) Volume (-)
Baltagi et al. (2006) (7)	China	Stock	Stamp tax	Volume (-)
Becchetti et al. (2014) (18)	France	Stock	Securities transaction tax	Corwin-Schultz (CS) estimator (+) Turnover (-) Amihud ratio (-)
Capelle-Blancard and Havrylchyk (2016) (15)	France	Stock	Securities transaction tax	Spread (no impact) Price impact liquidity ratio (no impact)
Cappelletti et al. (2017) (25)	Italy	Stock	Securities transaction tax	Bid-ask spread (+)
Chung et al. (2003) (27)	Taiwan	Stock index futures	Securities transaction tax Reduction	Liquidity ratio (+)
Galvani and Ackman (2021) (20)	Italy	Stock	Financial transaction tax (FTT)	Bid-ask spread (+) Amihud ratio (no impact)
Gomber et al. (2016) (23)	France	Stock	Securities transaction tax	Relative spread (+) Depth (-)
Hvozdyk and Rustanov (2016) (24)	Italy	Stock	Securities transaction tax	Quoted spread (+) Relative quoted spread (+)
Irshad and Shanmugam (2016) (30)	India	Gold futures	Commodity transaction tax (CTT)	Bid-ask spread (+)
Rühl and Stein (2014) (26)	Italy	Stock	FTT	Quoted spreads (+) Volume (no impact)
Sahoo and Kumar (2011) (28)	India	Commodity Futures	CTT	Volume (-)
Sehgal and Agrawal (2019) (29)	India	Commodity Futures	CTT	Volume (-)
Umlauf (1993) (16)	Sweden	Stock	Securities transaction tax	Volume (-)
Colliard and Hoffmann (2017) (22)	France	Stock	FTT	Quoted spread (no impact) Effective spread (no impact) Realized spread (no impact) Price impact (no impact) Depth (-) Resiliency (-)
Bloomfield et al. (2009) (19)	Lab experiment	Stock	FTT	Volume (-) Depth (no impact) Spread (+) Price impact (no impact)
Frino et al. (2010) (37)	Europe	Carbon futures	Transaction costs reduction	Quoted spread (+) Relative spread (+) Depth (no impact)

-, indicates a negative impact; +, denotes a positive impact.

of one year before and after taxation. However, another set of studies contradicts these findings, these state that tax has no significant impact on liquidity (15, 19). Despite Cappelletti et al. (25) and Meyer et al. (1) finding evidence of increased spread (indicative of declining liquidity) post-taxation, they also record that the tax had no significant impact on the number of trades (volume) in their study. The study by Becchetti et al. (18) on the French markets uses both turnover ratios as well as spread measures for liquidity and finds inconclusive effects of the tax on liquidity. Similarly, Galvani and Ackman's (20) investigation on the Italian markets uses both spread and Amihud's measure and concludes that while spreads widen post-taxation, Amihud's measure remains unaltered. Evidence of no impact of tax on liquidity is also recorded by Capelle-Blancard and Havrylchyk (15) in France using daily trading value, turnover ratios, Corwin-Schultz (CS) spreads, and liquidity ratios for six months before and after taxation. There are few studies in India on CTT (2013) and its effect on liquidity using intraday data. Sahoo and Kumar (28) use ex-ante intraday data from 2006 to 2008 and forecast reduced liquidity post-CTT. Sehgal and Agrawal (29) use monthly data of turnover, traded volume, and Hiu-Hubel liquidity from 2011 to 2016 and conclude that liquidity will decline post-taxation. Irshad and Shanmugam (30) posit a decline in gold futures trading post-CTT using daily trading

value and volume from 2010 to 2016. In general, activity-based measures for liquidity using daily data are popular, but using intraday data is superior, as it provides greater insights into the trading patterns. The most prominent pattern with intraday liquidity data is the "U" shape, which is confirmed in the stock markets by Ahn and Cheung (31). The "U"-shaped pattern where the spread is highest as the trade day opens, declines during the day, and concludes by widening at the close. This pattern is also observed in the Indian stock futures market, as documented by Krishnan and Mishra (32); studies based on intraday commodity trading patterns predominantly focus on volatility and observe volatility clustering (33), but literature on liquidity/volume-based patterns is almost nonexistent. However, understanding patterns helps participants of the market to maintain inventory and deal with information asymmetry problems. A "reverse J" shaped pattern has also been observed when bid-ask spreads are plotted against time by McInish and Wood (34). A "reverse U" shaped pattern is also observed in some markets specifically for depth measures of liquidity, while others are observed to be stable throughout the day. It is interesting to note that the trading patterns are also associated with market microstructure, i.e., a quote-driven market exhibits the "U" shape pattern more often than an order-driven market. While order-driven markets have stable liquidity levels throughout the day.

