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Risk of window dressing: Quarter-end spikes in the Japanese yen Libor-OIS spread *

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Abstract

It is well documented in literature that funding condition has been subject to the undue influence of distorted incentives of banks to lend and borrow at quarter ends under Basel III. We investigate whether or not funding risk possibly also suffers the same. Using a state space model, we find quarter-end spikes in the Japanese yen Libor-OIS spread, which arguably reflect a higher funding risk premium at quarter ends, during the global financial crisis and in recent years. The phenomenon in the former episode suggests that quarter-end reporting under Basel II might already have an effect on the functioning of funding markets, as banks found the capital ratio requirement sharply more binding or constraining. The spikes in the latter episode, which are attributable to the effect of the leverage ratio requirement under Basel III, are found to be negative, reflecting partly the scarcity of high-quality collaterals against the backdrop of a large-scale asset-purchase programme introduced by the Bank of Japan and partly a negative interest rate environment. The evidence adds to the argument in favour of supervisory practices that require banks to report/disclose their average leverage ratio for the quarter instead of their ratio for the last day of the quarter. However, despite the currently proposed reform, given that the capital ratio remains quarter-end-based, there could still be quarter-end spikes in funding risk premium in times of financial adversity.

Keywords: Libor-OIS spread, negative interest rate, liquidity risk, Basel III

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I. INTRODUCTION

This paper is motivated by the peculiar phenomenon of quarterly spikes in the cost of funding in the global banking network, which is arguably caused by regulatory reporting to central banks or other banking supervisory authorities concerned under the Basel III accord. Generally speaking, banking regulations are aimed to protect the safety and soundness of the banking system. Disturbance caused by regulations to financial markets due to compliance reasons should be kept to a minimum from an efficiency point of view. In particular, any unintended compliance consequences should be dealt with promptly and properly.

Recent findings of quarter-end disruptions to global funding markets therefore concern central banks. A study group under the Committee of the Global Financial System (CGFS) (2017) on repo market functioning devotes a great deal of its report to examining the impacts of quarter-end reporting on the behaviour of banks in providing liquidity.[5] In the literature, Munyan (2015), Arai et al (2016), Borio et al (2016), Bicu et al (2017), Egelhof et al (2017) and Du et al (2018) all observe some quarterly irregularity in the repo, cross-currency swap or other funding markets that is attributable to the new reporting requirement under Basel III.

Worse still, the hiccups caused by quarter-end reporting to funding conditions are not uniform or easily predictable. This is manifested in considerable volatility in both prices and volumes in funding markets over quarter ends.[6] The resulting uncertainty could cause increases in funding risk to banks during those intervals, adding an unnecessary burden, if not another source of instability, to the global financial system. The potential scale of the problem has caught the attention of the Basel Committee on Banking Supervision (BCBS), prompting it to issue a newsletter to condemn

[5] What is reported, rather than when or the frequency at which it is reported, actually holds key to the potential influence on banks' behaviour. As we shall discuss in the next section, their behaviour presumably should not change if they are required to report certain financial ratios as in their average in the quarter. It changes because they have to report the ratios as of the last day of the quarter, i.e., the supervisor takes only a snapshot of their balance sheet.

[6] CGFS (2017) "observed that repo markets have recently been characterized by volatilities in prices and volumes over period-ends (quarter-end and year-ends). This is likely to be driven by incentives that banks face to 'window-dress' their balance sheets. These incentives include regulatory constraints, such as the leverage ratio, the G-SIB surcharge and the SRF levy, but also include commercial or taxation considerations."

the window-dressing behaviour and subsequently also a consultative document to propose remedial revisions to leverage ratio disclosure requirements at the end of 2018 (BCBS, 2018a and 2018c). In view of supportive responses received from market participants and regulators, BCBS subsequently revised disclosure requirements on leverage ratios to add disclosures based on daily average values of securities financing transactions, to be effected in 2022 (BCBS, 2019b).

While the phenomenon of quarter-end spikes seems to be fairly recent according to the studies, quarterly reporting has actually been in place for quite some time. No doubt, the details of the leverage ratio framework under Basel III came to light only in 2014 and public disclosure began only in 2015 (BCBS, 2019a). However, before then, there had already been the capital ratio requirement under Basel II, which had been adopted by practically all major economies by 2008 (Bank for International Settlements, 2010). Under severe market conditions, the capital ratio requirement can be considerably more binding for banks, constraining excessive leverage in a similar way as leverage ratio does in calmer times (Brei & Gambacorta, 2014).

In fact, quarterly reporting requirements at the peripheral of the banking system could have caused strain to the funding market even before Basel II. In the US, such requirements for banks date back to 1976 and banks have since been required to file Consolidated Reports of Condition and Income (commonly referred to as “Call Report") for regulatory agencies' monitoring and inspection. Later in 2002, the Sarbanes-Oxley bill was enacted, requiring listed firms to disclose off-balance sheet items. During the global financial crisis (GFC), major regulators including the Securities and Exchange Commission and Japanese Financial Services Agency also made quarterly reporting mandatory for listed firms and a wide range of financial entities such as mutual funds.

This paper investigates whether or not funding liquidity risk (referred to as funding risk for short hereafter) also heightens at quarter ends as a consequence. Our investigation focuses on the Japanese yen (JPY) Libor market, probably the most popular funding currency in the world (Christiansen et al, 2011). JPY is also one of the most internationalised

currencies, which ranks fourth in terms of SWIFT payments and third in terms of foreign exchange turnover.[7] While US dollar (USD) is the most important international funding and payment currency, this study does not focus on the funding liquidity risk of the greenback because US banks are under quarterly average reporting regime for practically all Basel III requirements including, in particular, the leverage ratio.

The empirical work covers a much longer period of time than in previous studies. It contributes to the literature with three major findings. First, we find that quarter-end reporting results in quarter-end spikes not only in funding cost but also in the Libor-OIS spread, which is arguably attributable to increases in funding risk premium. Second, previous studies find spikes in funding cost only after 2014 but our results show that there were also spikes in the spread during the GFC. This means that in the absence of a leverage ratio requirement, the effect of quarter-end reporting can still spike up significantly in a stressful environment when the capital ratio requirement becomes binding or constraining. Third, the quarter-end spikes in the spread are negative in a negative interest rate environment.[8] This ostensibly counter-intuitive result is somewhat intriguing because it means that funding risk premium is also negative. As we shall discuss in more detail, the risk premium is negative as the penalty falls on the banks that are caught with excess liquidity in a negative interest rate environment.

