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Night Trading with Futures in China: The Case of Aluminum and Copper

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Abstract

We use high-frequency data to examine the effects of introducing a night trading session at the Shanghai Futures Exchange (SHFE) in 2013. For Copper, the realized volatility of the regular session is endogenously determined, while the night session is driven by the immediately preceding volatility of the London Metal Exchange (LME). In contrast, Chinese Aluminum futures are more resistant to exogenous factors and show pronounced long memory. We find no indications that the SHFE draws volume from LME. The existing break between daytime and night session has significant informational content and must be separated when processing intraday data.

\textit{Keywords:} SHFE, Futures Markets, Aluminum, Copper, High-frequency data, Night trading

\textit{JEL classification: C22; G15; Q37}

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1. Introduction and Literature Review

This paper is the first to address thoroughly the role of the newly introduced night trading sessions (NTS) for Chinese commodity futures markets. These markets are unique in that the large majority of the participants are individual or retail investors rather than institutions, and direct participation by foreign individual investors in the Chinese futures market is restricted.\footnote{Refer to Zhao (2015) for the history of Chinese futures markets and to Fan & Zhang (2020) for a detailed overview of institutional settings, regulations and trading rules and the investor structure of China’s commodity futures markets.}

To boost its role in global commodity trading, China is undertaking a number of measures, such as allowing international participants to trade in a range of commodity futures (currently crude oil, iron ore and PTA) and waiving income tax for foreign investors (Bloomberg, 2018). In addition, to offer market participants more flexible choices of hedging and the opportunity to react to news from international markets immediately upon their arrival, Chinese futures exchanges introduced NTS. Starting with Gold and Silver in July 2013, night trading was launched for most commodity futures contracts in China enabling trades for an additional 2.5 to 5.5 hours (varying across commodities) at night. The paper at hand connects research areas on extended trading periods for futures markets and on cross-market relations in the context of major commodity futures contracts in a rapidly emerging economy.

Extending the trading hours of futures markets has been a subject of research interest for a long time. Most studies investigate the effects of introducing pre-open and post-close trading sessions (e.g., Cheng et al., 2004; Hua et al., 2016; Sohn & Zhang, 2017; Wang et al., 2019) and document that trading time extensions facilitate price discovery. Further studies focus on overnight trading and find that a considerable portion of the entire day’s price discovery occurs during overnight trading (Joo et al., 2016) and extended trading sessions allow computing returns across international markets over the same time intervals despite different time zones which enables more precise risk measures (Fong & Martens, 2002). The majority of these studies focus on equity futures markets and explore extensions of existing trading sessions rather than introducing new, stand-alone night trading sessions.
This work focuses on the effects of NTS’ introduction on China’s Copper and Aluminum futures markets. China is a significant player in the global markets for non-ferrous metals with derivatives trading on the SHFE and China’s real activity being significantly related to base metals’ prices (Wang & Wang, 2017). Global primary Aluminum production increased by 5.8 percent in 2017, with a 10 percent increase in China and stable production in North America and Europe (Aluminum, 2018). The Aluminum market is exposed to continued political uncertainty, such as those related to US tariffs on Aluminum imports, with the US market becoming gradually closed to Chinese exporters, and stringent environmental regulations leading to closures of Aluminum operators. On the other hand, global demand for primary and recycled Aluminum is driven by the trend toward lightweight construction in the automotive industry. With Copper used widely in power and construction, the Copper market is experiencing volatility because of the escalating trade tension with the US, which adds to the fears of a slowdown in the world’s largest importer of Copper. After reaching a four-year high of almost USD 3,500 per ton in early June 2018, Copper fell sharply—by about USD 1,000 per ton—in the next month (FT, 2018). These recent developments emphasize the need to understand the volatility dynamics of these assets and the relationship of the Chinese futures to international commodity markets.

When the two-hour lunch break that occurs during regular daily trading is taken into account, a regular trading day of the SHFE during business hours comprises 4 hours. Adding four hours of trading at night doubles the active trading hours, which is likely to induce significant changes in the futures markets. Generally, extending the trading hours of one trading venue may increase the competition across exchanges if these trading venues offer futures contracts on the same commodities. The Chinese futures markets are unique in that to date, they are largely restricted for foreign investors. As of 2019, foreign individual investors are only allowed to trade crude oil, iron ore, and purified terephthalic acid (PTA) contracts. Hence, foreign retail (individual) investors have no access to industrial metal futures traded at the SHFE. Institutional investors have access to Chinese futures if they are members of the RMB Qualified Foreign Institutional Investor
program with the membership being subject to approval and quota of the government (Fan & Zhang [2020]). For these reasons, the potential competition between SHFE and LME targets predominantly Chinese institutional or retail investors who, previously active at the LME, may relocate their trading activities to SHFE as a result of the extended trading hours. This may be particularly appealing as trading at the SHFE instead of at the LME gives local investors the opportunity to trade in Renminbi directly, thus avoiding currency exposure to the USD. Based on an extensive dataset of intraday price records, we investigate the course of realized volatility and trading volumes over the recent years to shed light on the relationship between China’s Copper and Aluminum markets and the LME, which is the established venue for industrial metals trading.

The literature has indicated continuing improvement in the efficiency of China’s relatively young metals market (e.g., Xin et al. [2006]) and its growing global importance. A number of studies have specifically addressed the relationship between Chinese and international non-ferrous metal markets. Li & Zhang (2008) concluded that, in the period between November 1993 and June 2006, the SHFE’s and the LME’s Copper futures prices had a long-run relationship, with the influence of the LME on the SHFE being more pronounced than the other way round. Fung et al. (2010) examined the information flow and market efficiency between the US and Chinese Aluminum and Copper futures markets over the period from 1999 to 2009 and found that the two futures prices were co-integrated. Using data from 2005 to 2011, Li & Zhang (2013) concluded that the price impact of the SHFE’s Copper futures on the LME’s Copper futures has been increasing since 2007, while the reverse effect has been decreasing. Rutledge et al. (2013) investigated the price links and information transitions between the Copper markets of the COMEX, the LME and the SHFE between June 2006 and May 2011 and saw significant bidirectional Granger causality across the three markets. Yin & Han (2013) found bidirectional but asymmetric lead/lag relationships and volatility spillovers between the

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2The COMEX issues futures contracts on Copper and Aluminum, but while the COMEX’s Copper futures have notable trading volumes, the trading in Aluminum futures has been thin, so there are too few high-frequency price records to warrant a reliable estimate of daily realized volatility. For this reason, the present study focuses on the LME as an international metal-prices benchmark.
LME and the SHFE, as well as between the NYMEX and the SHFE, with the stronger effect from the two developed markets to the two immature markets in the time series from January 2004 to April 2012. Hou et al. (2015) used data from November 2000 to January 2012 to show the increasingly prominent role of the SHFE in the price-formation process and the cross-volatility spillover effects in the Copper market since 2008. Looking at the period between August 2007 and April 2016, Kang et al. (2018) documented that London’s nonferrous futures market generally leads Shanghai’s market, especially in the medium-run.

Most of the aforementioned studies were based on closing prices that were sampled at a daily frequency or less and did not account for the differing times when the individual markets are open. Moreover, as their data samples span periods before the night trading was launched in China, the links between the Chinese and international markets have not been assessed against the backdrop of the newly extended trading hours. Breaking close-to-close returns of futures on Copper, soybeans and rubber into overnight and open-to-close returns in the context of Value-at-Risk (VaR) and expected shortfall estimations, Liu & Yunbi (2014) showed that the information that accumulates during non-trading hours contributes substantially to overall risks, with non-trading VaR weights exceeding 40 percent in these markets. In particular, the information that accumulates during non-trading hours appears to be more important than the information that accumulates during trading hours. Using time-stamped bid and ask prices and trade prices for the three-month Copper futures contracts traded on the COMEX, the LME and the SHFE from July 2005 to December 2005, Lien & Yang (2009) documented a significant unidirectional volatility spillover from the LME to the SHFE. Using daily data of sixteen commodity futures up to October 2011, Fung et al. (2013) suggested that China’s commodity futures markets are likely to be driven by local market dynamics that occur during the daytime, as foreign markets’ trading sessions’ returns have a significant impact on China’s overnight (close-to-open) returns, but China’s commodity futures contracts’ daytime (open-to-close) returns are not led by foreign daytime returns. These studies make clear that, before the introduction of night trading, overnight and daily dynamics
differed to a considerable extent, and overnight information from international markets that arrives while the Chinese futures exchanges are closed causes a large part of the overall metal market’s volatility.

To the best of our knowledge, only a few studies have addressed the effect of Chinese futures markets’ night trading.\(^3\) Fung et al. (2016) used daily prices and trading activity data from Chinese commodity futures to document that the returns have become more symmetric and that interactions between trading activity and volatility have conformed better to the observed patterns in developed markets. Using daily closing and opening prices, Du (2018) ran VAR models to predict commodity returns and volatility and established the presence of a leading effect of overnight returns to daytime trading returns. Jin et al. (2018) and Xu & Zhang (2019) used intraday data to investigate the price discovery and market quality of Chinese gold markets and provided evidence of the importance of NTS in this regard. Using daily data of Chinese commodity futures, Zhao (2020) investigates the impact of NTS on the price dynamics of the domestic Chinese futures market and suggests that the overall efficiency of Chinese commodity futures prices has improved after the introduction of NTS. Based on daily data for Chinese and intraday data for US markets, Jiang et al. (2020) study the market quality of the SHFE futures contracts on precious metals and document that the market quality of SHFE futures has increased.

Our work is also related to the vast literature on volatility estimation, forecasting and spillovers across markets based on intraday data in commodities (e.g., Souček & Todorova 2013; Haugom et al. 2014; Sévi 2014; Todorova et al. 2014; Gong & Lin 2017; Klein 2018; Nguyen & Walther 2020; Liu & Gong 2020; Luo et al. 2020; among many others). The importance of overnight periods as well as the availability of high-frequency data of related markets for volatility forecasting has been conclusively documented in previous studies (e.g., Lyócsa & Todorova 2020; Wang et al. 2015). In the area of commodities, an overwhelming majority of contributions address energy (and mostly oil) markets mostly using data of developed markets.