Summarizing the literature survey, we observe three main gaps that our paper will address. First, the ambiguity in theoretical literature. While several studies find evidence of reduced liquidity due to transaction tax (1, 7, 15, 22–24), on the contrary, many studies also find that transaction tax has no impact on liquidity (18–20). Studies record a negative impact of taxation on liquidity due to the migration of traders/participants quitting the markets due to increased cost of capital (16, 35). Contrarily, no impact of tax is also recorded (19) based on the efficient market hypothesis, stating that shocks like taxation only have a temporary effect. Secondly, the existing literature on future trading and its liquidity is thin; the majority of the empirical literature is derived from examining the stock markets, but it is intriguing to note that commodities are vastly different compared to equity in several aspects highlighted in the study by Gorton and Geert Rouwenhorst (36), who found that the commodity futures returns were inversely correlated with stock returns; Frino et al. (37) examine carbon futures and transaction costs in Europe and strangely discover that cost reduction led to increased spreads due to information symmetry, unlike the stock markets. Commodities are also associated with inventory and storage costs, which are absent in stock markets. Global trends of supply and demand also impact trading in commodities, especially for crude oil and gold futures. Thirdly, only a handful of studies examine intraday data in the context of emerging markets. Studies based on CTT in India (28–30) use either ex-ante or daily or monthly data, while intraday evidence of the impact of CTT and shifting intraday trading patterns due to taxation of commodity markets is nonexistent. Predominantly, most of the literature on transaction taxes is also based on Italy, France, Sweden, and the United States. Based on the three arguments, we stipulate that the theoretical evidence of the impact of transaction tax on liquidity measures is ambiguous at best especially in the context of emerging markets and utilizing intraday measures. Hemmelgarn et al. (38) also highlights the need for empirical work in the field of transaction taxes while reviewing extant literature in the European Union. Consequently, this paper aims to analyze the effect of CTT on the prevailing liquidity in the market using intraday measures. We differ from the study by Sahoo and Kumar (28) by examining both pre- and post-event data while also examining intraday trading patterns pre- and post-taxation graphically for further insights. This allows us to capture liquidity dynamics closely and provide insights into liquidity patterns relevant for traders.

Thus, we formulate the null hypothesis:

> Hypothesis $1_{(0)}$: The transaction tax has no impact on market depth in the post-CTT period.
>
> Hypothesis $2_{(0)}$: The tax has no impact on spread measures in the post-CTT period measures.

Data and methodology

Our paper focuses on the effect of CTT on intraday liquidity measures. CTT was discussed in the Union Budget (2008–2009) for the first time and was formally introduced on 1^{st} July 2013 in India at the rate of 0.01% payable by sellers. CTT implementation was aimed to reduce speculative trading which in turn decreases the commodity market volatility resulting in market stability. CTT is analogous to Financial Transaction Tax (FTT) which is charged on stocks. The tax was also believed to be an effective way to increase the government's revenue base.

Sample data

The data is sourced from the Multi-Commodity Exchange in India (MCX). MCX is one of the top Indian commodity exchanges and provides a platform for trading commodity futures to market participants. Three-day intraday data was collected from both 2013 and 2014 and analyzed (1^{st}, 2^{nd}, and 3^{rd} of January from the years 2013 and 2014). The period from 2013 to 2014 was selected because this period sees a significant regulatory change in transaction costs, i.e., CTT, which impacts liquidity). Our study was subject to data availability; 2013–2014 intraday data was comprehensive and made available to us.

Each day provided transactions from 10:00 to 23:45 hours, which are the active hours for MCX, India. Also, as per

the regulations at MCX, the orders are matched based on price-time priority. Price conditions on an order placed by a trader lead to two types of orders, namely a limit order (investor desired price is set for executing an order) or a market order (prevailing market price is used to execute an order). Time conditions on an order placed by a trader also lead to four types of orders. These are—Day Order—this order lasts for a day; Good Till Cancelled (GTC)—this order lasts until the traded contract expires. Good Till Date—this order lasts until the date specified while placing the order, and Immediate or Cancelled (IOC)—the order is executed immediately or is cancelled. For the current analysis, both the trade and order books were used to construct a time series of intraday orders and their respective traded prices using a five-minute time interval.

The intraday data points were aggregated to give daily liquidity estimates for ease of interpretation. The contracts studied were copper futures, copper mini futures, crude oil futures, gold futures, gold petal futures, gold guinea futures, and gold mini futures. For further details refer to **Table 2**. These commodities represent the most liquid non-agricultural commodities in the national commodity exchanges of India. Among precious metals, gold futures are traded the most; in the case of base metals, copper futures are the most popular, and crude oil is the most traded contract in the case of energy futures.