This paper is organized as follows. In the next section, we review existing literature on the phenomenon of quarter-end spikes. Section III explains our methodology to detect the quarter-end spikes in funding risk. The empirical results are reported in section IV. Section V concludes with a brief discussion of the policy implication.

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[7] According to SWIFT, JPY's share as a domestic and international payments currency was 3.3% in January 2019, trailing behind USD (40.1%), EUR (34.2%) and GBP (7.1%). According to the BIS Triennial Central Bank Survey in April 2016, JPY accounts for 11.0% of the total OTC foreign exchange turnover, second only to USD (44.1%) and EUR (15.6%).

[8] The existence of paper currency, i.e., cash, provides depositors a choice to hold cash when a negative interest rate is applied. Therefore, ZLB is a theoretical boundary for policy rates to be effective. In reality, however, negative interest rate policy is feasible as there are costs associated with holding cash. Euro Area, Switzerland, Denmark and Japan once all entered a negative interest rate era.

II. QUARTER-END EFFECTS ON FUNDING CONDITION AND FUNDING RISK

Over the past decade, the global financial landscape has encompassed considerable changes, as supervisory authorities around the world gradually implemented regulatory reforms with a view to strengthening the resilience of banks. Among these reforms, Basel III requires banks to report/disclose their leverage ratio—essentially Tier 1 capital divided by a non-risk-weighted total exposure measure including both on- and off-balance sheet items—on a quarterly basis, which has greatly impacted the behaviour of banks in borrowing and lending. As of November 2018, 26 out of the 27 Basel Committee jurisdictions had leverage ratio reporting in force (BCBS, 2018b).

It is important to point out that quarter-end reporting *per se* is not the issue. The issue is whether banks are required to present a general picture of their financial conditions for the quarter, e.g., reporting some average ratios for the quarter, or specifically the state of their financial conditions as of the end of the quarter, i.e., providing just a snapshot of the conditions on the last day of the quarter. In the US they are required to report the ratios using the daily or monthly average figures in the quarter, a practice that may be referred to as quarter-average reporting.[9] However, in most other countries, including Japan, Switzerland and those in the euro area, the required ratio is the one for the last day of the quarter.[10] The latter supervisory practice, which indirectly encourages banks outside the US to window-dress their balance sheet at certain times through reducing the size or changing the composition of their assets, has far-reaching implications for funding markets.

One of the outcomes is that non-US banks have the incentives to strategically avoid taking short-term positions towards quarter ends to keep their leverage low. The overnight repo market is perhaps most clearly affected. Although US banks supposedly do not have the same incentives, funding markets have no national boundary. Considerable foreign participation means that US dollar funding is arguably subject to the same influence of foreign supervisory practices. Munyan (2015) shows contrasting

[9] Generally speaking, daily average is calculated for on-balance sheet assets and month-end average for off-balance sheet exposures.

[10] UK authorities followed their US counterparts to require banks to report their quarterly average ratios at the end of the quarter from Q1 2017. UK banks used to submit their month-end ratios on a monthly basis.

seasonality patterns in the daily repo positions between quarter-end reporting banks and quarter-average reporting banks. Egelhof et al (2017) provide a lucid account of how different US and non-US banks behave in the USD overnight repo market. They find that between Q1 2016 and Q1 2017 European banks lend an average of only a net $0.25 billion per day on quarter-end dates in the interdealer repo market, compared to a whopping net $33 billion per day on average during the quarter.

Quarter-end reporting does not only affect overnight funding. To keep leverage low at the end of the quarter, quarter-end reporting banks would refrain from engaging in one-week lending in the last week of the quarter or one-month lending in the last month of the quarter, as any such lending will appear on the balance sheet as of the last day of the quarter.[11] Put it another way, they have less incentive to lend in the one-week market in the last week of the quarter than in the previous 12 weeks; their appetite for lending one-month is also likely to be more subdued in the third month of every quarter than in the first two months. Not surprisingly, Arai et al (2016) find that US banks tend to raise rates at the short end of the money market towards quarter ends due to stricter leverage ratio requirements imposed in 2013. Borio et al (2016) show that one-week repo rates and the one-week USD/JPY cross-currency basis have started to exhibit quarter-end spikes since 2014, and argue that the spikes reflect increasing difficulty in arbitrage due to greater importance attached to quarter-end reporting and regulatory ratios following regulatory reforms. Similar observations in the one-week and one-month (but not the three-month) bases in the cross-currency basis swap markets are also documented by Du et al (2018), who attribute it to higher balance sheet costs arising from the quarterly risk-weighted and non-risk-weighted capital requirements for banks under Basel III.

Besides active window dressing ahead of regulatory reviews, banks may also adjust their positions towards quarter-ends in response to clients' demand. Some studies refer to it as the "passive" window dressing or preferred habitat for liquidity, which is practised by money market lenders who tend to hold more cash towards quarter ends to meet their obligations

[11] Loans of the three-month or longer tenor, no matter at which time of the quarter they are made, cannot escape from being captured by the snapshot at quarter ends and are thus not subject to the same distortive incentive.

such as coupon payments and other financial commitments (Griffiths & Winters, 2005; Kotomin, & Winters, 2006). However, the impact of such passive window dressing on funding markets appears minimal as there are no noticeable quarter-end spikes in the repo and Libor rates in the pre-GFC period or in the period between GFC and the introduction of the leverage ratio disclosure requirement. In any case, if, for some reason, the passive window dressing behaviour would only kick in when banks get closer to hitting regulatory constraints, then the existence of such behaviour should reinforce the observations about the possible impact of quarter-end reporting on funding rates as discussed above.