\(^3\)A line of literature has used intraday data for volatility forecasting of the SHFE’s industrial metal futures with heterogeneous autoregressive (HAR) models (e.g., Zhu et al. 2017; Zhang et al. 2018a; Gong & Lin 2018). These studies did not address the introduction of NTS.
We contribute to the research on global futures markets in three primary ways. First, we use an extensive set of high-frequency data to obtain the precise realized volatility of futures and match volatility and trading volume to individual trading sessions in the SHFE and the LME. Industrial metals are known to exhibit low seasonal variation in supply and demand (Geman & Smith, 2013), so there is no need to account for seasonal effects in the raw data. As explained below, we also use three-month futures contracts from both exchanges, so the results are not affected by issues that may arise for contracts that are nearing maturity. Second, we analyze the regular session and the night trading session at the SHFE and find that the dynamics of the realized volatility differ in both sessions. With the additional NTS, the break between the regular SHFE session and the NTS—labeled the evening break—is shown to have significant informational content, so we demonstrate that failing to treat the evening break separately for jump estimation purposes introduces a jump bias. Without separating this evening break, 59% of jumps are wrongly identified as such in our dataset. Third, we find that the realized volatility of LME futures is a major driver of the realized volatility of Copper in the NTS. In contrast, Aluminum trading volume has surged in recent years, and realized volatility seems to be driven mainly by local factors, with the LME volatility playing only a negligible role.

The remainder of this paper is organized as follows. The methodology and intraday separation of returns are outlined in Section 2. Data and preliminary analyses are presented in Section 3. Section 4 discusses the estimation results and Section 5 summarizes the main findings and concludes this article.

2. Methodology

2.1. Intraday returns and separation of the night trading session

The empirical analysis uses intraday data and starts with a comprehensive overview of return and trading dynamics before and after the launch of NTS. The trading hours at the LME and the SHFE, including the NTS, are visualized in Figure 1.

Intraday returns \( r_{j,t} \) on day \( t \) are defined as the log difference of two consecutive prices,

\[
r_{t,j} = \log P_{t,j} - \log P_{t,j-1}, \quad \text{for} \quad j = 2, \ldots, M,
\]
where $M$ denotes the number of intraday prices and $t = 1, \ldots, N$. Here, we use prices sampled at five-minute frequencies, which is discussed further in Sec. 3. Analogously, an open-to-close return over a particular trading session is defined as the log difference of the closing and opening prices of this trading session.

This return describes only the price changes during active trading hours. We follow the standard notation and define the overnight return of day $t$ to refer to the preceding non-traded period prior to the trading hours of day $t$. The closing price of the last trading session of trading day $t-1$, and the opening price of the current day $t$ yield the overnight return $r^*_{t,\text{ON}}$, defined as

$$r^*_{t,\text{ON}} = \log P_{t,\text{open}} - \log P_{t-1,\text{close}}. \quad (2)$$

Before the introduction of night trading, the close-to-close return $r^*_{t,\text{cc}}$ is calculated for $t = 2, \ldots, N$ as

$$r^*_{t,\text{cc}} = \log P_{t,\text{close}} - \log P_{t-1,\text{close}}. \quad (3)$$

Hence, the pre-NTS close-to-close return can be decomposed to

$$r^*_{t,\text{cc}} = r^*_{t,\text{ON}} + r^*_{t,(1)}, \quad (4)$$

where $r^*_{t,\text{ON}}$ is the overnight return based on the opening and closing prices of the regular sessions of two consecutive days as defined in Eq. (2) and $r^*_{t,(1)}$ refers to the return during trading of the regular session, subsequently defined in Eq. (5)

Using the SHFE's additional NTS beginning on December 20, 2013, which runs from 13:00 GMT to 17:00 GMT (21:00 to 1:00 CST), we undertake a further decomposition of the returns. Ignoring the gap between the end of the regular session at 7:00 GMT (15:00 CST) and the beginning of the NTS at 13:00 GMT (21:00 CST) would lead to including an implicit jump in the intraday returns, which may yield positively biased jump components and lead to spurious inferences in statistical analyses. Therefore, similar to an overnight

\footnote{The SHFE has a lunch break between 11:30 and 13:30 CST that is strictly observed, so the daily trading session comprises four hours of active trading: from 09:00 to 11:30 and from 13:30 to 15:00 China Standard Time (CST). Since the lunch break is not subject of this study, we define the regular daily trading session from 09:00 to 15:00 CST, disregarding this suspension of trading.}
return, we define an SHFE-specific evening break return, $r_{t}^{EB}$, which is calculated as

$$r_{t}^{EB} = \log P_{t,open}^{nts} - \log P_{t,close}^{reg}; \tag{5}$$

where $P_{t,open}^{nts}$ is the opening price of the NTS starting at 13:00 GMT (21:00 CST), and $P_{t,close}^{reg}$ is the closing price of the regular session, ending at 7:00 GMT (15:00 GMT). Consequently, we obtain two returns covering the open market sessions, $r_{t}^{(1)}$ and $r_{t}^{(2)}$, for the regular day-time session and the NTS, respectively. In the notation of Eq. (1), we then obtain

$$r_{t}^{(1)} = \sum_{j=1}^{K} r_{t,j} = \log P_{t,close}^{reg} - \log P_{t,open}^{reg}, \quad \text{and} \quad r_{t}^{(2)} = \sum_{j=K+1}^{M} r_{t,j} = \log P_{t,close}^{nts} - \log P_{t,open}^{nts}; \tag{6}$$

where $K$ is the last index of intraday returns within the regular trading hours. It holds that $K \leq M$, as the NTS is occasionally not carried out, such as when the following day is a bank holiday.

After the introduction of the NTS, the overnight return on day $t$ now only refers to the logarithmic price difference of the closing price of the NTS at time $t - 1$ and opening price of the regular session on day $t$:

$$r_{t}^{ON} = \log P_{t,open}^{reg} - \log P_{t-1,close}^{nts}; \tag{7}$$

Therefore, the daily close-to-close return after introduction of the NTS is comprised of four components,

$$r_{t}^{cc} = r_{t}^{ON} + r_{t}^{(1)} + r_{t}^{EB} + r_{t}^{(2)}; \tag{8}$$

which are analyzed separately below. This decomposition of returns is also visualized in Figure [1].

Given the decomposition of the close-to-close returns in Eq. [3] and Eq. [4], the main difference between the overnight return before ($r^{*,ON}$) and after ($r^{ON}$) the introduction of
the NTS is the fragmentation across the evening break and NTS given as

\[ r_{t+1}^{\ast,\text{ON}} = r_{t}^{\text{EB}} + r_{t}^{(2)} + r_{t+1}^{\text{ON}}, \]

which is discussed in detail in Section 4.

Analogously, the daily trading volume \( v_t \) is also decomposed into the trading volume during the regular session, \( v_t^{(1)} \), and the trading volume during the NTS, \( v_t^{(2)} \), which yields the total daily volume \( v_t = v_t^{(1)} + v_t^{(2)} \).

![Trading hours of LME and SHFE on weekdays, including the night trading session (since December 20, 2013) in GMT. Return separation before the introduction of the NTS are marked above the trading blocks and augmented with an asterisk (\( r_{t+1}^{\ast,\text{ON}}, r_{t+1}^{\ast,\text{cc}}, \) and \( r_{t+1}^{\ast,(1)} \)) to distinguish from the separation past the introduction of the NTS, marked below the trading blocks, with the separation given in Eq. (8).](figure1.png)

2.2. Realized volatility

The daily realized volatility on day \( t \), denoted \( RV_t \), is widely estimated in literature as the sum of squared intraday returns.\(^5\) Like Eq. (6), we calculate the realized volatility for the regular and NTS separately:

\[ RV_t^{(1)} = \sum_{j=1}^{K} r_{t,j}^2 \quad \text{and} \quad RV_t^{(2)} = \sum_{j=K+1}^{M} r_{t,j}^2. \]

\(^5\)Similar to the majority of related studies, the terms ‘variance’ and ‘volatility’ are used interchangeably throughout the text.
For non-trading periods, the corresponding squared returns, \((r_{ON}^t)^2\) and \((r_{EB}^t)^2\) are used as proxies of the volatility\(^6\). As in Todorova et al. (2014), Todorova (2015), and Zhu et al. (2017), we decompose the daily realized volatility into intraday volatility during actively traded hours and overnight or trading break volatilities which are proxied by squared returns. Summing the individual components over a 24h hour period yields the 24h realized volatility,

\[
RV_t^{(24)} = (r_{ON}^t)^2 + RV_t^{(1)} + (r_{EB}^t)^2 + RV_t^{(2)}.\tag{10}
\]

2.3. Heterogeneous Autoregressive Models

To model the realized volatility of the regular session, \(RV^{(1)}_t\), the NTS, \(RV^{(2)}_t\), and the 24-hour volatility, \(RV^{24}_t\), we begin with a simplistic heterogeneous autoregressive (HAR) model version for each component given in Eq. (11.1), (12.1), and (13.1) below. This HAR specification follows the standard definition of Corsi (2009) and puts the realized volatility over a future period \(t + 1\) in relation to the asset’s average realized volatility on the last day, the last week, and the last month, respectively, with an unpredictable error term \(\varepsilon_t\). Weekly and monthly components are daily averages of realized volatility over the corresponding periods of five or twenty-two trading days. The HAR model effectively depicts short and long memory in realized volatilities and is popular in the recent literature\(^7\). The HAR model has been shown to capture volatility transmission across various markets in the context of LME industrial metals (Todorova et al., 2014).