The raw data was in the range of 100,000–200,000 data points for each commodity future per day. The orders were classified as buy or sell orders, which is defined by the trader; this data was available to us. This was aggregated into 5-minute intervals. Further, the trade and order book transactions were matched, and outliers (data points found outside of trading hours) were removed. Based on the matched data points from the trade and order book, liquidity measures for commodity futures were calculated.

TABLE 2 | The details of the quality specifications and the lot size of the sample futures contracts offered by Multi Commodity Exchange India.

Commodity future	Details
Multi-Commodity Exchange (MCX) copper	Grade 1 electrolytic, 1MT
MCX copper mini	Grade 1 electrolytic, 250 kg
MCX crude oil	Light sweet crude oil 100 barrels
MCX gold	995 and 999 purity 1 kg
MCX gold mini	995 and 999 purity 100 g
MCX gold guinea	999 purity 8 g
MCX gold petal	999 purity 1 g

Non-parametric approach for data analysis

Each commodity was treated independently for the sake of comparative analysis. The measures were subjected to descriptive analysis; we found, based on the Shapiro-Wilks test, that the data distributions of the liquidity measures were all deviating from normality. Hence, nonparametric tests were chosen to ensure that no information is lost and the structural integrity of the data is retained.

To study the change in liquidity of the contracts over time, a sample comparison was carried out using a non-parametric related sample test, namely the Wilcoxon signed-rank test. This test uses matched samples, in our case pre- and post-CTT liquidity measures, and assists in identifying significant changes in liquidity. This approach is similar to the method used by Chung et al. (27) for comparing the impact of transaction tax on stock index future trading. The approach is based on Equation (1), where "W" denotes the Wilcoxon test statistic, while "μ" represents the sample mean before and after CTT; "k" denotes the sample being considered ranging from k to n, "R" denotes the rank, and "Sgn" represents the sign function, which is +1 if (μ_{after}-$\mu_{beforeCTT}$) is positive and -1 if (μ_{after}-$\mu_{beforeCTT}$) is negative.

$$W = \Sigma_{k=1}^{n}[\mathrm{Sgn}\,(\mu_{After\ CTT,k} - \mu_{Before\ CTT,k}) \times R_k] \quad (1)$$

Finally, a graphical analysis of the liquidity measures is done to study liquidity movements throughout the day. The paper utilized four liquidity measures presented in **Table 3**. The liquidity measures given in **Table 3** were chosen based on Marshall et al. (3). Some of the measures overlap with proxies that have been extensively used in the literature on stock markets and their liquidity (**Table 1**). In developed economies designated market makers enhance the liquidity of the market by absorbing excessive supply and quenching

TABLE 3 | Liquidity measures used for the analysis and their formulae.

Liquidity measure	Symbol	Calculation
Effective spread	ESPR	2^{*} [ln (Traded Price$_t$) – ln (Midpoint$_t$)]
Average spread	ASPR	av(Ask Price$_t$) – av(Bid Price$_t$)
Proportional average spread	PASPR	$\frac{\mathrm{av(Ask\ Price_t)} - \mathrm{av(Bid\ Price_t)}}{\mathrm{av(Ask\ Price_t)}}$
Depth	DEP	$\frac{\mathrm{Ask\ Volume_t} + \mathrm{Bid\ Volume_t}}{2}$

The table describes the liquidity measures used for the study based on Marshall et al. (3) and Brockman and Chung (39). Traded prices are determined using the trade book data, whereas the midpoint of the bid-ask spread is calculated from the order book-matched intervals. The average bid/ask spread is determined over 5-minute intervals. The volume for bid or ask is calculated by aggregating the bid volume and ask volume over a 5-minute interval.

unprecedented demand, but in India, due to the absence of designated market makers (until 2017) in the commodity futures market, quoted spreads are omitted as a liquidity measure. Also, we do not have tick-size-based regimes in India, which exist for the stock markets. The measure of transaction cost incurred by the trader is the effective spread. It is closest to the actual transaction costs incurred. Average spread, on the other hand, considers the prevailing spread in the market; the proportional average spread is normalized using the average ask price, and finally, the depth of the market is measured using the total number of contracts traded for a given time interval. Depth is often used as a direct measure of liquidity, as it indicates the total volume traded as a proxy for prevailing demand and supply. It is seen that depth and spread have an inverse relationship in the stock market. Finally, it is interesting to note other spread measures for examining liquidity were inappropriate for the futures markets and hence not used for the study. Roll's implicit bid-ask spread (40) using the first-order serial covariance assumes an informationally efficient market as well as a constant flow of quotes. Futures markets help in the process of price discovery—hence efficiency fluctuates; additionally, the flow of orders exhibits gaps in time. Similarly, Amihud's measure as used by Coughlan and Orlov (41) was also rendered ineffective in the commodity futures markets in India due to no trades or low trade periods, which makes the denominator tend towards zero. Quote-based spreads were also avoided, as the futures market is primarily order-driven.