As a result of banks' or their clients' desire to window-dress towards quarter ends, the associated unpredictability of the funding conditions at those times raises funding risk. As observed by the CGFS (2017), repo markets have in recent years been characterized by greater volatility in prices and volumes over quarter ends. We find this also happens to the interbank money market. Table 1 shows that Libor's volatility is significantly higher towards quarter ends than during the rest of the quarter. The increase in the volatility is more obvious when Libor is de-trended. Arai et al (2016) find that uncertainty about funding conditions at quarter-ends also reduces global banks' market-making activities in the cross-currency swap market. It is alleged that uncertainty about quarter-end funding rates makes it difficult for market-makers to quote bid/ask spreads for term instruments in the FX swap market over quarter ends. They show that the average hourly bid-ask spreads for the USD/JPY and EUR/USD currency forwards are usually much wider during quarter ends.

Table 1. Test for equality of variances of JPY Libor during quarter-end

	1W	**1M**	**1W De-trended**	**1M De-trended**
Test for equality of variances				
F-test	4.57 ***	1.03	11.38 ***	2.12 ***
	0.00	*0.35*	*0.00*	*0.00*
Siegel-Turkey	2.27 **	0.79	5.80 ***	5.77 ***
	0.02	*0.43*	*0.00*	*0.00*
Bartlett	668.54 ***	0.85	2,128.94 ***	477.61 ***
	0.00	*0.36*	*0.00*	*0.00*
Std. Dev.				
Quarter end	0.50	2.10	0.38	0.08
Rest of quarter	0.24	2.07	0.11	0.05

Notes:

1. Probabilities are in *italic*.
2. ***, ** and * denote statistically significant at 1%, 5% and 10% levels.
3. Sample covers all available data, i.e., 1 Dec 1997 to 12 June 2018 for one-week Libor and 2 Jan 1990 to 12 June 2018 for one-month Libor.
4. De-trended Libor refers to the cyclical component of Libor after applying HP filter.

Meanwhile, there has been a major reappraisal of counterparty and funding risks since the GFC. This is reflected in the gap between the Libor and the rate of the overnight indexed swap (OIS) (Chart 1). The Libor is essentially an interest rate at which banks lend to each other on an uncollateralized basis in the Eurodollar market and, hence, considerable counterparty and funding risks are involved. However, OIS, which requires no exchange of principals, instils a minimum of these risks. The different nature of the two kinds of transactions renders the Libor-OIS spread a widely-accepted measure of counterparty and funding risk premiums, although there has been an intense debate about which risk premium might have accounted for more of the spread during crisis periods (Michaud & Upper, 2008; Hou & Skeie, 2014; Iida et al, 2016; McAndrews et al, 2016; Schwarz, 2018). In assessing banks' resilience under the Basel III framework, the Bank for International Settlements (2018) employs the spread as an indicator of funding stress. In any case, in connection with the effect of quarter-end snapshot reporting, it would be interesting to see if the spread is higher at the end of the quarter. If it is, then we would argue that it probably reflects the increase in funding risk caused by the heightened uncertainties about funding cost at quarter ends.[12]

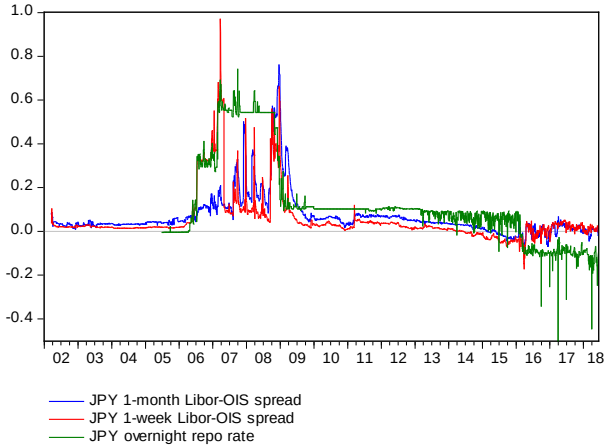
III. METHODOLOGY

All data used in this paper are drawn from Bloomberg and DataQuery of JPMorgan Markets, which are detailed in the Appendix. Chart 1 shows the one-week and one-month JPY Libor-OIS spreads and overnight repo rate. All three series were close to zero before the GFC before rising sharply towards and during the crisis. While the overnight repo rate and Libor-OIS spreads returned to normal levels after the GFC, they started to fluctuate again and trended slightly downwards as accommodative monetary

[12] That is, unless there are reasons to believe that counterparty risk is also subject to some quarterly influence.

policies kicked in from around 2013. On 29 January 2016, the Bank of Japan took another step further and introduced a negative rate policy, sending the repo rate into negative territory, with occasionally some very large downward spikes. Meanwhile, the Libor-OIS spreads rebounded somewhat but their volatility increased significantly.

Chart 1. One-week and one-month JPY Libor-OIS spreads and overnight repo rate



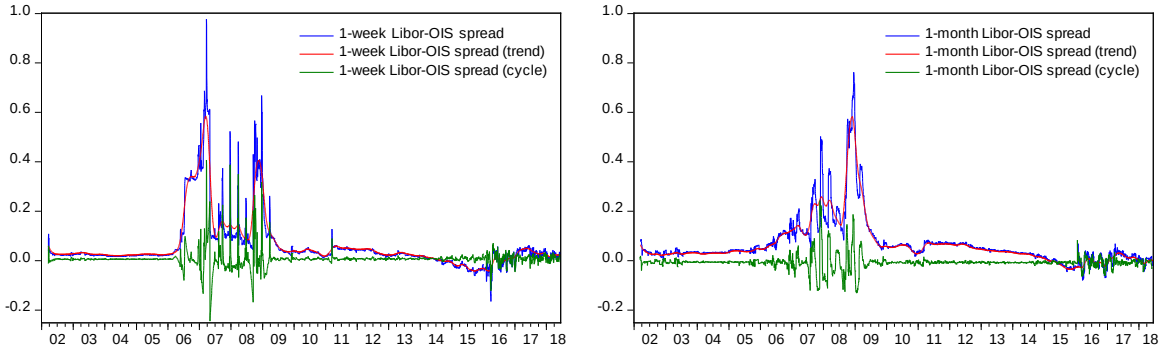
Sources: Bloomberg and JPMorgan.

