Article

Connectedness and Spillovers between Japanese Money Market Instruments

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Abstract

This paper explores the transmission mechanism among Japanese money market instruments of different maturities and risk characteristics from 2007 to 2020. We document that high interconnectedness coincides with financial market crises, stress and elevated uncertainty. Furthermore, the transmission of shocks across maturities and risk characteristics is not consistent with the logic of the monetary transmission mechanism. The policy implications are twofold. First, referring to financial regulators' paradigm shift from estimation-based (e.g. LIBOR) to alternative rates (TONA), there might not be a 'one fits it all' model for which risk-free rate is a better alternative. Second, the effectiveness of monetary policy varies across currencies and remains vulnerable to domestic and international developments. If, or when, the Bank of Japan abandons its near-zero interest rate policy, close attention needs to be paid to the behaviour of the first stage of the monetary transmission mechanism.

Keywords: Dynamic connectedness, FX swaps, Interest rates, LIBOR, Money markets, Monetary policy, OIS, TONA, TVP-VAR.

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1. Introduction

In this paper,[2] we explore the transmission mechanism among Japanese money market instruments of different maturities and risk characteristics from 2007 to 2020. To do so, we adopt a framework that combines a time-varying parameter vector autoregressive (TVP-VAR) model with the dynamic connectedness approach (Diebold and Yilmaz, 2009, 2012, 2014; Chatziantoniou, Gabauer and Stenfors, 2020, 2021). The methodology allows the examination of the degree to which changes in various variables (in our case, interest rates) are connected to and influence each other.

The empirical study aims to shed light on the paradigm shift from the London Interbank Offered Rate (LIBOR) to alternative risk-free rates such as the Tokyo Overnight Index Average (TONA) and subsequent implications on the effectiveness of the monetary transmission mechanism.

Following the LIBOR manipulation scandal, financial regulators have recommended a shift from LIBOR to alternative rates that are more robust (BIS, 2013; IOSCO, 2013; Muchimba, 2022). Since, various jurisdictions have shifted or are shifting from LIBOR rates to alternative money market rates (Schrimf and Sushko, 2019). For example, the US has selected the Secured Overnight Financing Rate (SOFR), a secured overnight interest rate, as the alternative. The UK has adopted the Sterling Overnight Index Average (SONIA), a transaction-based average rate based on banks' GBP overnight borrowing from financial institutions and institutional investors (BOE, 2023). Japan has adopted the TONA as an alternative reference rate, a measure of the cost of borrowing in the JPY unsecured overnight interbank market (BOJ, 2023).

Notable is that jurisdictions are faced with different alternative reference rates. To achieve "robustness", arguably, one of the crucial considerations of a reference rate is that it should track the movements of the central bank target rate. This is because central banks achieve the monetary and price stability objectives through their influence on short-term money market instruments and market expectations. Thus, understanding the transmission of monetary policy within and across these potential rates is critical-particularly for a country like Japan, which, at the time of writing, has not yet diverted from its longstanding policy of near-zero short-term interest rates.

2. Data

We use daily data for three different JPY money market rates: overnight index swaps

(OISs), LIBOR and foreign exchange swap implied rates (FXIRs). The data is collected from Bloomberg, and the period covered is from 2 January 2007 to 31 December 2020. We include 1M, 3M and 6M maturity categories to capture the very short-end, medium-term, and long end of the money market yield curve. The very short-end represents the first stage of the monetary transmission mechanism, i.e. the channel from the central bank policy rate to the short-end of the money market yield curve. All in all, this allows us to capture the transmission of monetary policy innovations from the very short-term to the medium and long end of the money market yield curve.