For the regular session, the simple HAR is estimated for the periods before and after

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\(^6\)The lunch break is not separately accounted for, and the price change during this halt in trading is treated as a regular intraday return.

\(^7\)The standard HAR is augmented and modified to account for different stylized facts, such as jumps (e.g. Barndorff-Nielsen, 2004, Andersen et al., 2007), separation in continuous and non-continuous RV components (e.g. Patton & Sheppard, 2015), realized semi-variances (e.g. Patton & Sheppard, 2015), among many others, and has also been applied successfully to the Chinese industrial metal futures markets (e.g. Zhang et al., 2018a, Gong & Lin, 2018). A broad overview of HAR specifications can be found in, for example Sévi (2014).
the introduction of the NTS, so, we obtain two sets of estimates for Eq. (11.1),

$$RV_{t+1}^{(1)} = \beta_0 + \beta_1 RV_t^{(1)} + \beta_2 RV_{t-5,t}^{(1)} + \beta_3 RV_{t-22,t}^{(1)} + \varepsilon_t.$$  

(11.1)

To determine what influence the previous day has on the regular session’s volatility, we include the evening break as well as the realized volatility of the immediately preceding NTS,

$$RV_{t+1}^{(1)} = \beta_0 + \beta_1 RV_t^{(1)} + \beta_2 RV_{t-5,t}^{(1)} + \beta_3 RV_{t-22,t}^{(1)} + \beta_4 RV_{t}^{(2)} + \beta_5 \left(r_{EB}^t\right)^2 + \varepsilon_t.$$  

(11.2)

Next, we replace the evening break and the NTS’s volatility with the previous days’ realized volatility on the LME, $RV_t^{LME}$ to determine the influence of the LME on the regular SHFE session,

$$RV_{t+1}^{(1)} = \beta_0 + \beta_1 RV_t^{(1)} + \beta_2 RV_{t-5,t}^{(1)} + \beta_3 RV_{t-22,t}^{(1)} + \beta_4 RV_{t}^{LME} + \varepsilon_t.$$  

(11.3)

For the NTS, we again begin with the simple HAR to identify internal dependencies and long memory,

$$RV_{t+1}^{(2)} = \beta_0 + \beta_1 RV_t^{(2)} + \beta_2 RV_{t-5,t}^{(2)} + \beta_3 RV_{t-22,t}^{(2)} + \varepsilon_t.$$  

(12.1)

This simple HAR is then augmented with the regular session’s realized volatility and that of the same day’s evening break,

$$RV_{t+1}^{(2)} = \beta_0 + \beta_1 RV_t^{(2)} + \beta_2 RV_{t-5,t}^{(2)} + \beta_3 RV_{t-22,t}^{(2)} + \beta_4 RV_{t}^{(1)} + \beta_5 \left(r_{EB}^{t+1}\right)^2 + \varepsilon_t.$$  

(12.2)

As we did with the regular session, we replace the evening break with the realized volatility of the LME during that break only to directly measure the impact of the LME on the

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8 For reasons of parsimony, we do not include $(r_{ON}^t)^2$ in these HAR variants as estimates are insignificant before and after the introduction of NTS. These results are available on request.

9 While this approach makes forecasting for the next day unfeasible, we seek to explain the volatility behaviour of the NTS.

10 To that end, the LME’s RV is calculated for the time slot from 07:00 to 13:00 GMT.
evening break’s volatility at SHFE:

$$RV_{t+1}^{(2)} = \beta_0 + \beta_1 RV_t^{(2)} + \beta_2 RV_{t-5,t}^{(2)} + \beta_3 RV_{t-22,t}^{(2)} + \beta_4 RV_{t+1}^{(1)} + \beta_5 RV_{t+1}^{LME-EB} + \varepsilon_t. \quad (12.3)$$

For the daily realized volatility $RV^{(24)}$, we carry out a standard HAR for the period before and after the introduction of the NTS,

$$RV_{t+1}^{(24)} = \beta_0 + \beta_1 RV_t^{(24)} + \beta_2 RV_{t-5,t}^{(24)} + \beta_3 RV_{t-22,t}^{(24)} + \beta_4 RV^{24,LME}_t + \varepsilon_t. \quad (13.1)$$

This HAR is augmented with the LME’s daily realized volatility to account for the LME’s possible influence on the daily realized volatility, including all breaks,

$$RV_{t+1}^{(24)} = \beta_0 + \beta_1 RV_t^{(24)} + \beta_2 RV_{t-5,t}^{(24)} + \beta_3 RV_{t-22,t}^{(24)} + \beta_4 RV^{24,LME}_t + \varepsilon_t. \quad (13.2)$$

All models are estimated with White’s adjusted heteroscedasticity-consistent least-squares regression (White, 1980).

2.4. Detection and estimation of intraday jumps

While keeping the realized volatility models as simple as possible, we address jumps separately. We show that ignoring the evening break introduces a positive jump bias. We calculate jumps with the bi-power variation (BPV) as introduced by Barndorff-Nielsen (2004),

$$BPV_t = \mu^{-2}_1 \left( \frac{M}{M-1} \right) \sum_{j=1}^{M-1} |r_{t,j}||r_{t,j+1}|.$$

We follow the jump detection approach of Huang & Tauchen (2005) and calculate the jump component $J_{t,\alpha}$ as

$$J_{t,\alpha} = I_{\{Z_t > \Phi_\alpha\}} (RV_t - BPV_t) \quad (14)$$

with

$$Z_t = \sqrt{M} \frac{1 - BPV_t \cdot RV_t^{-1}}{\sqrt{\mu_1^{-4} + 2\mu_1^{-2} - 5}} \max(1, TQ_t \cdot BPV_t^{-2})$$
and $\mu_1 = \mathbb{E}(Z) = \sqrt{2/\pi}$. The tri-power quarticity $TQ_t$ is defined as

$$TQ_t = M \mu_{4/3}^{-3} \sum_{j=1}^{M-2} |r_{t,j}|^{4/3} |r_{t,j+1}|^{4/3} |r_{t,j+2}|^{4/3},$$

where $\mu_p = 2^{p/2} \cdot \Gamma \left(1/2 \cdot (p + 1) \right) \cdot \Gamma \left(1/2 \right)$. If $\alpha = 0.5$, Eq. (14) is equivalent to the jump detection in Barndorff-Nielsen (2004).

As the previously defined jump measure is not robust to very small or very high jumps or jump-like intraday returns (e.g. a non-separated evening break), Andersen et al. (2012) proposed median RV measures. We use the following definition as an additional robustness check for jumps estimation,

$$MedRV_t = \frac{\pi}{6 - 4\sqrt{3} + \pi} \frac{M}{M - 2} \sum_{j=2}^{M-1} \text{med} \left( |r_{t,j-1}|, |r_{t,j}|, |r_{t,j+1}| \right)^2,$$

then

$$J_{t,\alpha}^{MedRV} = I \left\{ Z_{t,MedRV} > \Phi_\alpha \right\} (RV_t - MedRV_t),$$

with

$$Z_{t,MedRV} = \sqrt{M} \frac{1 - MedRV_t \cdot RV_t^{-1}}{\sqrt{0.96 \max \{1, MedRQ_t \cdot MedRV_t^{-2} \}}},$$

$$MedRQ_t = \frac{3\pi}{9\pi + 72 - 52\sqrt{3}} \frac{M}{M - 2} \sum_{j=2}^{M-1} \text{med} \left( |r_{t,j-1}|, |r_{t,j}|, |r_{t,j+1}| \right)^4.$$

We report $J_{t,\alpha}$ and $J_{t,\alpha}^{MedRV}$ for $\alpha = 0.99$ with and without separating the evening break to demonstrate the importance of a separate break that is similar to an overnight period.

3. Data

We obtain five-minute futures price data and volumes for the SHFE’s and the LME’s futures contracts on Copper and Aluminum from Thomson Reuters Tick History. In the case of the Chinese futures, we roll the futures contracts to the next most liquid

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11Setting $\alpha = 0.5$ implies $Z_t > 0$ which is the case when $RV_t > BPV_t$.
12We use the open and close prices of five-minute price intervals.
month when the daily trading volume of the current contract is exceeded. As a result, we usually use intraday data from three-month futures contracts, which are very liquid (e.g., Zhang 2018). As the LME trades three-month futures contracts on Aluminum and Copper, the exchange’s most frequently traded contracts, every day, this study uses the LME’s three-month contracts. We note that the physical properties of the underlying metals for primary contracts in both exchanges are referring to the same standards. Hence, contracts across exchanges refer to the same quality of commodity.

Our sample period spans January 4, 2010, to May 21, 2018, yielding N=2,035 observation days. The sample period is split on December 20, 2013, the day the SHFE introduced the NTS for futures contracts of Copper and Aluminum, along with other commodities. Prior to the NTS, we record approximately $M = 48$ five-minute price observations per day for the SHFE, and with the NTS, this number increases to $M = 95$ intraday data records. The additional NTS is suspended if the following day is a holiday, while the regular session is traded. The number of observations for Aluminum is only insignificantly different. A detailed overview of daily and intraday observations is given in Table 1. The SHFE’s prices for Copper and Aluminum are given in RMB/ton, and the contract size is set at five tons. The LME’s prices are denominated in USD/ton, and the contract size is set at twenty-five tons.

Figure 2 plots the daily closing prices for Copper and Aluminum futures. As a general observation, prices declined between 2011 and 2016 and increased again from 2016 to mid-2017. Aluminum in particular showed severe losses in late 2017 and the beginning of 2018, which can be directly linked to the tense relationship between China and the US because of the US’s imposed and announced tariffs on imports of steel and base metals.