To detect quarter-end spikes in the Libor-OIS spreads, we first extract the cycle component from the time series of the Libor-OIS spreads, and then build a state space model to describe the relationship between the Libor-OIS spreads and quarter-end dummies. To extract the cycle component from its trend, the Hodrick-Prescott (HP) filter is applied to the Libor-OIS spreads and repo rates to de-trend the time series, which are shown in Chart 2.[13] We use 2 for the smoothing parameter in the HP filter, as recommended by Hodrick & Prescott (1997).[14] The de-trended (i.e., cycle) components are then employed for our analysis.

[13] For prudence, we've also employed another smoothing method, centred moving average, to de-trend the time series. The results remain largely unchanged.

[14] A larger smoothing parameter generates a smoother trend line. For example, Ravn & Uhlig (2002) recommend to use 4 for the parameter instead of 2 for studying US business cycles. However, our analysis focuses on the deviations from the trend. If the trend is too smooth, the quarter-end spikes may be overstated during crisis times.

Chart 2. Trend and de-trended components of JPY Libor-OIS spreads



Source: Bloomberg.

We first investigate whether there are quarter-end spikes in risk premiums in interbank borrowing market and repo market. The former is primarily driven by unsecured funding liquidity risk and counterparty credit risk, whereas the latter is mostly driven by secured funding liquidity risk. These risk factors can co-move with each other under certain market conditions. The effects are estimated separately over the whole sample period, as well as the crisis period and post-crisis period. The post-crisis period starts on 5 October 2010 when Bank of Japan introduced the Comprehensive Monetary Easing.

$$Y_T(t) = b_1 + b_2 Q_T(t) + v(t)$$

where $T \in \{1W, 1M\}$ and $Y \in \{Spread, RSpread\}$; $Spread$ is the de-trended Libor-OIS spread and $RSpread$ is the de-trended repo-OIS spread; Q_{1W} and Q_{1M} are dummy variables that equals one on the last five and twenty trading days of a quarter respectively, and zero otherwise ; v is the error term. In the estimation, b_1 is expected to be zero as the dependent variable is de-trended; b_2 represents the quarter-end spikes during post-crisis period; $b_2 + b_3$ depicts the quarter-end spikes during crisis period.

If quarter-end spikes are identified, we then estimate the time-varying size of the spikes as well as the spill-over effect using a state-space model in both periods. In the model, quarter-end spikes in the de-trended Libor-OIS spreads, which are arguably driven by increases in funding risk, are depicted by latent variables. Among these variables, the model allows for the dynamics to work between the overnight repo rate and the Libor-OIS spreads as funding condition in the repo market would in theory feed through to the risk assessment of the participants in the

interbank money market.[15] The overnight repo rate, instead of its spread over effective Fed funds rate, is used to gauge overnight liquidity condition. This is because a rise in the effective Fed funds rate is also an indication that funding liquidity is tight. The feed-through is specified as one-way only from the secured funding market to unsecured funding market, as counterparty credit risk embedded in Libor-OIS spread is less likely to affect the secured funding liquidity risk in repo. The latent variables are modelled as interactions with a dummy variable, which distinguishes the quarter-end period from the remaining time of the quarter. When the latent variables are equal to zero, there are no quarter-end spikes; when the latent variables are positive (negative), the quarter-end liquidity stress is reflected in the positive (negative) quarter-end spikes.

The model is estimated in the state space form using the Kalman filter. The measurement equations describe the relationships between the output variables (i.e., the de-trended Libor-OIS spreads and the de-trended repo rate) and the state variables (i.e., latent interbank funding risk premiums), while the transition equations reflect the dynamics and interactions among the state variables, including a first-order autocorrelation structure. If there are no quarter-end spikes in the Libor-OIS spreads, the state variables in the measurement equation should be zero. The measurement and transition equations are expressed as below.

Measurement equations:

$$\begin{pmatrix} Spread_{1W}(t) \\ Spread_{1M}(t) \\ Repo(t) \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} + \begin{pmatrix} Q_{1W}(t) & 0 & 0 \\ 0 & Q_{1M}(t) & 0 \\ 0 & 0 & Q_{1M}(t) \end{pmatrix} \begin{pmatrix} sv_1(t) \\ sv_2(t) \\ sv_3(t) \end{pmatrix} + \begin{pmatrix} e_1(t) \\ e_2(t) \\ e_3(t) \end{pmatrix}$$

$$where\ e_1 \sim N(0, c_4), e_2 \sim N(0, c_5)\ and\ e_3 \sim N(0, c_6)$$

Transition equations:

$$\begin{pmatrix} sv_1(t) \\ sv_2(t) \\ sv_3(t) \end{pmatrix} = \begin{pmatrix} c_7 \\ c_8 \\ c_9 \end{pmatrix} + \begin{pmatrix} c_{10} & 0 & c_{11} \\ 0 & c_{12} & c_{13} \\ 0 & 0 & c_{14} \end{pmatrix} \begin{pmatrix} sv_1(t-1) \\ sv_2(t-1) \\ sv_3(t-1) \end{pmatrix} + \begin{pmatrix} \mu_1(t) \\ \mu_2(t) \\ \mu_3(t) \end{pmatrix}$$

[15] The repo market plays a key role in providing funding liquidity to banks. Repo transactions, which are collateralized by high quality liquid securities, are deemed free of counterparty credit risk such that repo rates can serve as a good proxy of funding condition.

$$where\ \mu_1 \sim N(0, c_{15}), \mu_2 \sim N(0, c_{16})\ \ and\ \ \mu_3 \sim N(0, c_{17})$$

$Spread$ is the de-trended Libor-OIS spread; $Repo$ is the de-trended general collateral repo rate; Q_{1W} and Q_{1M} are dummy variables that equals one on the last five and twenty trading days of a quarter respectively, and zero otherwise; sv_1 and sv_2 are the latent variables representing the change in the funding risk for the one-week and one-month tenors respectively at quarter-ends, and sv_3 represents the change in the cost of funding during quarter-ends; e and μ represent the error terms in the measurement and transition equations, which follow a normal distribution.

Since all dependent variables are de-trended, the constants c_1, c_2, c_3, c_7, c_8, and c_9 are expected to be zero. The coefficients c_{11} and c_{13} denote the degree of interaction between the overnight liquidity condition and the interbank funding risk at the one-week and one-month tenors, and are expected to be zero or positive.