An OIS is an over-the-counter interest rate derivative where two participants agree to exchange fixed and floating interest payments on a notional principal for an agreed period. It involves the exchange of a fixed rate for a period for the geometric average of the overnight rates during the period. The geometric average considers the fact that the notional principal and accrued interest are reinvested for the duration of the contract. The OIS is calculated as follows (ISDA, 2021):

$$OIS=\left[\prod_{i=1}^{d_o}\left(1+\frac{Benchmark\ Level_{i*}n_j}{Day\ Count\ Basis}\right)-1\right]*\frac{Day\ Count\ Basis}{d} \tag{1}$$

Where d_O is the number of applicable business days until maturity in a calculation period, i is the applicable business day in a series of whole numbers from 1 to d_O, each representing the relevant applicable business day in chronological order from, and including, the first applicable business day in the calculation period. $Benchmark\ Level_{i*}n_j$ represents floating rate for the applicable business day (TONA for JPY). *Day Count Basis* is the assumption for the number of days in a year (365 for JPY). The fixed rate in an OIS contract is referred to as the OIS rate. For a vanilla OIS for a year or less, there is no exchange of cashflow, and funds are only exchanged at the conclusion of the contract. Hence, the OIS contract has limited liquidity and counterparty risk and is regarded as a risk-free asset reflecting both current and expected future overnight interest rates over the horizon of the contract. Thus, OIS, as risk free rates are used to represent market expectations of future short-term central bank interest rates, which according to the logic of the monetary transmission mechanism, should transmit shocks to other instruments. It is therefore a good candidate to represent market expectations in the analysis.

LIBOR is used to capture the transmission of volatility in the unsecured JPY money market. Since LIBOR rates are derived from the unsecured market segment and there is an exchange of cashflow between parties, they should reflect liquidity, credit, and term premia over and above the OIS (BOE, 2007; Poskitt, 2011; Stenfors, 2014, 2018). For monetary policy to be effective, market expectations (OIS) of future short-term rates should be transmitted to interbank money market rates such as the LIBOR.

The third money market interest rate used is the implied JPY interest rate from the foreign exchange (FX) swap market-following the covered interest parity (CIP). FX swaps represent a collateralised segment of the money market and contain significantly less credit risk than deposits. According to the CIP equation, interest rate differentials between two currencies are reflected in the FX forward market. Otherwise, arbitrage would be possible. In terms of JPY against USD, this can be expressed as:

$$(1+i_t^{JPY})=\frac{F_t^{USD/JPY}}{S^{USD/JPY}}(1+i_t^{USD}) \tag{2}$$

where i_t^{USD} is the USD interest rate, and i_t^{JPY} the JPY interest rate for maturity t. $S^{USD/JPY}$ and $F_t^{USD/JPY}$ represent the FX spot and forward rates between the currencies respectively. In practice, banks typically quote FX swaps, rather than FX forward prices to each other (an FX swap is a combination of an FX spot transaction plus an FX forward transaction done simultaneously but in the opposite direction). Consequently, the implied JPY interest rate from the FX swap market ("FXIR") can be written as:

$$(i_t^{JPY})=\frac{S^{USD/JPY}+SW_t^{USD/JPY}}{S^{USD/JPY}}(1+i_t^{USD})-1 \tag{3}$$

Where $SW_t^{USD/JPY}$ represents the FX swap price for maturity t.

3. Methodology

To measure the dynamic connectedness and transmission of shocks in a system of variables, Diebold and Yilmaz (2009, 2012, 2014) is the most applied framework. The Diebold and Yilmaz model offers both the static and dynamic analysis of the network using the widely applied Vector Autoregressive Model (VAR) developed by Sims (1980). This paper adopts the TVP-VAR model in the spirit of Antonakakis et al. (2020) to measure the dynamic connectedness and transmission of monetary policy in selected short-term reference rates. This approach focusses on variance decompositions, which allow for the aggregation of spillover effects across instruments extracting a wealth of information into a single spillover measure. The following TVP-VAR model is estimated as suggested by the Bayesian Information Criteria (BIC) is estimated for the three instruments and maturity categories:

$$Z_t=B_tZ_{t-1}+u_t \qquad u_t\sim N(0,\ S_t) \tag{4}$$

$$vec(B_t)=vec(B_{t-1})+v_t \quad v_t\sim N(0,\ R_t) \tag{5}$$

Where Z_t, Z_{t-1} and u_t are kX1 dimensional vectors, representing all variables (FXIR, LIBOR and OIS for the 1M, 3M and 6M maturity categories) in t, t−1, and the respective error term. B_t and S_t are kXk dimensional matrices, $vec(B_t)$ and v_t are k^2X1 dimensional vectors and R_t is a K^2xK^2 dimensional matrix.