Results and discussion

Table 4 presents the summary statistics for the variables measuring liquidity used in the study. Each of the variables has two columns within; the column titled "2013" depicts

TABLE 4 | Descriptive statistics of the variables measuring liquidity in 2013 and 2014.

Commodity		ESPR		ASPR		PASPR		DEP	
		2013	2014	2013	2014	2013	2014	2013	2014
Copper	Mean	0.00437	0.00397	1.15057	1.08392	0.00257	0.00231	2.65366	3.61705
	Median	0.00373	0.00324	0.87988	0.81199	0.00195	0.00172	2.54902	3.94180
	Std. Dev.	0.00351	0.00307	0.97319	0.92823	0.00219	0.00197	0.94451	1.81238
	# of Obs	279	501	279	501	279	501	279	501
Copper mini	Mean	0.0042	0.0071	1.3572	1.4219	0.0029	0.0030	2.4206	2.4905
	Median	0.0029	0.0070	0.9192	1.2070	0.0020	0.0026	2.3532	1.7960
	Std. Dev.	0.0042	0.0032	1.6421	1.0693	0.0035	0.0023	0.5457	5.3124
	# of Obs	303	501	303	501	303	501	303	501
Crude oil	Mean	0.0167	0.0067	12.4925	21.4970	0.0025	0.0035	4.7919	4.3400
	Median	0.0112	0.0062	11.6936	17.7419	0.0023	0.0030	5.1248	4.6586
	Std. Dev.	0.0369	0.0031	47.8865	14.1067	0.0102	0.0023	1.9873	1.5107
	# of Obs	129	294	129	294	129	294	129	294
Gold	Mean	0.0390	0.0226	61.3718	139.5293	0.0019	0.0049	1.3573	1.5708
	Median	0.0365	0.0179	109.1490	141.7702	0.0035	0.0050	1.3481	1.6128
	Std. Dev.	0.0228	0.0157	636.6418	145.9451	0.0206	0.0052	0.1909	0.3347
	# of Obs	417	498	417	498	417	498	417	498
Gold mini	Mean	0.0042	0.0140	27.8950	128.5945	0.0009	0.0044	3.0250	2.4113
	Median	0.0032	0.0102	19.1517	120.1988	0.0006	0.0041	2.9339	2.3046
	Std. Dev.	0.0038	0.0123	77.1418	211.0194	0.0026	0.0073	0.6372	0.8102
	# of Obs	348	501	348	501	348	501	348	501
Gold guinea	Mean	0.0134	0.0110	320.8082	97.2598	0.0130	0.0042	5.1097	4.5514
	Median	0.0111	0.0091	296.7596	90.2993	0.0120	0.0038	2.6916	2.5459
	Std. Dev.	0.0102	0.0089	257.1076	127.0117	0.0104	0.0055	6.1285	6.7097
	# of Obs	501	444	501	444	501	444	501	444
Gold petal	Mean	0.0054	0.0070	14.2904	15.3543	0.0046	0.0053	33.4966	25.1028
	Median	0.0033	0.0056	11.2888	13.2134	0.0036	0.0045	15.3405	10.5887
	Std. Dev.	0.0061	0.0065	18.2041	15.5668	0.0059	0.0054	51.5078	43.8049
	# of Obs	252	492	252	492	252	492	252	492

The table describes the mean, median, and standard deviation of the aggregated liquidity measures used for the study, along with the sample size (# of Obs) used. "ESPR," "ASPR," "PASPR," and "DEP" refer to effective spread, average spread, proportional average spread, and depth, respectively. The statistics are presented for both 2013 (pre-tax period) and 2014 (post-tax period).

the mean, median, and standard deviation measured in 2013, and a similar approach has been used for the column titled "2014."

The commodity-wise discussion of the summary statistics is presented below.

Copper futures

In the case of copper futures, the mean effective spread (ESPR) of copper declined by 9.98% from 2013 to 2014. Since spread is an indicator of illiquidity, its decline indicates an improvement. The average spread (ASPR), as well as the proportional average spread (PASPR), has also declined by 5.79% and 10.26%, which is consistent with the conclusion that liquidity has increased. The depth is seen to increase by 36.30%. Overall copper futures witness a marginal improvement in market liquidity; this supports the views of Bloomfield, O'Hara, and Saar (19), who state that a shock such as transaction taxes is temporary and has no severe impact. We also anticipate a minimal disruption in copper sales owing to the high demand in the industry.

Copper mini futures

Copper mini futures show an increase in mean spread measures. An increase is seen in all spreads in 2013–2014: effective spread increased by 69.12%, average spread by 4.77%, and proportional average spread by 2.89%. Increasing spreads are a sign of reducing liquidity. While depth also shows a negligible increase of 2.89% in 2014. On the whole copper mini exhibits decreased liquidity, extending support to the views of Amihud and Mendelson (13), who state that transaction tax hinders trading and adversely impacts liquidity. While copper futures are highly popular, copper mining is a less popular counterpart.