IV. EMPIRICAL RESULTS

The estimation results show that there are quarter-end spikes in Libor-OIS spreads of both one-week and one-month tenors during both crisis period and post-crisis periods (Table 2). The spikes in crisis period are positive whereas the spikes in post-crisis period are negative. As for repo-OIS spreads, significant spikes for both tenors appear during post-crisis period with a negative sign; however during post-crisis period, the coefficient for one-week repo-OIS spreads is not significant. This is consistent with the fact that quarter-end regulatory ratios reported during GFC (i.e., under Basel II) did not take repos into consideration.

Table 2. OLS estimation results

Crisis period	***Libor-OIS***		***repo-OIS***	
	1W	**1M**	**1W**	**1M**
b_0	-0.0027**	-0.0075***	0.0000	-0.0010*
	(0.0010)	(0.0009)	(0.0008)	(0.0005)
b_1	0.0345***	0.0243***	-0.0004	0.0031***
	(0.0037)	(0.0017)	(0.0027)	(0.0009)
Adj. R-squared	0.0361	0.0882	-0.0004	0.0050
F-statistics	84.56	216.76	0.02	12.26
Log likelihood	3,631	4,249	4,367	5,640
Num. of Obs.	2,232			
Sample period	3/15/2002 - 10/4/2010			
Post-crisis period	***Libor-OIS***		***repo-OIS***	
	1W	**1M**	**1W**	**1M**
b_0	0.0006**	0.0017***	0.0017**	0.0036***
	(0.0003)	(0.0003)	(0.0007)	(0.0004)
b_1	-0.0083***	-0.0059***	-0.0218***	-0.0119***
	(0.0010)	(0.0005)	(0.0026)	(0.0008)
Adj. R-squared	0.0323	0.0631	0.0348	0.1081
F-statistics	67.84	136.06	73.22	243.94
Log likelihood	6,057	6,319	4,186	5,497
Num. of Obs.	2,006			
Sample period	10/5/2010 - 10/5/2018			

Notes:

1. Standard errors are in the bracket.
2. ***, ** and * denote statistically significant at 1%, 5% and 10% levels.

With quarter-end spikes identified, we estimate the state-space model for the whole sample period as well as the two sub-periods. Table 2 shows the results of the state space model estimated by means of maximum likelihood. The constants c_1, c_2, c_3, c_7, c_8, and c_9 are statistically indifferent from zero as expected. Since the coefficients for autocorrelation c_{10} and c_{12} are arguably close to one, the latent variables sv_1, sv_2 and sv_3 can be viewed as following a random walk with a time-varying drift term. The drift terms in the one-week and one-month Libor-OIS spreads are related to the idiosyncratic risk and the liquidity risk in the overnight repo rate sv_3 by a degree of interaction c_{11} and c_{13}. The estimates show that the quarter-end spikes in the overnight repo rate feed through to the

interbank market by 12% at the one-week tenor, but there is no significant spill-over to the one-month tenor over the whole sample period. If estimated for the two sub-periods separately, the spill-over to one-week Libor market increased to 49% during the crisis period, but remained statistically indifferent from zero for the one-month tenor. During the post-crisis period, the spill-over effect becomes significant for one-month tenor only, at 3%.

Table 2. Estimation results of the state space model

Measurement equations	***Whole period***	***Crisis period***	***Post-crisis period***
c_1	-0.0014*	-0.0043**	0.0006**
	(0.0008)	(0.0019)	(0.0003)
c_2	-0.0037***	-0.0117***	0.0017***
	(0.0005)	(0.0011)	(0.0002)
c_3	0.0005	-0.0009	0.0015***
	(0.0004)	(0.0007)	(0.0004)
Transition equations			
c_7	0.0024	0.0090	-0.0004
	(0.0023)	(0.0083)	(0.0003)
c_8	0.0003	0.0007	-0.0002
	(0.0003)	(0.0007)	(0.0003)
c_9	-0.0012	0.0002	-0.0046*
	(0.0012)	(0.0006)	(0.0027)
c_{10}	0.8587***	0.7683***	0.9577***
	(0.0248)	(0.0866)	(0.0125)
c_{11}	0.1201*	0.4934**	-0.0091
	(0.0671)	(0.2476)	(0.0379)
c_{12}	0.9820***	0.9802***	0.9300***
	(0.0034)	(0.0082)	(0.0148)
c_{13}	0.0217	-0.0094	0.0299**
	(0.0301)	(0.0795)	(0.0151)
c_{14}	0.4660***	0.8674***	0.1538***
	(0.0146)	(0.0497)	(0.0177)
Log likelihood	21,879	7,722	17,749
Num. of Obs.	3,384	1,378	2,006
Sample period	6/23/2005 - 6/12/2018	6/23/2005 - 10/4/2010	10/5/2009 - 6/12/2018
AIC	-12.92	-11.18	-17.68
Schwarz criterion	-12.89	-11.12	-17.63

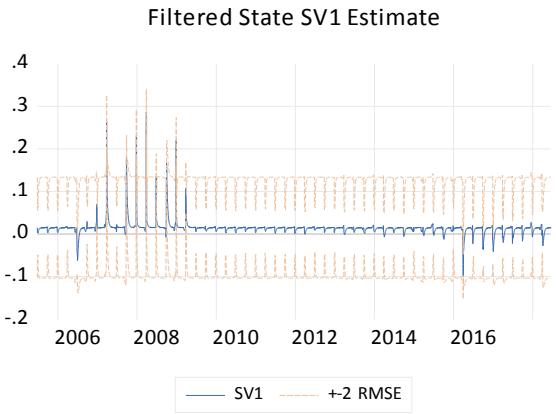
Notes:

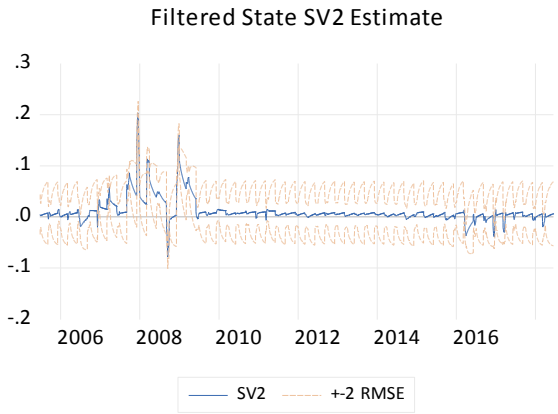
1. Standard errors are in the bracket.
2. ***, ** and * denote statistically significant at 1%, 5% and 10% levels.