The H-step ahead (scaled) generalized forecast error variance decomposition (GFEVD) by Koop et al. (1996) and Pesaran and Shin (1998) are calculated. Notably, the GFEVD is completely invariant to the order of variables, contrary to the orthogonalized forecast error variance decomposition (Diebold and Yilmaz, 2009). The estimated TVP-VAR model is transformed into a TVP-VMA process:

$$z_t=\sum_{i=1}^{p}B_{it}z_{t-i}+u_t=\sum_{j=0}^{\infty}A_{jt}u_{t-j} \tag{6}$$

The (scaled) GFEVD normalises the unscaled GFEVD, $\varnothing_{ij,t}^{g}(H)$ so that each row sums to 1. In this regard, $\varnothing_{ij,t}^{\tilde{g}}(H)$ represents the effect on variable i's forecast error variance of from variable j, also called directional pairwise connectedness from j to i.

$$\varnothing_{ij,t}^{g}(H)=\frac{S_{ii,j}^{-1}\sum_{t=1}^{H-1}(i'_iA_tS_ti_j)^2}{\sum_{j-1}^{k}\sum_{t=1}^{H-1}(i_iA_tS_tA'^{i_i}_t)} \tag{7}$$

$$\varnothing_{ij,t}^{\tilde{g}}(H)=\frac{\varnothing_{ij,t}^{g}(H)}{\sum_{j=1}^{k}\varnothing_{ij,t}^{g}(H)} \tag{8}$$

Where $\sum_{j=1}^{k}\varnothing_{ij,t}^{\tilde{g}}(H)=1$, $\sum_{j=1}^{k}\varnothing_{ij,t}^{\tilde{g}}(H)=k$ and i corresponds to a selection vector with unity on the i^{th} position and zero, otherwise. Based on the GFEVD, the following connectedness measures are derived as per Diebold and Yilmaz (2012, 2014)

$$TO_{jt}=\sum_{i=1,i\neq j}^{k}\tilde{\varnothing}_{ij,t}^{g}(H) \tag{9}$$

$\tilde{\varnothing}_{ij,t}^{g}$ is the impact of a shock in variable j has on variable i, therefore $TO_{jt}=\sum_{i=1,i\neq j}^{k}\tilde{\varnothing}_{ij,t}^{g}(H)$ represents the aggregated impact a shock on variable j has on all other variables, also referred to as total directional connectedness to others.

$$FROM_{jt}=\sum_{i=1,i\neq j}^{k}\tilde{\varnothing}_{ij,t}^{g}(H) \tag{10}$$

$FROM_{jt}=\sum_{i=1,i\neq j}^{k}\tilde{\varnothing}_{ij,t}^{g}(H)$ shows the aggregated influence that all the other variables have on variable j, also referred to the total directional connectedness from others.

$$NET_{jt}=TO_{jt}-FROM_{jt} \tag{11}$$

Subtracting the impact variable j has on others by the influence of others have on variable j leads to the net total directional connectedness, which provides information regarding whether a variable is a net transmitter or net recipient of shocks. If $NET_{jt}>0$, then the variable is a net transmitter of shocks, and if $NET_{jt}<0$, then the variable is the net recipient of shocks.

$$TCI_t = k^{-1}\sum_{j=1}^{k} TO_{jt} \equiv k^{-1}\sum_{j=1}^{k} FROM_{jt} \tag{12}$$