Crude oil futures

The effective spread of crude oil has declined in 2013–2014 by 60.15%. On the other hand, the average spread and proportional average spread have increased by 72.07% and 40.81%, respectively. The depth, however, has declined by 9.43%. The deviation of effective spreads in the case of crude oil is due to the use of a midpoint instead of the bid price. This implies that the ask price and the bid price have a higher deviation, which isn't surprising given the erratic price changes in the crude oil market.

Gold futures

In the case of gold futures, the effective spread has declined by 42.02%, whereas the average spread and the proportional average spread have increased by 127.35% and 152.89%, respectively from 2013 to 2014. The depth has also shown an increase of 15.73%. This pattern is seen to be like that of crude oil. Although demand for gold is stable, its price fluctuates often, leading to similar patterns like crude oil futures.

TABLE 5 | Results of the Wilcoxon signed-rank test.

Commodity		DEP14 - DEP13	ESPR14 - ESPR13	ASPR14 - ASPR13	PASPR14 - PASPR13
Copper	Z score	-16.7530[a]	-0.4150[a]	-1.4500[b]	-2.528[b]
	p-value	0.0000	0.6780	0.1470	0.0110
Copper mini	Z score	-7.6020[a]	-9.9890[a]	-3.1290[a]	-2.7340[a]
	p-value	0.0000	0.0000	0.0020	0.0060
Crude oil	Z score	-10.5930[a]	-4.1030[b]	-4.1850[a]	-2.5520[a]
	p-value	0.0000	0.0000	0.0000	0.0110
Gold	Z score	-15.5530[a]	-13.0590[b]	-1.2450[a]	-1.6910[a]
	p-value	0.0000	0.0000	0.2130	0.0910
Gold mini	Z score	-3.6730[a]	-12.588[a]	-6.5150[a]	-6.4820[a]
	p-value	0.0000	0.0000	0.0000	0.0000
Gold guinea	Z score	-5.0290[a]	-4.2920[a]	-13.2770[a]	-12.9110[a]
	p-value	0.0000	0.0000	0.0000	0.0000
Gold petal	Z score	-2.8100[a]	-3.2240[a]	-0.4430[b]	-0.1230[a]
	p-value	0.0050	0.0010	0.6580	0.9020

The table shows the results of liquidity changes over time for the sample commodity futures, using the non-parametric Wilcoxon signed-rank test. "ESPR," "ASPR," "PASPR," and "DEP" refer to effective spread, average spread, proportional average spread, and depth, respectively. The 1% significance levels are also indicated.

[a]represents a significant result where value in 2014 < value in 2013 (significant negative ranks).

[b]represents a value of 2014 > value in 2013 (significant positive ranks).