The sign and value of the latent variables (sv_1, sv_2, sv_3) indicate the direction and size of the quarter-end spikes respectively. If the values of latent variables are close to zero, there are no quarter-end spikes identified in the dependent variables. Chart 3 plots the estimated sv_1's and sv_2's in the sample periods. The dotted lines are the respective state variables plus or minus twice the standard error.

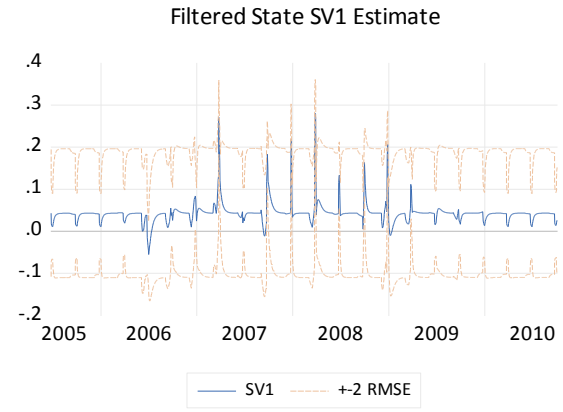
Chart 3. Estimated one-week and one-month state variables

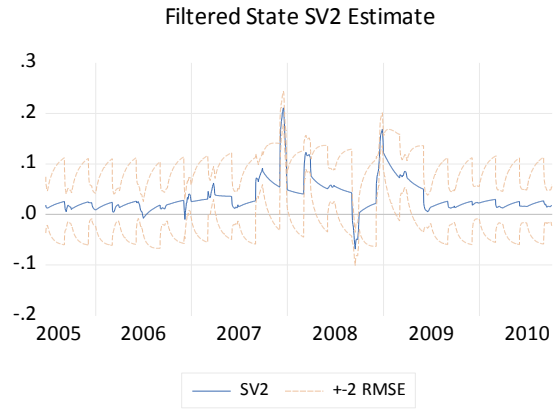
Whole period



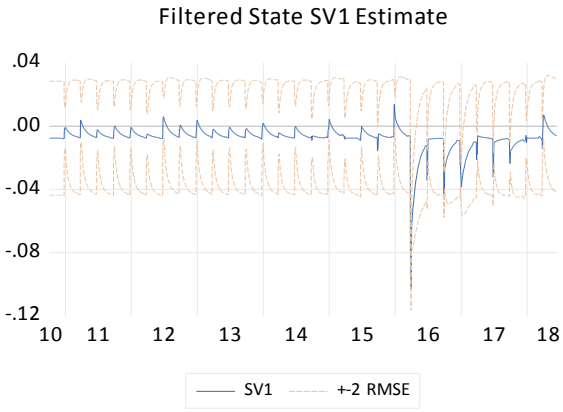


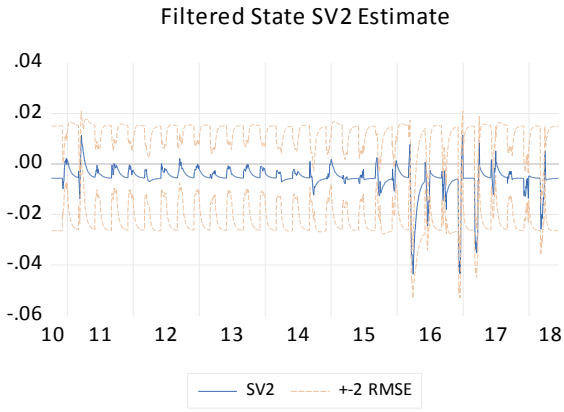
Crisis period





Post-crisis period





From the results we can see that estimations in sub-sample periods are consistent with the whole period estimation. During the GFC, there were sizable positive quarter-end spikes, which suggest that regulatory reporting under Basel II already had an impact on the Libor-OIS spreads on a quarterly basis conditional on heightened liquidity risk.[16] This may reflect that even though there was no leverage ratio requirement at that time, the capital ratio requirement became considerably more binding or imposing within a short period of time.[17] As the economy weakened sharply and the global banking network came under severe stress, write-offs and provisions increased, eroding capital rapidly. At the same time, the risk weights used to compute the capital ratio also rose. The main reason is that in times of crisis, it would be difficult for banks to use internal models to game the calculation of the capital ratio, as risk by most, if not all, measures would increase sharply (Karmakar & Baptista, 2017). Under these circumstances, banks would arguably exercise extreme caution towards lending, particularly so during quarter ends for fear of the capital ratio falling below their own desired levels of adequacy or even breaching the minimum requirement in some cases. As a consequence, funding risk premium increased sharply at those intervals. Whether or not such behaviour should also be dubbed as window dressing is debatable, as banks probably did not categorically or intentionally lend more during the quarter and less towards the end of it as a strategic move.

As financial markets returned to normalcy to a considerable extent, the spikes almost disappeared or became very small in the four to five years following the GFC. This is consistent with the popular belief that boom times would tend to bias the capital ratio upwards, rendering it unconstraining, as measured risks underestimate the true risk positions and banks may employ models to game the calculation by compressing their risk weights to unwarrantedly low levels.

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[16] As a robustness check, we performed analyses on an alternative version of the model to control for the GFC effect by introducing a dummy variable for the GFC period, on its own or interacting with the state variables, in each of the measurement equations. Based on the estimation results, the coefficients for the GFC dummy are statistically indifferent from zero and the remaining coefficients stay largely unchanged compared with our baseline model.

[17] This is consistent with Brei & Gambacorta's (2014) finding that the pro-cyclicality of total exposure is more pronounced than risk-weighted assets. Hence, the leverage ratio will decline for any given capital ratio during economic upturns but the other way round is true during economic downturns.