TCI, the total connectedness index represents the average impact one variable has on all others, if this measure is relatively high, it means that the interconnectedness of the network is high and therefore the market risk is high, as a shock in one will influence all the other variables. A low value demonstrates that most variables are independent from each other which in turn means that a shock in one variable will not cause other variables to change, resulting into low market risk.

$$NPDC_{ij,t} = \tilde{\varnothing}_{ij,t}(H) - \tilde{\varnothing}_{ji,t} \tag{13}$$

Since all variables above offer information on an aggregated basis, $NPDC_{ij,t}$ indicates the bidirectional relationship between variable j and i. The net pairwise directional connectedness demonstrates whether variable i is driving variable j, and vice-versa. In this case, the impact variable i is subtracted from variable j, or vice versa. If $NPDC_{ij,t}>0$, then variable I is dominating, and if $NPDC_{ij,t}<0$, then variable i is being dominated by variable j.

4. Empirical results

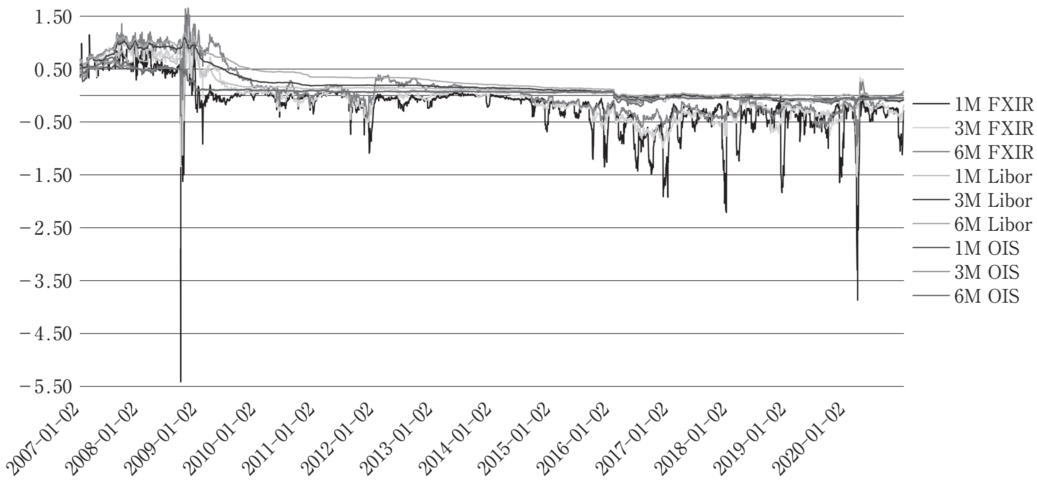
Figure 1 below shows JPY interest rates for the period 2 January 2007 to 31 December 2020.

As can be seen, OIS and LIBOR rates have been close to zero throughout the period studied. However, FXIRs have been considerably more volatile and often negative. A notable spike is the immediate aftermath of the Lehman Brothers collapse, which resulted in a dry-up of USD funding. Banks, therefore, resorted to the FX swap market to source the USD funding-making it more expensive to borrow USD from the FX market via the JPY market (Stenfors, 2019, 2021). Another peak of the implied rates was recorded on 19 March 2020, during the early period of the COVID-19 pandemic.

Table 1 and Figure 2 below present the static connectedness of JPY money market instruments.[3)]

Table 1 shows the average connectedness measures, namely, TCI, on-diagonal, off-diagonal elements, "TO", "FROM", "NET", and net pairwise directional connectedness (NPDC). The TCI measures the extent of the connectedness of variables in a network and shows the percentage of the FEVD of a variable in a network explained by all other variables in the network. A TCI of 0 means that the variables of interest are independent of each other. On the other hand, a value of 100 shows high connectedness; therefore, a shock in one variable will affect other variables in the network or system of variables (Chatziantoniou, Gabauer and Stenfors, 2021). From a monetary policy transmission perspective, the higher

Figure 1: JPY interest rates



Source: Bloomberg and authors' calculations.