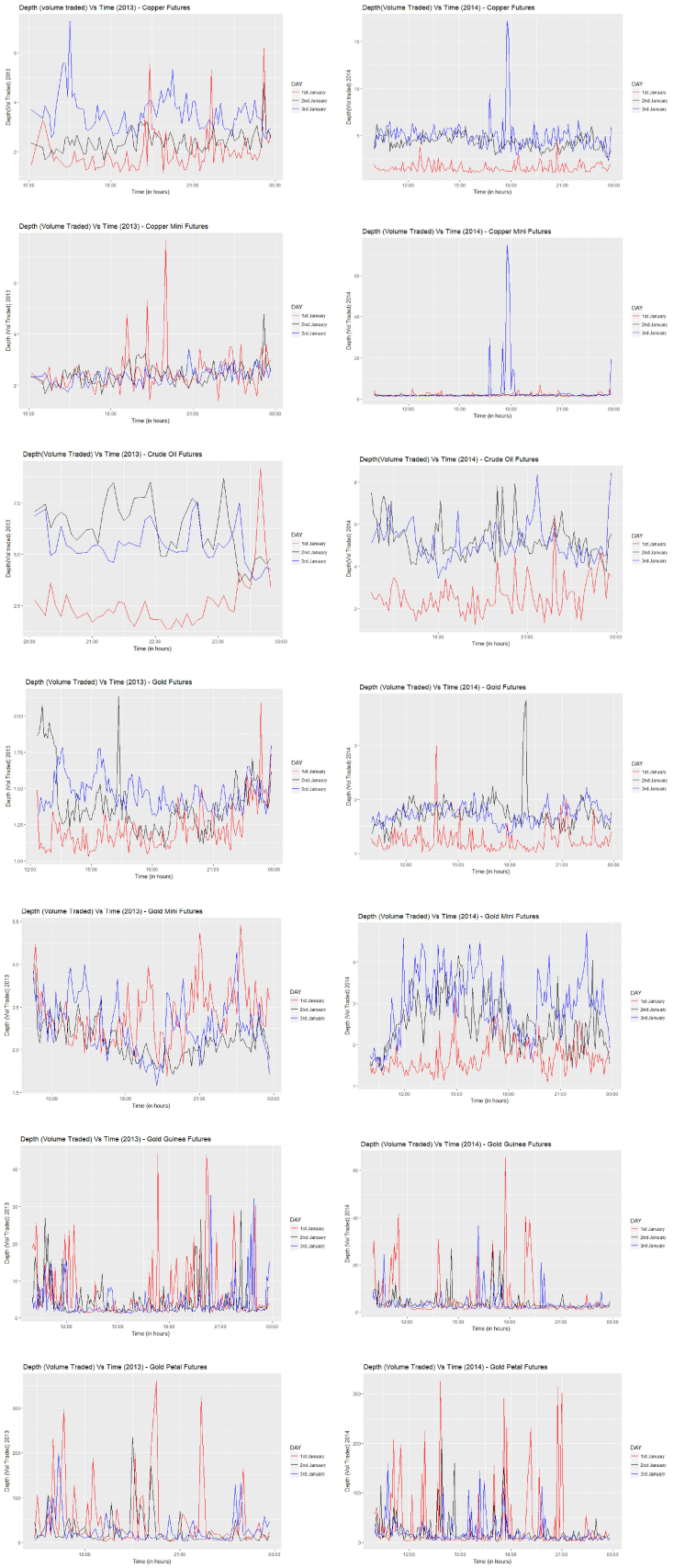

FIGURE 2 | The graphs represent intraday depth (volume of contracts traded) movements in copper futures, copper mini futures, crude oil futures, gold futures, gold guinea futures, gold mini futures, and gold petal futures. The graphs compare the movement in 2013 to the post-CTT period in 2014.