The spikes turned negative and began to grow significantly in the first quarter of 2016, though remaining smaller than those during the GFC. This coincides with the Bank of Japan's policy change to introduce negative interest rate in January 2016. The fact that the spikes are negative means that funding risk is more negative at quarter ends than at other times. Intuitively, funding risk being negative seems a bit difficult to conceive.[18] But when interest rates are negative, lenders need to pay interest to borrowers as financial markets are flooded with liquidity. Hence, it is not those who are caught short of liquidity that get penalized but those who turn out to be swamped with it.[19] In other words, funding risk is no longer the risk of not having sufficient funds to meet financial obligations but that of having too much. Put it another way, in a negative interest rate environment the risk lies with borrowing, not lending, and hence falls squarely on the borrower, not the lender.

The situation was exacerbated by the introduction of a considerable increase in the purchase of government securities by the Bank of Japan in 2014 amid the backdrop of a general paradigm shift from unsecured to secured funding markets and centrally-cleared trades (both in repo and derivatives markets) in view of a major counterparty risk reappraisal following the GFC. The resulting fall in the supply of, coupled with an increase in the demand for, high-quality collaterals caused the cost of short-term funding to dip into negative territory, as reflected in the downward spikes in the overnight repo rate in Chart 1, a phenomenon not confined to Japan but also seen in some major economies in Europe around the same time including France and Germany. This may be attributable to the increased risk of being unable to find a counterparty to place cash with at quarter ends (CGFS, 2017).[20]

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[18] Christiansen et al (2011) attribute the negative systematic risk for JPY to the currency's safe haven nature. However, their theory cannot explain the phenomenon that negative spikes emerged only in a negative interest rate environment despite the fact that JPY has remained a safe haven currency for the whole sample period.

[19] Lopez et al (2018) find that banks experience significant loses in net interest income in a negative interest rate environment and are compensated by significant increases in fees, capital gains and gains in on securities and insurance. The losses in net interest income are driven by the non-reducing deposit expenses due to difficulty in cutting nominal deposit rates to below zero. Nucera et al (2017) find that in a negative policy rate environment, some banks are more likely to become undercapitalised in a future potential crisis. Demiralp et al (2017) argues that banks with higher excess liquidity suffer more from the negative rate policy and are more sensitive to further rate cuts in the negative range.

[20] The feedback received at the CGFS study group's Roundtable with market participants reveals that some players have faced considerable difficulties in placing cash, especially at quarter ends, sometimes to the extent that some counterparties refused to take cash via reverse repos at the any price.

V. CONCLUDING REMARKS

In a drive to protect the safety and soundness of the banking system, regulators around the world have since the GFC stepped up efforts in implementing Basel III. While the accord is well defined and agreed upon among regulators globally, there is considerable room or freedom to manoeuvre as to how they carry out their supervisory practice for institutional or other practical reasons. In most jurisdictions, the supervisor takes only a snapshot of the balance sheet of the banks at the end of the quarter to determine if they meet certain regulatory requirements, which has given a huge incentive for banks to window-dress themselves up at the reporting time.

As these banks do not necessarily operate solely in their own jurisdictions, their behaviour has an impact on funding markets globally. Hence, no major funding market can be insulated, regardless of whether the regulatory authorities concerned adopt the quarter-end or quarter-average reporting system. This is best exemplified by what happens in the overnight US repo market, as discussed in detail in section II. Likewise, the Japanese or UK regulatory authorities are not to be blamed for the problem with the JPY Libor market under this study.

As a result of the window-dressing behaviour, funding condition is subject to quarterly disturbance. What is more concerning is the unpredictability associated with the disturbance that heightens funding risk. This paper finds that funding risk premium is noticeably higher at quarter ends in the JPY Libor market during the GFC and since 2016. We believe that the phenomenon during the GFC reflects that even before the introduction of the leverage ratio requirement, banks could have found the capital ratio requirement sharply more binding or constraining in times of extreme market adversity under Basel II. In the latter episode, the higher (negative) quarter-end funding risk premium is attributable to snapshot reporting requirement for the leverage ratio under Basel III in an environment accentuated by a lack of supply of high-quality collaterals and negative interest rates.

The phenomenon of quarter-end spikes in funding cost as uncovered by previous studies calls for supervisory authorities concerned to assess the

efficiency and effectiveness of the snapshot reporting practice. If the spikes represent disruptions to the functioning of funding markets, then there is a need to consider whether or not the costs of the practice are outweighed by its benefits, e.g., a lower compliance cost (compared to quarter-average reporting). However, if the phenomenon means that banks only adhere to the regulations at quarter ends but not at other times, then it is questionable whether or not the practice is an effective way of administering and ensuring compliance, as the banking system may not be as safe and sound as the regulations are targeted to achieve.

In view of the implications for financial stability, the UK, where banks were required to report month-end leverage ratios (and quarter-end leverage ratios under the Capital Requirement Directive IV since 2014), already joined the US and switched to quarter-average reporting in 2017. The ramification also underscores the rationale and urgency of BCBS (2019b) seeking remedies to the current leverage ratio disclosure requirements by adding a quarter-average-based calculation of the securities financing component of the ratio.[21] The revision released in June 2019 will be effected from 1 January 2022 onwards, allowing for banks and regulators to adjust gradually. The finding in the paper that quarter-end snapshot reporting causes quarter-end spikes not only in funding cost but also possibly in funding risk lends further support to such moves.

However, these initiatives can only help remove or contain window dressing behaviour of banks during normal market conditions when the leverage ratio requirement tends to be more binding or imposing than does the capital ratio. The finding about the quarter-end spikes in funding risk during the GFC suggests that such behaviour may still re-surface under a stressful financial environment as the capital ratio, which is quarter-end-based, ebbs.

[21] The key change is to require banks to base their calculation of the leverage ratio on the average daily value over the quarter of adjusted gross securities financing transaction assets included in on-balance sheet exposures.

REFERENCES

Arai, F., Makabe, Y., Okawara Y., & Nagano T. (2016). Recent trends in cross-currency basis. *Bank of Japan Review, September,* 1-7.

Bank for International Settlements (2010). 2010 FSI survey on the implementation of the new capital adequacy framework. *Bank for International Settlements Occasional Paper No.* 9. https://www.bis.org/fsi/fsipapers09.pdf.

Bank for International Settlements (2018). The financial sector: post-crisis adjustment and pressure points. *BIS Annual Economic Report, Chapter III*, 43-61.