Table 1: Average Dynamic Connectedness

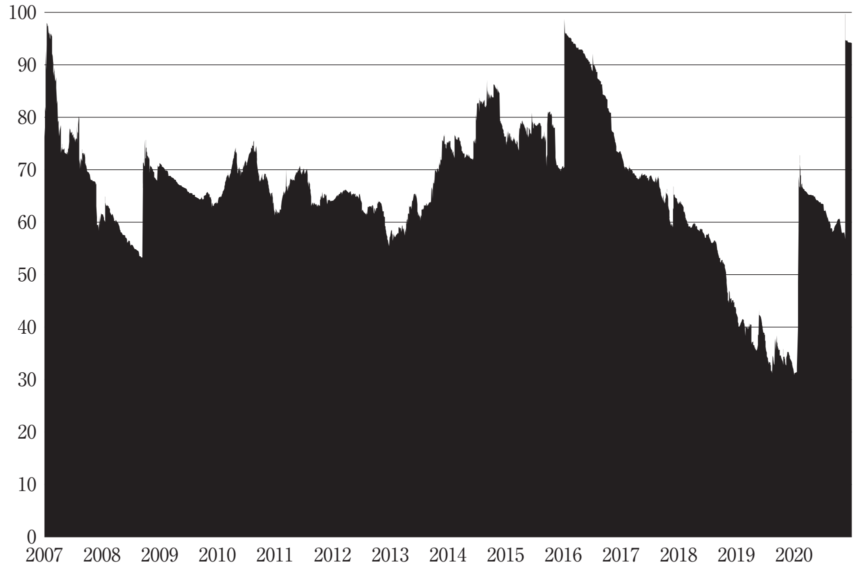
	1M FXIR	3M FXIR	6M FXIR	1M LIBOR	3M LIBOR	6M LIBOR	1M OIS	3M OIS	6M OIS	FROM
1M FXIR	47.67	18.15	11.8	8.76	4.09	3.14	2.05	2.03	2.3	52.33
3M FXIR	17.04	40.97	19.16	5.66	4.7	3.81	2.33	2.94	3.39	59.03
6M FXIR	11.81	20.61	41.87	5.05	3.76	4.47	3.19	4.11	5.13	58.13
1M LIBOR	7.89	5.83	5.72	43.39	14.5	9.68	3.86	4.44	4.68	56.61
3M LIBOR	3.6	5.48	4.94	17.15	38.96	14.48	5.07	5.19	5.13	61.04
6M LIBOR	2.83	4.11	5.35	13.39	15.72	38.42	6.37	6.61	7.19	61.58
1M OIS	1.74	2.44	2.87	6	5.71	6.94	40.88	18.02	15.41	59.12
3M OIS	1.97	2.84	3.54	6.46	5.85	6.47	14.76	37.32	20.77	62.68
6M OIS	2.13	3.05	4.25	7.22	6.45	7.58	12.44	19.79	37.08	62.92
TO	49.02	62.51	57.63	69.69	60.79	56.57	50.09	63.14	64	533.44
Inc. Own	96.69	103.48	99.49	113.08	99.75	95	90.96	100.46	101.08	TCI
NET	−3.31	3.48	−0.51	13.08	−0.25	−5	−9.04	0.46	1.08	59.27

Source: Bloomberg and authors' calculations.

the TCI, the higher the chance that variables will react to the monetary policy actions of the central bank.

The TCI at 59.27 in Table 1 shows that the network of JPY interest rates is reasonably closely interconnected. Decomposing the TCI index into “TO” and “FROM” measures, the “TO” index shows the extent to which a variable transmits shocks to other variables in the network. On the other hand, the “FROM” shows the shocks a variable receives from the entire system of variables. Table 1 shows that the largest contributions to the “TO” spillover are 1M LIBOR (69.69), 6M OIS (64), 3M OIS (63.14) AND 3M FXIR (62.51). The 1M and 6M JPY FXIRs, 3M and 6M LIBORs, and the 1M OIS are net receivers of shocks in the network.