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14 For Aluminum at the LME, specifications dictate that the underlying metal is “High quality primary Aluminum” following the designation P1020A or designation A199.70 in the GB/T 1196-2008 (Rulebook LME, p. 189). The SHFE states that for its primary Aluminum futures, the underlying Aluminum must comply with the specifications outlined in GB/T1196-2008 designation A199.70, in line with the LME specifications. For Copper, the LME defines its underlying metal as Grade A Copper following one of the standards: BS EN 1978:1998, GB/T 467-2010, or ASTM B115-10. At SHFE, Copper quality follows GB/T467-1997 or BSEN 1978:1998. We thank an anonymous reviewer for pointing out possible differences and the existence of Aluminum Premiums at LME.

15 Additional details on contract specifications can be found in Fan & Zhang (2020).

16 To avoid additional volatility emerging from foreign exchange markets, we do not incorporate the effects of foreign exchange rates into our calculations of returns on the LME.
Panel A: Copper

<table>
<thead>
<tr>
<th></th>
<th>Full Sample</th>
<th>Period 1 ($T_1$)</th>
<th>Period 2 ($T_2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dates</td>
<td>01/04/2010 – 05/21/2018</td>
<td>01/04/2010 – 12/19/2013</td>
<td>12/20/2013 – 05/21/2018</td>
</tr>
<tr>
<td>$n_{total}$</td>
<td>148,554</td>
<td>46,298</td>
<td>102,256</td>
</tr>
<tr>
<td>$N_{total}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M_{total}$</td>
<td>73.0</td>
<td>48.3</td>
<td>95.0</td>
</tr>
<tr>
<td>$N$</td>
<td>2,035</td>
<td>959</td>
<td>1,076</td>
</tr>
</tbody>
</table>

Panel B: Aluminum

<table>
<thead>
<tr>
<th></th>
<th>Full Sample</th>
<th>Period 1</th>
<th>Period 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_{total}$</td>
<td>144,976</td>
<td>44,263</td>
<td>100,713</td>
</tr>
<tr>
<td>$M_{total}$</td>
<td>71.2</td>
<td>46.2</td>
<td>93.6</td>
</tr>
<tr>
<td>$N$</td>
<td>2,035</td>
<td>959</td>
<td>1,076</td>
</tr>
</tbody>
</table>

Table 1: Number of total intraday ($n_{total}$) and average daily intraday ($M_{total}$) observations as well as number of observation days ($N$) for Copper and Aluminum for the full sample and the split sample analysis at the SHFE.

Descriptive statistics on the intraday returns defined in Eq. (8) and visualized in Figure 1 are given in Table 2 for Copper and in Table 3 for Aluminum. As their development in our sample period is a key element of the analysis of the NTS, a detailed breakdown follows in the next section.

We process the raw data of SHFE volumes. The SHFE trading volume data on futures contracts are double-side counted, recording volume for the long and corresponding short transaction separately and summing both in the five-minute data provided. We account for this reporting when we compare the SHFE’s and the LME’s volume data.

Figure 2: Prices of Copper and Aluminum futures contracts from January 4, 2010 to May 21, 2018
### Descriptive Statistics

**Panel A:** Period 1 (observations 1:959), January 4, 2010 – December 19, 2013

<table>
<thead>
<tr>
<th></th>
<th>$r_t^{ON}$</th>
<th>$r_t^{(1)}$</th>
<th>$r_t^{EB}$</th>
<th>$r_t^{cc}$</th>
<th>$RV_t^{ON}$</th>
<th>$RV_t^{(1)}$</th>
<th>$RV_t^{EB}$</th>
<th>$RV_t^{cc}$</th>
<th>$v_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.0090</td>
<td>-0.0082</td>
<td>-0.0169</td>
<td>1.1553</td>
<td>0.8444</td>
<td>330.840</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>0.0372</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.2025</td>
<td>0.5232</td>
<td>282.460</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>-6.7265</td>
<td>-4.8326</td>
<td>-5.6587</td>
<td>0.0000</td>
<td>0.0000</td>
<td>24.668</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>6.2441</td>
<td>4.0792</td>
<td>6.6452</td>
<td>45.2732</td>
<td>17.1618</td>
<td>1,390.478</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std</td>
<td>1.9754</td>
<td>0.9510</td>
<td>1.4411</td>
<td>3.7657</td>
<td>1.0163</td>
<td>199.072.644</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Skewness</td>
<td>-0.5688</td>
<td>-0.0547</td>
<td>-0.2642</td>
<td>7.2699</td>
<td>6.0243</td>
<td>1.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kurtosis</td>
<td>11.5908</td>
<td>5.2567</td>
<td>5.7351</td>
<td>66.6639</td>
<td>64.5528</td>
<td>5.69</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Panel B:** Period 2 (observations 960:2035), December 20, 2013-May 21, 2018

<table>
<thead>
<tr>
<th></th>
<th>$r_t^{ON}$</th>
<th>$r_t^{(1)}$</th>
<th>$r_t^{EB}$</th>
<th>$r_t^{cc}$</th>
<th>$RV_t^{ON}$</th>
<th>$RV_t^{(1)}$</th>
<th>$RV_t^{EB}$</th>
<th>$RV_t^{cc}$</th>
<th>$v_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.0027</td>
<td>-0.0004</td>
<td>-0.0329</td>
<td>0.0365</td>
<td>0.0009</td>
<td>0.0562</td>
<td>0.5423</td>
<td>0.2014</td>
<td>0.5231</td>
</tr>
<tr>
<td>Median</td>
<td>0.0000</td>
<td>-0.0000</td>
<td>0.0227</td>
<td>0.0222</td>
<td>0.0000</td>
<td>0.0566</td>
<td>0.3734</td>
<td>0.0000</td>
<td>0.0363</td>
</tr>
<tr>
<td>Minimum</td>
<td>-1.9213</td>
<td>-3.3299</td>
<td>-5.8432</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0591</td>
<td>0.3734</td>
<td>0.3734</td>
</tr>
<tr>
<td>Std</td>
<td>0.2372</td>
<td>0.7187</td>
<td>0.4478</td>
<td>0.7514</td>
<td>1.1287</td>
<td>0.3013</td>
<td>0.6689</td>
<td>0.4261</td>
<td>0.4550</td>
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<tr>
<td>Skewness</td>
<td>0.6255</td>
<td>-0.0045</td>
<td>0.0720</td>
<td>-0.3501</td>
<td>-0.1614</td>
<td>12.2817</td>
<td>5.1989</td>
<td>5.4148</td>
<td>13.8264</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>29.7467</td>
<td>5.5730</td>
<td>5.1858</td>
<td>11.4755</td>
<td>5.6771</td>
<td>87.4359</td>
<td>41.0244</td>
<td>49.1622</td>
<td>277.5415</td>
</tr>
</tbody>
</table>

Table 2: Descriptive statistics of Copper intraday returns and realized volatilities for the periods without night trading session (Panel A, January 4, 2010 – December 19, 2013) and with daily decomposition after introduction of the night trading session (Panel B, December 20, 2013–May 21, 2018).

### Descriptive Statistics

**Panel A:** Period 1 (observations 1:959), January 4, 2010 – December 19, 2013

<table>
<thead>
<tr>
<th></th>
<th>$r_t^{ON}$</th>
<th>$r_t^{(1)}$</th>
<th>$r_t^{EB}$</th>
<th>$r_t^{cc}$</th>
<th>$RV_t^{ON}$</th>
<th>$RV_t^{(1)}$</th>
<th>$RV_t^{EB}$</th>
<th>$RV_t^{cc}$</th>
<th>$v_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.0075</td>
<td>-0.0148</td>
<td>-0.0208</td>
<td>0.3675</td>
<td>0.3916</td>
<td>42.669</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>0.0009</td>
<td>0.0032</td>
<td>0.0009</td>
<td>0.0000</td>
<td>0.0000</td>
<td>42.669</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>-4.3816</td>
<td>-3.1188</td>
<td>-5.3581</td>
<td>0.0000</td>
<td>0.0192</td>
<td>2.792</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std</td>
<td>1.9086</td>
<td>11.3700</td>
<td>10.9001</td>
<td>97.6131</td>
<td>297.7872</td>
<td>20.80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>1.5107</td>
<td>0.2136</td>
<td>-0.7306</td>
<td>8.9521</td>
<td>14.3045</td>
<td>3.96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kurtosis</td>
<td>17.0061</td>
<td>11.3700</td>
<td>10.9001</td>
<td>97.6131</td>
<td>297.7872</td>
<td>20.80</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Panel B:** Period 2 (observations 960:2035), December 20, 2013-May 21, 2018

<table>
<thead>
<tr>
<th></th>
<th>$r_t^{ON}$</th>
<th>$r_t^{(1)}$</th>
<th>$r_t^{EB}$</th>
<th>$r_t^{cc}$</th>
<th>$RV_t^{ON}$</th>
<th>$RV_t^{(1)}$</th>
<th>$RV_t^{EB}$</th>
<th>$RV_t^{cc}$</th>
<th>$v_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.0133</td>
<td>-0.0464</td>
<td>0.0090</td>
<td>0.0299</td>
<td>0.0049</td>
<td>0.0398</td>
<td>0.5394</td>
<td>0.1106</td>
<td>0.4925</td>
</tr>
<tr>
<td>Median</td>
<td>0.0000</td>
<td>-0.0417</td>
<td>0.0000</td>
<td>0.0376</td>
<td>0.0000</td>
<td>0.0014</td>
<td>0.3471</td>
<td>0.0325</td>
<td>0.2678</td>
</tr>
<tr>
<td>Std</td>
<td>0.1990</td>
<td>0.7563</td>
<td>0.3226</td>
<td>0.5983</td>
<td>1.0122</td>
<td>0.2979</td>
<td>0.6013</td>
<td>0.7274</td>
<td>0.8734</td>
</tr>
<tr>
<td>Skewness</td>
<td>-2.5146</td>
<td>0.1875</td>
<td>-2.5504</td>
<td>0.3537</td>
<td>0.2475</td>
<td>15.2876</td>
<td>3.4728</td>
<td>28.3901</td>
<td>13.2770</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>58.2443</td>
<td>6.2441</td>
<td>44.5709</td>
<td>7.8120</td>
<td>6.0719</td>
<td>269.6948</td>
<td>22.6142</td>
<td>91.9036</td>
<td>277.8154</td>
</tr>
</tbody>
</table>

Table 3: Descriptive statistics of Aluminum intraday returns and realized volatilities for the periods without night trading session (Panel A, January 4, 2010 – December 19, 2013) and with daily decomposition after introduction of the night trading session (Panel B, December 20, 2013–May 21, 2018).
As a possible contributing factor to the realized volatility of the NTS at the SHFE, we integrate the realized volatility at the LME for the most liquid Copper and Aluminum futures of the previous day (RV_{t}^{LME}) in Eq. (11.3) and during the evening break at SHFE of the same day (RV_{t+1}^{LME-EB}) in Eq. (12.3). In order to measure the impact the latter, we calculate the realized volatility at the LME over a window from 07:00 to 13:00 GMT. This period spans the evening break at SHFE and represents a time with high trading volumes at LME. In particular, this window covers price discovery of the LME Official Price for three months futures contracts of Aluminum and Copper, which is used as global reference price.