Basel Committee on Banking Supervision (2018a). Statement on leverage ratio window-dressing behaviour. *Bank for International Settlements BCBS Newsletter*, 18 October, https://www.bis.org/publ/bcbs_nl20.htm.

Basel Committee on Banking Supervision (2018b). Implementation of Basel standards: A report to G20 Leaders on implementation of the Basel III regulatory reforms. *Bank for International Settlements BCBS,* November, https://www.bis.org/bcbs/publ/d453.pdf.

Basel Committee on Banking Supervision (2018c). Revisions to leverage ratio disclosure requirements. *Bank for International Settlements BCBS Consultative Document*, December, https://www.bis.org/bcbs/publ/d456.pdf.

Basel Committee on Banking Supervision (2019a). Sixteenth progress report on adoption of the Basel regulatory framework. *Bank for International Settlements BCBS, May*, https://www.bis.org/bcbs/publ/d464.pdf .

Basel Committee on Banking Supervision (2019b). Revisions to leverage ratio disclosure requirements. *Bank for International Settlements BCBS, June*, https://www.bis.org/bcbs/publ/d468.pdf.

Bicu, A., Chen L., & Elliott D. (2017). The leverage ratio and liquidity in the gilt and repo markets. *Bank of England Staff Working Paper No.* 690.

Borio, C. E., McCauley, R. N., McGuire, P., & Sushko, V. (2016). Covered interest parity lost: understanding the cross-currency basis. *BIS Quarterly Review,*

September 2016.

Brei, M. & Gambacorta, L. (2014). The leverage ratio over the cycle. *Bank for International Settlements Working Papers no.* 471.

Christiansen, C., Ranaldo, A., & Söderlind, P. (2011). The time-varying systematic risk of carry trade strategies. *Journal of Financial and Quantitative Analysis, 46*(4), 1107-1125.

Committee on the Global Financial System (2017). Repo market functioning. *Bank for International Settlements CGFS Papers No.* 59, https://www.bis.org/publ/cgfs59.pdf.

Demiralp, S., Eisenschmidt, J., & Vlassopoulos, T. (2017). Negative interest rates, excess liquidity and bank business models: Banks' reaction to unconventional monetary policy in the euro area. *Koç University-TUSIAD Economic Research Forum Working Papers 1708.*

Du, W., Tepper, A., & Verdelhan, A. (2018). Deviations from covered interest rate parity. *The Journal of Finance, 73*(3), 915-957.

Egelhof J., Martin A., & Zinsmeister N. (2017), Regulatory incentives and quarter-end dynamics in the repo market. *Federal Reserve Bank of New York Liberty Street Economics (blog), August.*

Griffiths, M. D., & Winters, D. B. (2005). The turn of the year in money markets: Tests of the risk-shifting window dressing and preferred habitat hypotheses. *The Journal of Business, 78*(4), 1337-1364.

Hodrick, R. J., & Prescott, E. C. (1997). Postwar US business cycles: an empirical investigation. *Journal of Money, credit, and Banking*, 1-16.

Hou, D., & Skeie, D. (2014). LIBOR: Origins, economics, crisis, scandal, and reform. *Federal Reserve Bank of New York Staff Reports*, 667.

Iida, T., Kimura, T., & Sudo, N. (2016). Regulatory reforms and the dollar funding of global banks: Evidence from the impact of monetary policy divergence. *Bank of Japan Working Papers No*. 16-E-14.

Karmakar S., & Baptista, D. (2017). Understanding the Basel III leverage ratio requirement," *Economic Bulletin and Financial Stability Report Articles and Banco de Portugal Economic Studies.*

Kotomin, V., & Winters, D. B. (2006). Quarter-end effects in banks: preferred habitat or window dressing?. *Journal of Financial Services Research*, *29*(1), 61-82.

Kotomin, V., Smith, S. D., & Winters, D. B. (2008). Preferred habitat for liquidity in international short-term interest rates. *Journal of Banking & Finance*, *32*(2), 240-250.

Lopez, J. A., Rose, A. K., & Spiegel, M. M. (2018). Why have negative nominal interest rates had such a small effect on bank performance? Cross country evidence. *NBER Working Paper No.* 25004.

McAndrews, J., Sarkar, A., & Wang, Z. (2016). The effect of the term auction facility on the London interbank offered rate. *Journal of Banking & Finance*.

Michaud, F. L., & Upper, C. (2008). What drives interbank rates? Evidence from the Libor panel. *International banking and financial market developments*, *3*, 47.

Munyan, B (2015): “Regulatory arbitrage in repo market”, *US Department of the Treasury OFR Working Papers No.* 15-22.

Nucera, F., Lucas, A., Schaumburg, J., & Schwaab, B. (2017). Do negative interest rates make banks less safe?. *Economics Letters*, *159*, 112-115.

Ravn, M. O., & Uhlig, H. (2002). On adjusting the Hodrick-Prescott filter for the frequency of observations. Review of economics and statistics, 84(2), 371-376.

Schwarz, K. (2018). Mind the Gap: Disentangling Credit and Liquidity in Risk Spreads. *The Wharton School University of Pennsylvania Working papers*.

APPENDIX

The one-week and one-month Libors are reported by ICE on every London working day at 11:55am, based on submission from a panel of international banks. The one-week and one-month OIS rates are the closing bid prices obtained from Bloomberg at daily frequency. The JPY OIS is indexed to the Bank of Japan estimated unsecured overnight call rate. The general collateral repo rates are obtained from the DataQuery of JPMorgan Markets. The sample period spans 23 Jun 2005 to 12 Jun 2018, subject to data availability. Table A1 shows the summary statistics of the de-trended variables after applying the HP Filter as explained in Section II.

Table A1. Summary statistics of de-trended variables

	JPY		
	$\boldsymbol{Spread_{1W}}$	$\boldsymbol{Spread_{1M}}$	$\boldsymbol{Repo}$
Mean	0.00	0.00	0.00
Median	0.00	0.00	0.00
Max.	0.58	0.35	0.20
Min.	-0.22	-0.22	-0.58
Std. Dev.	0.05	0.04	0.04
Skewness	2.73	2.23	-1.37
Kurtosis	25.77	21.80	26.90
Num. of Obs.	4,238	4,238	3,384

Source: Bloomberg and JPMorgan.