Figure 2: Total Dynamic Connectedness



Source: Bloomberg and authors' calculations.

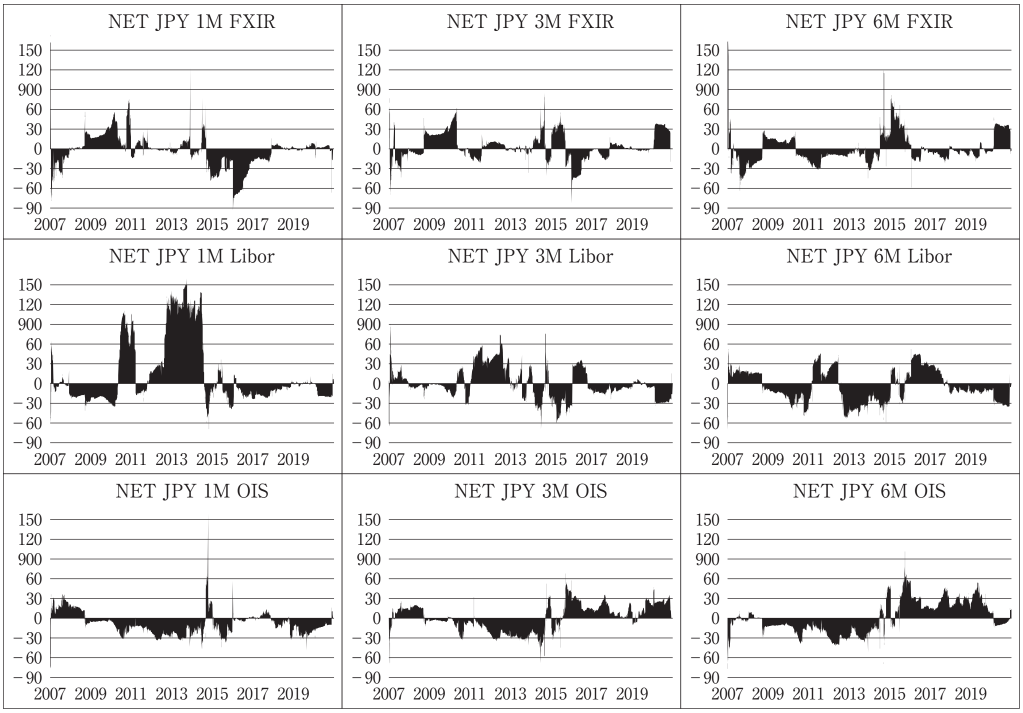
Figure 2 below shows the dynamics of the interconnectedness of the JPY money market instruments over time.

Noteworthy is that the TCI is mostly above 60, showing that the instruments are highly interrelated over time. The TCI varies with time, with peaks coinciding with significant market developments. As indicated by Chatziantoniou, Gabauer and Stenfors (2021), high interconnectedness of interest rates occurs during market stress when risk premia increase-resulting in central bank interventions.

A notable peak in TCI (64) in December 2008 was recorded after Lehman Brothers' collapse on 15 September 2008. Consequently, the Bank of Japan reduced the uncollaterised overnight call rate target from around 0.5% to 0.3% on 31 October 2008. This rate was further reduced to around 0.1% on 19 December 2008. The TCI was as high as 98.7% on 8 January 2016, remained above 90 up to 23 June 2016. It began to decline but was still above 80 up until the end of October 2016. The period of a high TCI from September 2016 onwards coincides with the introduction of the "framework for strengthening monetary easing" by the Bank of Japan in September 2016. This involved the introduction of Quantitative and Qualitative Monetary Easing (QQE) and a yield curve control. Under this arrangement, there was a commitment to Japan's short-term and long-term rates. Further, the Bank of Japan dedicated to increasing the monetary base until the inflation target was met (BOJ, 2016).