4. Results: What has changed with the introduction of the night trading session?

This section discusses our analysis of the impact of introducing an additional trading period at the SHFE. First, we focus on intraday returns and their decomposition to determine how the SHFE’s futures markets changed with the integration of a trading session that is synchronized with the LME’s and the COMEX’s main trading hours, in addition to the regular session. Second, we address the development of trading volumes to explore the importance of this new trading session in particular and the maturing of the SHFE in general. Finally, we study the realized volatilities of the separate trading sessions and their interconnectedness to explain whether Chinese metal futures’ volatility is driven by endogenous or exogenous factors. We finish with a note on jump estimation.

4.1. Intra-day return decomposition: on overnight and evening breaks

We follow the return decomposition introduced in Eq. (8) and compare descriptive statistics of the components which are presented in Table 2 for Copper and Table 3 for Aluminum. Box plots for these returns are visualized in Figure 3 and Figure 4 for Copper and Aluminum, respectively. Our subsamples are labeled T_1 for the period from

\footnote{17\text{Since the focus of this study is on Chinese industrial metal futures markets, no corresponding descriptive statistics are reported for the LME returns and realized volatilities for the sake of brevity. These statistics are available on request.}}
January 4, 2010 to December 19, 2013 and $T_2$ for the period after the introduction of the NTS running from December 20, 2013 to May 21, 2018.

We begin with the overnight return $r_{t_{ON}}^{T_1}$, defined in Eq. (2) before the introduction of the NTS and in Eq. (7) thereafter, which refers to the return between the closing price of the last traded five-minute block of the previous day and the opening price of the current day.\footnote{With the NTS, the overnight return is that between the NTS’s closing price and the regular session’s opening price, even though the NTS ends at 1:00 a.m. local time.} In $T_1$, the overnight return has the highest spread of outliers, ranging from -6.73 percent to 6.42 percent in the case of Copper. This range indicates that there are comparatively large overnight jumps and exogenous price shocks during the time in which the SHFE is not open for trading. After the introduction of the NTS, these previously volatile overnight returns become virtually non-existent in $T_2$. This is due to the fact that the overnight return in $T_1$ ($r_{T_1}^{ON}$) decomposes in $T_2$ into the return over the evening break ($r_{T_2}^{EB}$), the NTS ($r_{T_2}^{(2)}$), and the overnight return between NTS and next regular session ($r_{T_2}^{ON}$), according to Eq. (9). There are several possible explanations for the vanishing of $r_{T_2}^{ON}$, the most likely of which is that the LME is closed during those hours as well (Figure 1). These negligible overnight returns also indicate that the Chinese markets are not influenced to a significant extent by regular arrivals of news from other sources.

If there are no longer news effects or jumps during the SHFE’s now shortened overnight period, do news arrive exclusively during traded hours? The evening break period provides clear evidence that such is still not the case, as we find that returns from the evening break, $r_{T_2}^{EB}$ are significantly different from zero. Furthermore, these returns are much more distinctive than the overnight returns in $T_2$, as the mean and median are highly negative and are abnormal compared to those of $T_1$ or $T_2$ returns of the overnight, regular, or close-to-close periods. Therefore, we identify pronounced news arrivals and price jump effects in the evening break from the end of the regular session and the beginning of the night session. The previously significant overnight price movements are simply found in the evening break—after the regular session and before the NTS—and the NTS itself, which can now be controlled for separately with $r_{EB}^{T_2}$ and $r_{T_2}^{(2)}$. A possible explanation
for this are the trading session at the LME, where the ring trading session starts almost
two hours before the NTS at the SHFE begins. We note that the first and second ring
trading sessions for Copper and Aluminum fall into the evening break. For Copper and
Aluminum, the global reference price is discovered at the LME between 12:30-12:35 GMT
and 12:55-13:00 GMT, respectively. Furthermore, the continuous information flow (in-
cluding macroeconomic announcements) arriving during the evening break of the Chinese
markets is immediately reflected in the continuous trading activity of LMEselect, the
electronic trading system of LME, and has a significant impact on the opening dynamics
of the night trading session at the SHFE explaining the large evening break return at the
SHFE.

![Copper Return Decomposition](image)

Figure 3: Box plots of different intraday components for Copper following the decomposition in Eq. (8). Different disjoint periods are denoted by $T_1$ and $T_2$ which refer to the observations before (January 4, 2010 to December 19, 2013) and after (December 19, 2013 to May 21, 2018) the introduction of the NTS, respectively; yielding $n_1 = |T_1| = 959$ and $n_2 = |T_2| = 1076$ observations. The full sample of $n = 2035$
observations is plotted for $r^{ON}$, $r^{(1)}$, and $r^{CC}$. For $r^{EB}$ and $r^{(3)}$, which are defined for $T_2$ only, we omit
the index.

In this section, we identified several noteworthy effects of the introduction of NTS.
First, previously significant overnight returns at the SHFE vanish almost completely after
the introduction of the NTS. The NTS of the previous day dictates the opening price of
the current day, absent exogenous disturbances like news or contagion effects from other
markets. Second, extreme movements during trading sessions are reduced in magnitude
and numbers, perhaps because of a more evenly distributed trading time, where the NTS is
synchronized with the LME’s major trading hours. Third, the evening break has relatively large returns and now acts as the most important non-trading period at the SHFE when other markets are actively trading. While introducing a night trading session and with this, additional four hours of trading during the previous overnight (non-trading) period inevitably leads to a re-distribution of the previously observed large overnight returns, we are able to now narrow down the time slot from which the majority of the relevant information from the previous overnight period (before NTS) emerges, namely 7:00 am to 13:00 GMT. Finally, the magnitude of the large evening break’s returns underscores the necessity to treat it separately, as the literature is doing with overnight returns for major developed markets because returns during trading and non-trading market times have different dynamics (e.g., Andersen et al. 2011; Bertram 2004; Todorova & Soucek 2014).

4.2. Trading volumes: Has the SHFE become more attractive for traders with the introduction of the night trading session?

Copper volumes of the most liquid (3-month) futures contracts are plotted in Figure 5. With the introduction of the NTS, the plot distinguishes among total volume ($v_{T2}^{total}$), the

---

**Figure 4**: Box plots of different intraday components for Aluminum following the decomposition in Eq. (8). Different disjoint periods are denoted by $T_1$ and $T_2$ which refer to the observations before (January 4, 2010 to December 19, 2013) and after (December 19, 2013 to May 21, 2018) the introduction of the night trading session, respectively; yielding $n_1 = |T_1| = 959$ and $n_2 = |T_2| = 1076$ observations. The full sample of $n = 2035$ observations is plotted for $r^{ON}$, $r^{(1)}$, and $r^{CC}$. For $r^{EB}$ and $r^{(2)}$, which only exist in $T_2$, we omit the index.
volume in the regular session \((v^{(1)})\), and the volume in the NTS \((v^{(2)})\). How the originally reported volume evolves throughout our sample has several notable features.

First, sudden jumps in volume before the introduction of the NTS are present but are relatively infrequent, and if volume increases suddenly, it remains elevated for some time, suggesting some persistence. With the NTS, these volume spikes appear more frequently but are more short-lived, spanning only a few trading days. Second, the volume of the NTS was low compared to the regular session in the first year after being introduced to the SHFE. From 2015 on, the regular session’s and the NTS’s volumes are similar such that, if an abnormally high trading volume is observed in the regular session, the NTS also shows abnormally high trading volumes.

Unreported in this paper in detail is that the regular session’s and NTS’s volumes are almost perfectly correlated on daily resolution. This phenomenon reinforces that the appearance of sudden, short-lived volume spikes in the regular session is mirrored and further amplified in the night session, yielding very high total daily volumes. Overall, the trading volume after introducing the NTS appears to be much more volatile than before, and the NTS may be seen as a contributing factor to these higher deviations in volume.

![Figure 5: Volume of Copper SHFE futures decomposed to the respective components and smoothed by an MA(5). Different disjoint periods denoted by \(T_1\) and \(T_2\) are identical to the previous figures.](image)

We focus on the SHFE’s and the LME’s daily volumes to compare the development of traded volumes in global Copper futures markets. As of 2019, foreign individual investors are only allowed to trade crude oil, iron ore, and PTA contracts. Hence, foreign retail (individual) investors have no access to industrial metal futures traded at the SHFE. Institutional investors have access to Chinese futures under very restrictive conditions only.
For these reasons, the potential competition between SHFE and LME targets predominantly Chinese institutional or retail investors who, previously active at the LME, may relocate their trading activities to SHFE as a result of the extended trading hours. This may be particularly appealing as trading at the SHFE instead of at the LME gives local investors the opportunity to trade in Renminbi directly, thus avoiding currency exposure to the USD, if undesired. Furthermore, the NTS may target Chinese institutional traders from the LME Ring. As of 2019, there are nine Category 1 LME members, who can trade in the LME Ring, and there are Chinese companies among them (e.g., CCBI Metdist Global Commodities, GF Financial Markets). Potentially, these traders may be attracted by the NTS if the avoidance of a currency exposure prevails over the preference for batch trading.