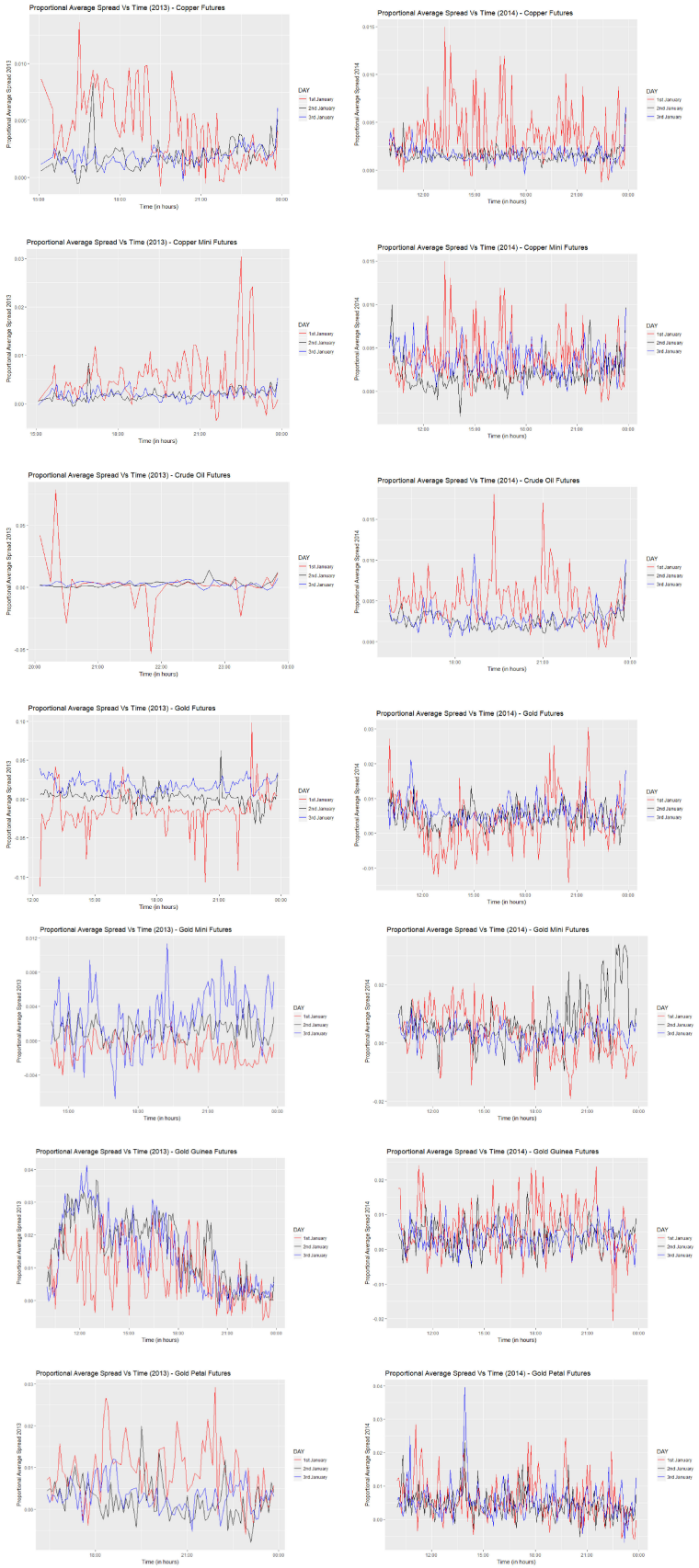

FIGURE 3 | The graphs represent intraday proportional average spread movements in copper futures, copper mini futures, crude oil futures, gold futures, gold guinea futures, gold mini futures, and gold petal futures. The graphs compare the movement in 2013 to the post-CTT period in 2014.

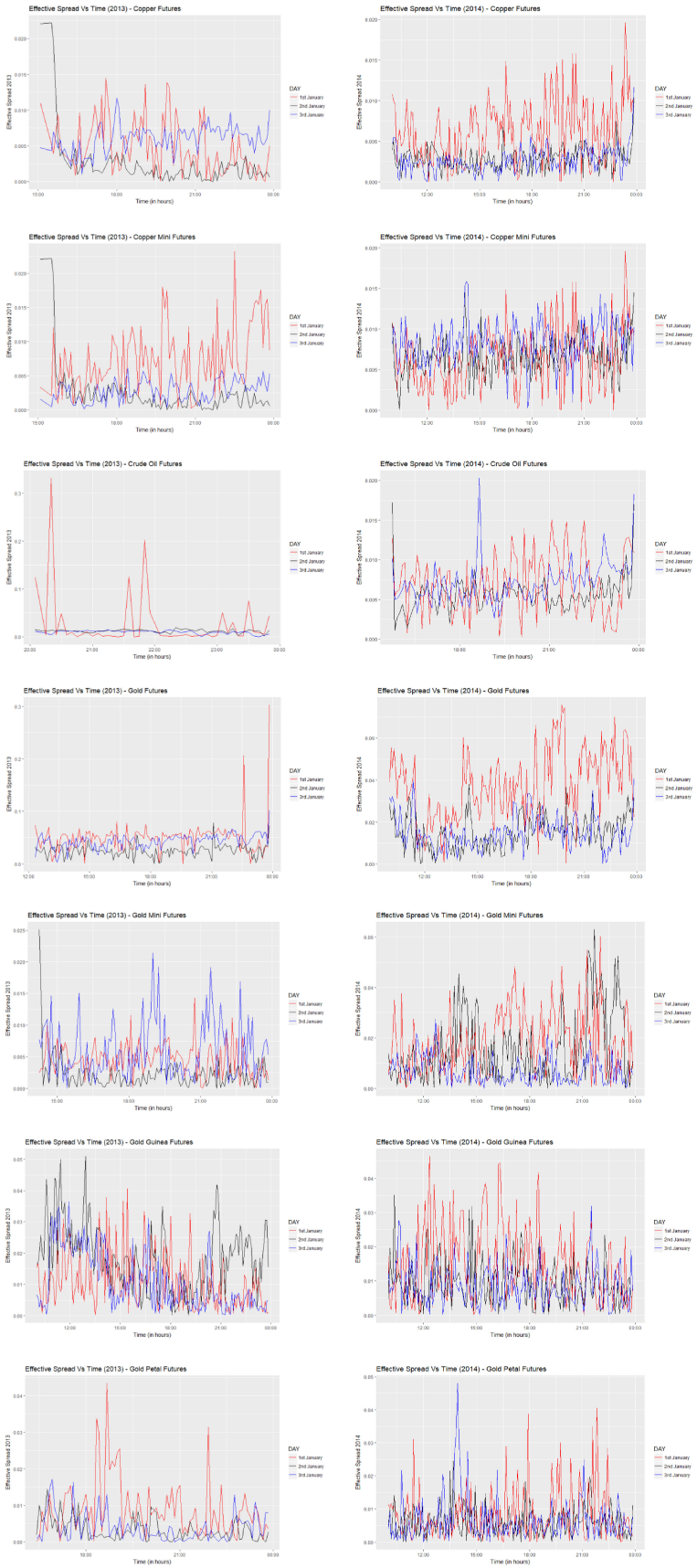

FIGURE 4 | The graphs represent intraday effective spread movements in copper futures, copper mini futures, crude oil futures, gold futures, gold guinea futures, gold mini futures, and gold petal futures. The graphs compare the movement in 2013 to the post-CTT period in 2014.

FIGURE 5 | The graphs represent average spread movements in copper futures, copper mini futures, crude oil futures, gold futures, gold guinea futures, gold mini futures, and gold petal futures. The graphs compare the movement in 2013 to the post-CTT period in 2014.