Further, high interconnectedness of JPY interest rates is observed for the period of March 2020. This coincides with the COVID-19 pandemic. According to the Bank of Japan, three measures were implemented to mitigate the COVID-19 crisis: a special programme

Figure 3: Net Total Connectedness



Source: Bloomberg and authors' calculations.

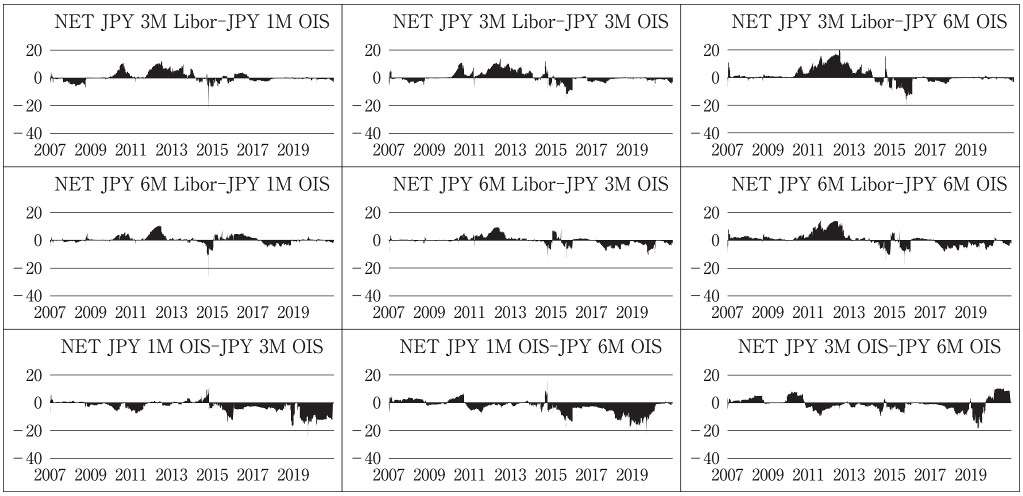
to support corporate financing through purchases of commercial paper and corporate bonds, provision of JPY and foreign currency funds, and the bank made purchases of ETFs and Japanese real estate investment trust (J-REITS) (BOJ, 2020).

Decomposing the TCI presented above; Figure 3 presents the net total directional connectedness and shows which individual variable is a driver (net transmitter) or receiver (net recipient) of shocks in the network or system of financial variables. A positive value shows the net transmission of shocks of a variable in the system, while a negative value means that a variable is a receiver of shocks and has no or limited influence on the other variables in the system.

Notable is that, on a net basis, the 3M and 6M FXIRs were net transmitters of shocks during the COVID-19 pandemic in 2020. LIBOR rates assumed mixed roles with the 1M being a net transmitter from 2010 to 2014. The 3M and 6M LIBOR rates assumed a net transmitting role during the 2007-08 global financial crisis. However, LIBOR rates were net receivers during the COVID-19 pandemic. On the other hand, the 1M OIS assumed a unique role of receiving shocks from the network, whereas the 3M and 6M OIS were net transmitters after 2014.

To shed more light on the transmission of shocks across money market instruments, Figure 4 below shows the direction of shocks (monetary transmission) between two variables (bi-directional relationship) in the system over time.

Figure 4: Net Pairwise Dynamic Connectedness



Source: Bloomberg and authors' calculations.

According to the monetary transmission mechanism, shocks should be transmitted from 1M to 3M and 6M rates before being transmitted to the long-term rates affecting household and firm decisions, output, inflation, and employment. Furthermore, relatively risk-free money market rates (OIS) should be more inclined to transmit shocks to riskier types rather than vice versa. Our findings, however, show that neither the short-term nor the risk-free rates are consistent transmitters of shocks to the network. Instead, a multifaceted picture emerges.