We adjust the trading volume for the differing contract sizes (SHFE’s 5 tons vs LME’s 25 tons per contract), as well as the SHFE’s double-side count in terms of long and short positions in 3-month futures contracts, yielding the comparable volume measures that are plotted in Figure 6. We find no indications that the introduction of the NTS attracted investors who would otherwise trade at the LME, as volumes at the LME did not decrease; on the contrary, there was a slightly upward trend in trading volume at the LME. If we observe spikes in the LME’s daily volumes, they are also observed during the SHFE’s NTS. The SHFE’s volumes are much more volatile, underscoring the speculative nature of Chinese investors. Adding to the speculative character of the SHFE, we also observe a significant difference in trade size, defined as volume per trade, between the regular session and the NTS. Albeit of similar overall trading volume, the volume per trade is between 20 and 25 percent smaller during the NTS than it is during the regular session.

The volume per trade over each session on daily resolution, which is visualized in Figure 7, suggests that retail investors are more active in the NTS and that, given the correlated trading volume, some positions are opened in the regular session and closed later in the NTS. This finding is in line with the documented speculative activity, most of which

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\(^{19}\) We divide SHFE volumes by factor two and multiply LME volumes by factor five. The resulting numbers in Figure 6 are total numbers of traded contracts per day in the SHFE futures specification; that is, five tons per contract.
is conducted through high-frequency transactions (e.g., Liao et al., 2016, Wellenreuther & Voelzke, 2019). Furthermore, the volume per trade decreases sharply throughout the NTS, which is plotted for thirty-minute blocks of the NTS in Figure 5. Trade sizes are lowest in the later hours, and trade values average around USD 80,000-120,000, too low to be considered purely institutional trades that are present in each thirty-minute block, as indicated by large outliers. Volume per trade is negatively correlated with Copper prices, which is further indication for the significant involvement of small investors that is of a primarily speculative nature. Unreported in detail here, the open interest in the SHFE-specific counting underlines this conjecture by featuring highly volatile day-to-day changes.

Trading volumes for Aluminum are plotted in Figure 8 with an identical decomposition.
For this SHFE futures, the daily trading volumes are different from those of Copper. Between 2012 and 2013, volumes were low, and contracts were only thinly traded. In Q3 2015, trading of Aluminum futures picked up with significant jumps in volume. From this point of time on, trading volumes exhibited a magnitude comparable to that of Copper futures. In Q3 2015, it appears that the market underwent a major change in trading activity. Since the SHFE reflects domestic speculative activity far more than industrial hedging (Wellenreuther & Voelzke, 2019), the surge in trading volumes might largely be driven by retail investors in China seeking trading opportunities because of the government’s interventions in the Chinese stock markets (e.g., Home, 2018). Mid-2015 the Chinese government quasi-banned shortselling of stocks as a countermeasure against the stock market crash. A ban that was lifted in 2016 but later reinstated again. However, this ban drove speculators into futures markets of industrial metals where prices continued to decline. This sharp decline in prices additionally boosted hedging demand from producers in these markets, further increasing activity on futures markets. This effect is also visible in Figure 5 for Copper 3M futures, albeit of smaller magnitude as trading volumes are generally higher than those of Aluminum.

Overall, we observe a change in the distribution of daily trading volumes. While total trading volumes remain comparable between pre-NTS periods and NTS periods, the volume of the regular session is more than halved, so it appears that trading volume simply migrates from the regular session to the NTS; we find no evidence that trading volume is pulled from the LME to the SHFE. In addition, it appears that the increased
trading volume reflects mostly domestic speculative activity rather than international
industrial hedging, so the increased variability in the SHFE’s trading activity might be
due to Chinese speculators becoming more active with an additional, synchronized trading
session that allows them to trade immediately on news arrivals during the night. Finally,
Aluminum markets are in transition, and trading volume increased in late 2015, which
was not linked to the introduction of the NTS.

4.3. Realized volatilities: What drives the separated trading sessions?

Descriptive statistics of the realized volatility measures are given in Table 2 and Ta-
ble 3 for Copper and Aluminum, respectively. For Copper, we find that the 24h realized
volatility, as the sum of all intraday components, decreased after the NTS was introduced.
The regular session’s realized volatility declined by almost 40 percent on average and in
relative terms. Similar to the returns of the NTS and the evening break period, we find
that $RV_{ON}^t$ is small, while $RV_{EB}^t$ is significantly larger. The NTS’s average realized volatil-
ities are similar to those of the regular session, but their maximum, standard deviation,
skewness, and kurtosis indicate a much broader dispersion with more extreme values than
those of the regular session. The NTS is characterized by higher intraday movements
than those of the regular session, suggesting that the daytime trading session’s and the
NTS’s volatility behavior differs and may have differing drivers.

Moving to the HAR model estimations with Eq. (11.1)-(13.2), we detect several
changes with the introduction of the NTS. The estimation results, adjusted $R^2$, and error
measures for Copper are given in Table 4. We focus first on the realized volatility of the
regular trading session, $RV_{(1)}^t$. Comparing the estimates of the basic HAR of Eq. (11.1)
of the period before and after the introduction of the NTS reveals that the medium to
long memory, measured by $\beta_2$ and $\beta_3$, decreases in significance. In the second period,
the previous day’s realized variance becomes much more important, with a significant
load of $\beta_1 = 0.3600$, while the parameters of the weekly and monthly realized variance
decrease. Augmenting the base HAR with the evening break and the realized volatility
of the NTS of the previous day shows the long memory decreasing farther, driven largely
by the previous NTS’s realized volatility. We also note that the $R^2$ increases significantly
when the NTS is included. The previous day’s evening break is not significant. If we replace the previously augmented factors with the LME’s realized daily volatility, we observe similar effects regarding the long memory and the goodness-of-fit, although they are slightly lower. The only significant components are the LME factor and the regular session’s weekly realized volatility.

Second, the basic HAR using only daily, weekly, and monthly historical volatilities in Eq. (12.1) is a poor fit for the realized volatility of the NTS formalized in $RV_t^{(2)}$ in terms of the regression’s explanatory power. Considering that the NTS follows the regular session on the same day, we control for intraday movements that may affect the realized volatility on a larger scale. We use the regular session’s volatility of the same day ($RV_{t+1}^{(1)}$), as well as the same day’s evening break to cover this news arrival in Eq. (12.2) and find that NTS-specific regressors (daily, weekly, and monthly $RV^{(2)}$) are no longer significant. However, the evening break and the regular session of the same day are highly significant, suggesting that there is less variance memory in the NTS, as neither short-, medium-, nor long-term memory is present in the NTS. The impact of news during the evening break appears to be the most pronounced driver of $RV^{(2)}$. To find the source of this impact, we replace the evening break with the LME’s realized variance during these break hours only, denoted $RV_{t+1}^{LME-EB}$, in Eq. (12.3). The goodness of fit increases from 0.1825 in the base model to 0.4028 in the current modification. The LME’s volatility factor has an exceptionally high load of $\beta_5 = 0.7984$ and is significant, as is the regular session’s $RV$, indicating that the NTS is driven primarily by this exogenous, short-term variance in the LME, which is observed during the immediately preceding non-traded hours. As this data is of the same day, forecasting model Eq. (12.3) is no longer as straightforward as other specifications, and we find no indication that the realized variance of the NTS of the previous day or any other horizon plays a role. The discovery of the global benchmark price of Copper futures at LME during the evening break seems to have significant informational content for Copper price volatility at the SHFE.

Finally, we compare the findings for the sum of all daily realized variance components in $RV_t^{(24)}$ in Eq. (13.1) which includes the high overnight return $RV_t^{ON}$ before introduction
of the NTS, as described in Sec. 4.1. The basic HAR achieves a poor fit in the pre-NTS period, but the fit changes for the second period, perhaps because of the reduced impact of unexpected jumps in the overnight return that have moved to the evening break, and the subsequent trading reaction to these jumps in the NTS. We find a strong immediate reaction to the previous day’s daily realized variance and declining significance for longer horizons, a finding that remains when we augment the daily volatility with the LME’s daily realized variance of the previous day in Eq. (13.2), where this factor is not significant.

<table>
<thead>
<tr>
<th></th>
<th>( RV_t^{(1)} )</th>
<th>( RV_t^{(2)} )</th>
<th>( RV_t^{(24)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_1 )</td>
<td>( T_2 )</td>
<td>( T_3 )</td>
<td>( T_4 )</td>
</tr>
<tr>
<td>( \beta_0 )</td>
<td>0.1458</td>
<td>0.1377</td>
<td>0.0854</td>
</tr>
<tr>
<td>( \beta_1 )</td>
<td>0.0034</td>
<td>0.0304</td>
<td>0.0307</td>
</tr>
<tr>
<td>( \beta_2 )</td>
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<td>0.0880</td>
<td>0.1860</td>
</tr>
<tr>
<td>( \beta_3 )</td>
<td>0.0011</td>
<td>0.0875</td>
<td>0.2851</td>
</tr>
<tr>
<td>( \beta_4 )</td>
<td>0.1200</td>
<td>0.0867</td>
<td>0.0720</td>
</tr>
<tr>
<td>( \beta_5 )</td>
<td>0.0012</td>
<td>0.0912</td>
<td>0.2095</td>
</tr>
</tbody>
</table>

Table 4: Parameter estimation results and robust standard errors in parenthesis of Copper futures for the HAR specifications defined in Eq. [11.1] - [13.2]. \( \beta_1, \beta_2, \) and \( \beta_3 \) denote the dependent variable’s own previous day’s, week’s and month’s components, respectively. In model [11.2], \( \beta_4 \) and \( \beta_5 \) denote the immediately preceding night trading session and evening break, respectively. In model [11.3], \( \beta_4 \) denotes the immediately preceding realized volatility of the LME Copper futures contract. In [12.2], \( \beta_4 \) and \( \beta_5 \) denote the day-time trading session and evening break on day \( t \), respectively. In [12.3], \( \beta_4 \) and \( \beta_5 \) denote the immediately preceding day-time trading session at SHFE and the realized volatility at LME during the evening break on day \( t + 1 \), respectively. In Eq. [13.2], \( \beta_4 \) denotes the LME realized volatility on day \( t \). The estimates are obtained with a White adjusted heteroskedastic consistent least-squares regression with robust standard errors given in parenthesis.