Gold mini futures

This contract has shown the largest increase in spreads in 2013–2014. The effective spread increased by 229.79%, the average spread increased by 360.99%, and the proportional average spread increased by 365.94%. The depth has declined from a mean of 3.02 to 2.41 leading to a fall of 20.29%. This result reinforces the conventional view put forward by Amihud and Mendelson (13).

Gold guinea futures

The mean effective spread for gold guinea has declined in 2014 by 17.84%; the average spread and proportional average spread have also reduced by 69.68% and 67.76%, respectively. The depth, which uses volume as a measure, has also declined by 10.93%. These results show that while spread measures capture improved liquidity, the traded volumes have declined.

Gold petal futures

Gold petal mean effective spread has increased in 2014 by 29.05%; average spread (7.44%) and proportional average spread (14.26%) have also increased. The depth has declined by 25.06%. This is again in line with the view that transaction tax exacerbates the prevailing market liquidity (13).

Overall, the summary statistics remain unclear; we observe a decline in the mean effective spread in 2013–2014 for copper, crude oil, gold, and gold guinea. However, copper mini, gold mini, and gold petal show an increase in the mean effective spread. Average spread and proportional average spread, which is a measure of market spreads, have increased for copper mini, crude oil, gold, gold mini, and gold petal, and it has declined for copper and gold petal. Depth has increased in copper, copper mini, and gold. The rest of the contracts (crude oil, gold mini, gold guinea, and gold petal) exhibit a decline in depth. The results of the effect of transaction tax on liquidity remain ambiguous from the summary statistics. At a cursory glance, it appears that the high transaction costs (due to taxes) are not captured in spread measures for all the contracts; therefore, participants are exempted from higher implicit transaction costs in the post-CTT period, consistent with the results of Meyer et al. (1). Subsequently, there is a need to statistically examine the data to confirm whether the changes in liquidity over the years 2013 and 2014 were significant. These results are shown in **Table 5**.

Table 5 shows the results of the changes in liquidity dynamics using the Wilcoxon signed rank test. We observe evidence of significant differences in liquidity over time; however, the direction of change in liquidity varies based on the measure considered. Depth consistently shows a significant decline post-CTT for all the commodity futures contracts. Indicative of reduced trading activity post-CTT, supporting the findings based on stock markets that a tax hinders liquidity (12, 13, 22, 24, 29). However, spread measures show mixed evidence and fail to accurately capture the increased transaction costs across all commodity futures consistent with the findings of Meyer et al. (1), Capelle-Blancard and Havrylchyk (15), Hemmelgarn et al. (38), and Cappelletti et al. (25). This indicates that intraday measures such as spread fail to capture higher implicit transaction costs in the short term (1). Only crude oil, gold, gold petal, and copper show some evidence of increasing spread post-taxation.

Furthermore, we conducted a visual analysis examining the daily liquidity movements for both 2013 (which is without tax) and 2014 (which includes the tax). **Figures 2**, **3**, **4**, and **5** plot the variables of the measures of liquidity over time, representing daily trading patterns. Each data series is plotted as a distinct line representing the sample day considered. There is no distinguishable U-shaped pattern observed, which is in general agreement with an order-driven market. Further, visual examination revealed that all the incoming orders remain stable throughout the day except for a few spikes, with the majority of the spread distribution following a mean-reverting pattern, typical for time-series data. Finally, with regard to the graphical analysis of depth, we notice that the majority of spikes occur during the most active trading window spanning from 16:00 to 20:00 hours. Gold futures, gold mini, and crude oil futures show higher trading activity throughout the day, indicating their popularity among traders. While the remaining contracts show feeble trading volumes.

Conclusion

Our study attempts to analyze commodity futures liquidity in the post-CTT period contracts in India. In the post-CTT period, depth declined for all contracts in 2014, but the spread measures show mixed/inconclusive results in the short term. Spreads reflect both transaction costs and market sentiment. However, in the case of depth, which is a representation of trading activity, this is seen to consistently decline. The visual analysis of the intraday patterns shows erratic fluctuations throughout the active trading hours, although there is no distinct pattern arising. The "U-shape" pattern with intraday stock spread is absent in the commodity futures market. Our study highlights some potential limitations in the field of commodity market research in emerging economies. First, the lack of comprehensive data restricts generalizability to markets outside the scope of commodities. Second, data limitations also reduce opportunities for robust model-based examinations, and third, there is ambiguity in the results and a lack of distinct patterns in trading due to varying

types of markets. Despite the limitations, our study enriches the current scanty liquidity-based literature for commodity markets in the context of an emerging economy like India. Our study contributes to existing literature in the field of transaction taxes and commodity markets in the emerging market context. A lack of significant shift in trading patterns and mixed results is also enlightening for policymakers to understand whether taxation in commodity markets is ideal for addressing speculative trades.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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