The static analysis shows that 3M FXIRs, 1M LIBOR, and 3M and 6M OIS are net transmitters of shocks. On the other hand, 1M and 6M FXIRs, 3M and 6M LIBORs, and the 1M OIS are net recipients of shocks in the network. Turning to the bi-directional relationship, while the 1M and 3M OIS assume mixed roles overtime, contrary to the logic of the monetary transmission mechanism, 3M OIS and 6M OIS dominates the transmission of shocks to 1M OIS. Similarly, the 6M OIS dominates transmission to the 3M OIS except during the COVID-19 pandemic.

Put bluntly, the monetary transmission mechanism logic appears to be "violated" after 2015. This is, for instance, evidenced by the observation that the 3M and 6M LIBOR dominate the transmission of shocks to the 1M LIBOR. Interestingly, the relationship between the 1M, 3M, and 6M maturity categories appeared to have become more disconnected when the Bank of Japan introduced its Yield Curve Control policies in September 2016. As suggested by Stenfors et al. (2022), the shift to the 10Y JGB yield as the new anchor for the BOJ could have shifted the attention and market expectations from short-term to long-term rates, thereby also affecting the first stage of the monetary transmission mechanism. On the other hand, the transmission of shocks from the 1M, 3M maturities to the 6M FX-IRs varies over time. Similarly, the 3M and 6M FXIRs dominate transmission to the 1M after 2014.

Turning to the bidirectional relationships between instruments, the OIS and LIBOR rates assume mixed roles overtime, with the former dominating transmission after 2014. Further, there are some periods when the two markets were completely disconnected. The picture is the same as regards to the transmission of shocks between the OIS and FXIRs. This implies that the interbank money market did not react to market expectations of future short-term interest rates. The fact that these two market segments begin to react to market expectations of the future short-term rates after the introduction of QQE in April 2013 is perhaps an indication that markets were confident that these measures would help to meet the Bank of Japan objectives. Indeed, the central bank expected the QQE to drastically change the market expectations in addition to other monetary transmission mechanism channels such as longer-term interest rates and asset prices (BOJ, 2013).

As regards to the bi-directional relationship between FXIRs and LIBOR rates, for the 1M maturity category, the former dominates transmission of shocks to the later during the 2007–09 financial crisis, up to 2011, and during the COVID-19 pandemic. For the 3M and 6M maturity categories, there is a mixed role, with the FXIRs dominating transmission of shocks to the LIBORs. The earlier periods coincide with occasions when the FX swap market was facing challenges due to increased counterparty risks (Shirakawa, 2021) and the USD funding strains present considerable challenges in the JPY FX swap market (Shabani, Stenfors and Toporoski, 2021).

5. Concluding remarks

This paper has investigated the connectedness and spillovers between Japanese money market instruments of different maturities and risk characteristics from 2007 to 2020. We document that the interconnectedness of interest rates is time-varying. High interconnectedness coincides with financial market crises, stress and elevated uncertainty. The transmission of shocks across maturities and risk characteristics is, however, different from the logic of the monetary transmission mechanism. These results have clear policy implications. First, reflecting on the regulators' paradigm shift from estimation-based (e.g. LIBOR) to alternative rates (TONA) that are more robust as regards the effective monetary transmission mechanism, there might not be a 'one fits it all' model as to which interest rates is a better alternative. This implies that jurisdictions need to understand the specific behaviour (in both crisis and calm periods) before selecting a benchmark. Second, the effectiveness of monetary policy varies across currencies and remains vulnerable to both domestic and international developments. If, or when, the Bank of Japan abandons its near-zero interest rate policy, close attention needs to be paid to the behaviour of the first stage of the monetary transmission mechanism.

Notes

1) The conclusions and recommendations contained in this does not represent the official position of the Board and Staff of the Bank of Zambia but entirely those of the author.

2) A significant part of this paper is drawn from Muchimba, L. (2023) A Paradigm shift from estimation-based to transaction-based money market benchmarks: An empirical assessment of collusion, robustness, and representativeness. Doctoral dissertation, University of Portsmouth.

3) A full set of summary statistics can be provided upon request.

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