The estimation figures for Aluminum futures, given in Table 5, show that the results for the regular session already differ from those of Copper. The long-term component measured by \( \beta_3 \) is significant throughout all modifications in Eq. [11.1]-[11.3]. Hence, a pronounced long memory in realized variance is detected which is not present in Copper futures. Shocks to variance die out at a much slower rate. The realized variance from the immediately preceding NTS has a significant impact on the regular session with \( \beta_4 = 0.2406 (0.0160) \) similar to what is identified for Copper in Eq. [11.2]. Replacing the NTS and evening break with the LME’s volatility in Eq. [11.3] decreases the goodness-of-fit and does not result in the LME having a significant impact (\( \beta_4 = 0.0049 (0.0086) \)) for the
regular session.

For the NTS, we again detect significant long memory in realized variance measured in $\beta_3$ in Eq. (12.1)-(12.3). This is fundamentally different from what we find for Copper. The realized volatility of the regular session of the same day appears to be the strongest driver of the immediately following NTS. The realized volatility of the NTS degenerates to two significant components. Firstly, an underlying long-memory component of previous shocks and RV average measured by $\beta_3$ remains significant. Secondly, a short-term impulse is generated from the realized volatility of the regular session of the same day measured by $\beta_4$ in Eq. (12.3). This translates to a straightforward mirroring of the regular session. If the volatility of price movements in the regular session is high (low), the volatility of the NTS is likely to be high (low) as well. We detect the same phenomenon for Copper. In contrast, neither the evening break nor the realized volatility estimate for the corresponding LME contract has a significant impact. The same holds for the 24-hour realized variance $RV_t^{(24)}$ (Eq. 13.1).

These results corroborate the findings regarding the increased trading volume in the SHFE’s Aluminum futures. The Aluminum futures market in China seems to have become a popular venue for speculative activities, so the market volatility in the NTS or over a 24-hour period is driven mostly by the own volatility dynamics, with less improvement in explanatory power when the LME’s realized volatility is included in the regressions. Copper in contrast, has not seen such growth rates in volume.

One of the contributing factors to this difference in the behavior of volatility in these markets stems from China’s market position. China is the top importer of primary Copper and accounts for roughly 40% of global imports. For Aluminum, China imports raw materials for the production of primary Aluminum where a significant share is then exported (Ding et al., 2016). China is self-sufficient in the Aluminum production and a net-exporter (ITC, 2019). Being an importer for Copper, markets are more affected by exogenous factors such as price shocks or elevated volatility in global markets. In the recent years, China’s critical external mineral dependence peaked at 69% for copper and 52% for aluminum (Zhang et al., 2018b). Being self-sufficient in the production and con-
sumption of Aluminum, the domestic futures markets seems to be encapsulated and not prone to significant sensitivity from exogenous factors. This phenomenon is known from other commodity markets such as crude oil (Sun et al., 2013, Boldanov et al., 2016, Lyócsa et al., 2019, Alqahtani et al., 2019).

Furthermore, the difference between the response of Chinese copper and aluminum futures contracts to their international counterparts is confirm to the finding of Chen et al. (2005) that the market response of actively traded futures to information shocks (among which these authors assign copper) is greater than those of less actively traded futures (among which these authors assign aluminum). Moreover, a more recent study (Zhang & Tu, 2016) finds copper to be more susceptible to international oil price shocks than aluminum. Zhang & Tu (2016) relate this stronger extent of transmission observed in the Chinese copper market to its maturity, liquidity and depth as compared to the aluminum market. Furthermore, the copper market is regarded as the most regulated and stable futures market in China (Zhang & Tu, 2016) and as such is more likely to be highly responsive to the international news flow.

Overall, we find that the behavior of realized volatility differs before and after the introduction of the NTS, so there are grounds for labeling this event a change point in volatility behavior. For Copper, the regular session becomes more predictable based on its own short-term history and the realized variance of the previous NTS. The newly introduced NTS is driven primarily by intraday factors: the regular session’s realized variance, the subsequent break in the same day, and most important, the LME’s realized variance during that break. This evidence indicates that there is a strong spillover effect from the LME to the SHFE’s NTS Copper markets. The once-important overnight period shrinks from 18.5 hours to 8.5 hours of no trading activity and is replaced by the evening break, with the LME as the main contributor of news impact on the SHFE. It appears that the regular session is an isolated session for Chinese investors and hedgers, with

\[20\] A further channel for explaining these results may stem from the existence of AL alloy, NASAAC and Alumina contracts traded on LME. The aluminum price discovery mechanism on LME might potentially be fragmented across (non-close) substitute contracts, such that none of them, including the comparable primary AL contract, could influence the AL futures pricing on SHFE and hence its volatility. This pathway is left to future research. We would like to thank an anonymous reviewer for this comment.
some degree of medium-range memory, while the NTS is driven primarily by the LME and short-term movements. For Aluminum, we find no evidence that the LME spills over to the SHFE, as Aluminum futures seem to be affected mainly by local news and less by the volatility coming from the LME.

4.4. On the severity of ignoring paused trading and the evening break

Extant research has usually separated the overnight break from intraday price movements for the purposes of volatility estimation and forecasting. Our findings and discussion suggest that the evening break and NTS should be separated in cases that are specific to the SHFE, as its dynamics are more significant than the overnight period. As we identified the differences in volatility behavior beginning in late December 2013 with basic HAR models, we do not use more sophisticated HAR-specifications that include jumps. However, we briefly demonstrate the impact on jump components and their detection of not treating the NTS as a separate period ignoring the evening break. In particular, some examples of affected models are HAR-CJ (Andersen et al. 2007), LHAR-CJ (Corsi & Reno 2012), or HAR-∆J (Patton & Sheppard 2015), which split the realized variance

<table>
<thead>
<tr>
<th>Model</th>
<th>RV₁(1)</th>
<th>RV₁(2)</th>
<th>RV₁(24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>T₂</td>
<td>T₂</td>
<td>T₁</td>
</tr>
<tr>
<td>β₁</td>
<td>0.0801</td>
<td>0.0727</td>
<td>0.0734</td>
</tr>
<tr>
<td>(0.0174)</td>
<td>(0.0225)</td>
<td>(0.0198)</td>
<td>(0.0267)</td>
</tr>
<tr>
<td>β₂</td>
<td>0.3636</td>
<td>0.2544</td>
<td>0.1533</td>
</tr>
<tr>
<td>(0.1277)</td>
<td>(0.0768)</td>
<td>(0.0740)</td>
<td>(0.0678)</td>
</tr>
<tr>
<td>β₃</td>
<td>0.1024</td>
<td>0.0903</td>
<td>0.0873</td>
</tr>
<tr>
<td>(0.0086)</td>
<td>(0.0712)</td>
<td>(0.0683)</td>
<td>(0.0812)</td>
</tr>
<tr>
<td>β₄</td>
<td>0.2406</td>
<td>0.0424</td>
<td>0.0424</td>
</tr>
<tr>
<td>(0.0160)</td>
<td>(0.0086)</td>
<td>(0.0091)</td>
<td>(0.0077)</td>
</tr>
<tr>
<td>β₅</td>
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<td>0.0620</td>
<td>0.0620</td>
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<tr>
<td>(0.0056)</td>
<td>(0.0056)</td>
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<td>(0.0056)</td>
</tr>
</tbody>
</table>

Table 5: Parameter estimation results and robust standard errors in parenthesis of Aluminum futures for the HAR specifications defined in Eq. (11.1) - (13.2). β₁, β₂, and β₃ denote the dependent variable’s own previous day’s, week’s and month’s components, respectively. In model (11.2), β₄ and β₅ denote the immediately preceding realized volatility of the LME Aluminum futures contract. In model (11.3), β₄ and β₅ denote the day-time trading session and evening break on day t, respectively. In (12.3), β₄ and β₅ denote the immediately preceding day-time trading session at SHFE and the realized volatility at LME during the evening break on day t + 1, respectively. In Eq. (13.2), β₄ denotes the LME realized volatility on day t. The estimates are obtained with a White adjusted heteroskedastic consistent least-squares regression with robust standard errors given in parenthesis.
into a continuous component and a jump component or include separate jump measures in the HAR framework.

The overall aim of this section is to provide evidence that the pause between the regular session and the NTS, which spans six hours, needs to be separated from the intraday data set, resulting in two separate intraday sets of high frequency data. This paper is the first that highlights this issue of the necessity of additional data pre-processing when dealing with high-frequency data from exchanges that feature an NTS.

If we would not separate the regular session and the NTS, the evening break $r_{EB}$—or in other words, the log difference of $P_{t,close}^{reg}$ and $P_{t,open}^{NTS}$—is treated as a intraday return of the chosen sampling frequency of the regular and night trading session, in this paper 5 minutes.

Assume the case of Copper. According to Table 2 and Table 6, the evening break $r_{EB}$ has a mean of $-0.0329\%$, a minimum of $-1.9488\%$, and a maximum of $2.4520\%$. The average 5-minute intraday return over all 5-minute returns over all daily observations in $T_2$ in the regular session is $-0.000096\%$ with an average minimum of $-0.2987\%$ and an average maximum of $0.2963\%$. For the NTS, the average is $0.000716\%$ with an average minimum of $0.2463\%$ and average maximum of $0.2502\%$. Differences of similar magnitude between the evening break return and intraday returns for the regular session and NTS are observable for Aluminum.

<table>
<thead>
<tr>
<th></th>
<th>Copper</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r_{EB}$</td>
<td>$r_{(1)}^{r_{t,j}}$</td>
</tr>
<tr>
<td>Mean</td>
<td>$-0.032900$</td>
<td>$-0.000096$</td>
</tr>
<tr>
<td>Min</td>
<td>$-1.948800$</td>
<td>$-0.298700$</td>
</tr>
<tr>
<td>Max</td>
<td>$2.452000$</td>
<td>$0.296300$</td>
</tr>
</tbody>
</table>

Note: 5-minute intraday returns of the regular session are denoted by $r_{(1)}^{r_{t,j}}$ with $j = 1, \ldots, M - 1$ while intraday returns of the NTS are denoted by $r_{(2)}^{r_{t,j}}$. For the minimum and maximum, we calculate the average over the minimum and maximum for each day $t \in T_2$.

Table 6: Comparison of the dimensionality of the evening break return $r_{EB}$ and 5-minute intraday returns for the regular session and the NTS for Copper and Aluminum underlying the necessity to separate $r_{EB}$ from the set of 5-minute intraday prices.

From Table 6 it becomes evident that the mean, minimum, and maximum of the evening break return $r_{EB}$ are several magnitudes greater than 5-minute returns in the regular session and NTS, both for Copper and Aluminum. The mean of $r_{EB}$ is roughly
350 (45) times greater than the intraday return mean in the regular (night trading) session for Copper and 13 (15) times for Aluminum.

Now under the assumption of not separating the intraday sets and the evening break, this \( r^{EB} \)—now element of the set of all 5-min intraday returns—is treated as 5-min return in all jump tests or even separations into jump and continuous components in HAR modeling. Given that this \( r^{EB} \) is—on average—several magnitudes greater than true 5-min returns, it severely biases all calculations involving intraday returns. Firstly, wrongly including \( r^{EB} \) in the set of 5-minute returns causes an upward bias in the daily measure of realized volatility \( RV_t \), which is the sum of squares of all 5-min returns, now including \( r^{EB} \). Secondly, all following measures like the bi-power variation \( BPV_t \) become biased for the same reasons as above. Thirdly, these effects cause the jump detection with \( J_{t,\alpha} \) as outlined in Eq. (14) and the following definitions utilizing the \( MedRV_t \) measure (now also upwardly biased) with \( J_{t,\alpha}^{MedRV} \) to detect this \( r^{EB} \) as an intraday jump over a period of 5-min.

These jumps are clearly falsely identified jumps as they do not stem from 5-min returns or any price movement on high frequency resolution. They are simply a price movement over several non-traded hours. Hence, they cannot be treated as intraday jump, nor utilized as such in separating the \( RV_t \) in more sophisticated models and we find an absolute necessity to separate this \( r^{EB} \) as it is being done with other non-traded periods (e.g. the overnight return) in high frequency data modeling.

If we do separate the evening break from the high frequency data sets, only true 5-min returns remain in the sets, yielding a correctly calculated \( RV_t \) and all other measures, including jumps.

In what follows, we calculate jump components according to the definition of Eq. (14) for the case of no separation \( (J_{t,\alpha}^{no\text{-sep}}) \) and correctly separated for the regular session and the NTS as the daily sum of intraday jumps \( J_{t,\alpha}^{reg} + J_{t,\alpha}^{NTS} \). We repeat these calculations for the \( MedRV \) measure of Andersen et al. (2012). The results are visualized in Figure 9 for both types of measures for Copper futures.

Figure 9 makes clear that neglecting to separate the evening break yields more pro-
Figure 9: Top: Jump components without separating the evening break (\(J_{t,\alpha}\), blue) and as sum of the jump components of the regular session (\(J_{reg,t,\alpha}\)) and the NTS (\(J_{NTS,t,\alpha}\)) with separation of the evening break (red). Bottom: Analogous plot with a jump detection based on the median RV (MedRV) approach of Andersen et al. (2012).

nounced jump components and indicates jumps during trading hours where there are none. Of course, some jumps remain during the regular session’s and the NTS’s trading hours, but these are less regular than by failing to separate the regular session and the NTS. This effect holds for both jump measures, but it becomes more obvious when the MedRV measure is used, as it is more robust to very small and very high jumps. With the separation, far fewer jumps are detected. Hence, ignoring the evening break as such introduces a positive jump bias. For the MedRV measure, roughly 59% of all detected jumps disappear if the evening break is separated. If we only consider jumps of significant magnitude, that is all jumps measures at the 75th percentile, 73% of jumps are wrongly identified and vanish when separating the evening break.

Subsequently, models that cover jumps separately (e.g. the HAR-CJ) are likely to yield more significant (in both magnitude and statistical significance) jump components, which might lead to spurious conclusions based on non-existent jumps. This is simply due to the fact that these jumps should have not been identified as such in the first place. The aim of this paper is not to highlight any decline in jumps nor present the separation as optionality. Removing \(r^{EB}\) is an absolute necessity as otherwise, all calculations are biased or even wrong, rendering all following HAR modeling and results questionable at best.
All calculations of high frequency measures such as $RV_t$ and $BPV_t$ should only be based on intraday data sets, in the case of SHFE data two separate sets per day, intermitted by a separated $r^{EB}$.

Hence, one of the main findings of our paper is that correctly separating $r^{EB}$ is of utmost importance when calculating $RV$’s and jump measures. We are the first to even address this issue in written as we observe a growing number of research targeting high frequency data in Chinese markets.

In general, the reasons for jumps being detected by either of the introduced jump measures are manifold. Examples are residuals of microstructure noise, news arrival, (changes in) sentiment, and liquidity issues. Usually, intraday jumps are irregular and pose challenges to forecasting (Degiannakis & Filis, 2018, Degiannakis et al., 2020, Luo et al., 2019), whereas the importance of jumps with respect to volatility prediction varies across commodities (Prokopczuk et al., 2016). Nguyen & Prokopczuk (2019) find that jumps in commodity markets are correlated across markets to a certain extent. This manuscript does not explore what causes or drives these jumps but rather highlights that without separation of the evening break, a false jump within a 5min data window of significant magnitude and regular occurrence would be recorded. However, the evening break spans multiple hours and as such, does not qualify to be considered a jump by the defined intraday measures in the same sense that overnight returns are separated and treated differently regarding intraday volatility.

These findings have several practical implications. Risk management that is based on forecasts of realized volatilities is affected if the two trading sessions are not separated. Forecasting volatility of intraday prices in the presence of jumps is a particular difficulty (Corsi & Renò, 2012, Degiannakis & Filis, 2017, Luo et al., 2019), especially over longer time horizons. Having a positive jump bias and subsequently an increased volatility premium might also affect the pricing of derivatives themselves.

The results for Aluminum futures prices are qualitatively the same in terms of biased jump detection if the evening break is not separated. For the sake of brevity, detailed results are not presented here but are available on request.
5. Conclusion

We focus on the introduction of an additional trading session at the SHFE and its effects on Copper and Aluminum futures’ trading volumes and intraday price movements, as well as its role in global markets. Copper’s volatility behavior changed prominently at the end of 2013, as the NTS introduction caused a structural break in intraday dynamics of realized volatilities and prices. Previously large, the overnight return vanished and was replaced by returns from an evening break that had a strong impact on the volatility during the NTS. The synchronous trading with the LME during the NTS reduced overnight jumps as news predominantly arrive either during the evening break during or the NTS. The evening break is a significant factor in intraday movements and should be separated to avoid introducing a jump bias. The significance of this finding for research will increase as the popularity of modeling the intraday data of futures markets increases.

The volatility of Copper futures is largely affected by the LME, mainly during the NTS. On the other hand, the regular session depicts a short- and medium-term memory and is driven by endogenous elements. The LME seems to have negligible impact on the regular session, but it is an important exogenous driver for the NTS. No additional trading volume is detected after the introduction of the NTS, as the volume simply split between the regular session and the NTS. The LME, on the other hand, showed increasing volume, so there is no evidence that the SHFE pulled volume from the LME. Furthermore, the volatility of the SHFE’s trading volume increased after the introduction of NTS. Speculative investors may be exploiting the longer trading times, as indicated by the NTS’s volumes mirroring those of the previous regular session, which suggests that some positions are opened during the regular session and closed during the NTS. During the NTS, the trading volume per trade is 20-25 percent smaller than it is in the regular session, which suggests increased retail investor activity in the NTS.

In contrast, the Chinese Aluminum futures market seems to be more resistant against exogenous factors and to show a pronounced long-memory structure. The LME had no significant impact on either the NTS or the daily realized variance. Aluminum futures markets are in transition, with volume picking up significantly since late 2015, largely
driven by retail investors in China seeking new avenues for trading. Two contributing reasons to this apparent difference in volatility behavior are discussed here. Firstly, Aluminum markets have seen an unprecedented increase in speculative trades after the short-selling ban mid-2015. Secondly, China is an importer of primary copper while the consumption of primary aluminum is covered by its own production. This degree of self-sufficiency encapsulates the domestic physical and futures markets of Aluminum and makes them less sensitive to exogenous factors.

The present study work is the first to provide clear evidence that the gap between the regular session and the NTS should be handled accordingly to avoid compromising realized volatility models like HAR. The findings also indicate that the LME is the main driver of the evening break’s dynamics in the Chinese Copper markets, which could be exploited in more encompassing HAR specifications. Future research could also address in more detail jump models that incorporate the evening break. It would be of interest to analyze jumps and their correlation between the SHFE and LME. Drivers of these jumps remain to be identified. Finally, while we focus on Copper and Aluminum, NTSs have been introduced for most Chinese commodity futures contracts, so the analysis at hand can be extended to investigate the volatility of other commodity futures in China and their corresponding international benchmarks.
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