# *NETWORK MOTIF OF INTERBANK PAYMENT AS AN EARLY WARNING SIGNAL OF LIQUIDITY CRISIS*

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BANK INDONESIA

# OUTLINE

1. INTRODUCTION
2. THE CONCEPTUAL FRAMEWORK AND THEORETICAL BASIS
3. METHODOLOGY
4. RESULT OF THE RESEARCH
5. CONCLUSIONS AND POLICY IMPLICATIONS

# 1 INTRODUCTION

- The widespread impact of the global the financial crisis is due to the connectedness between actors on the financial markets
- In contrast to previous studies (Kawada, 2016; Squartini, et al., 2013), the present study intends to compare the motif connectedness between two banks (dyadic motif) in RTGS transactions, with clearing transactions as early warning signals.
- Inter-agency economic connectedness in the financial system are dynamic (Squartini, *et al.,* 2013). The patterns of connectedness can be altered either due to endogenous factors, or exogenous factors due to the pressures in the economy transmitted through interconnected financial linkages

# 2 THE THEORETICAL BAS

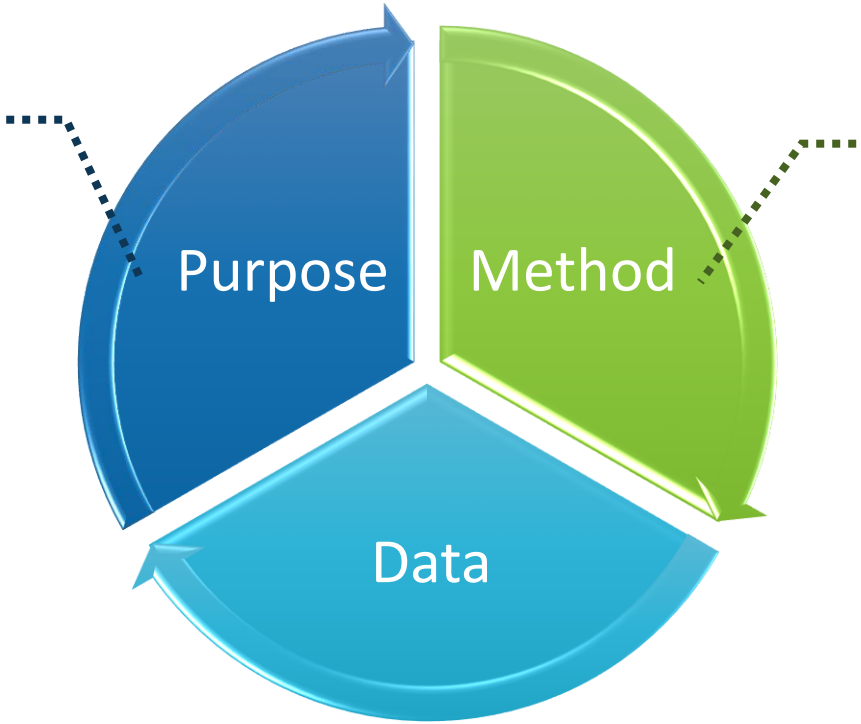
| | Soramaki *et al*. | Becher *et al.* | Schmitz and Puhr |
|---|---|---|---|
| YEAR | 2006 | 2008 | 2009 |
| RESEARCH | National crises may lead to changes in the payment system network topology | Analyzing relationship patterns within a network in UK using the degree of heterogeneity approach | Analyzing relationship patterns within a network in Austria using the degree of heterogeneity approach |

| | Squartini | Kawada | Craig and Von Peter |
|---|---|---|---|
| YEAR | 2013 | 2013 | 2014 |
| RESEARCH | Introducing Reciprocal Configuration Model (RCM) approach to explain the relationship motifs among the 3 banks in the network and the triadic motif in the network payment system is able to show early warning signal. | | Study showed that the network structure on Dutch financial markets spread around the core banks |

| | Baek | Leji *et al*. |
|---|---|---|
| YEAR | 2014 | 2016 |
| RESEARCH | Applying the core-periphery model to monitor the intraday liquidity of BOK-Wire+ using network indicators | Applying the core-periphery model to describe the banking network in the netherlands |

# 2 THE THEORETICAL BAS

To compare the motif connectedness between two banks (dyadic motif) in RTGS transactions with clearing transactions as an early warning signals




1. Null Model
2. Dyadic Motif
3. Cross Correlation Function

High-value payment transactions (RTGS) and retail transactions (clearing) in Indonesia

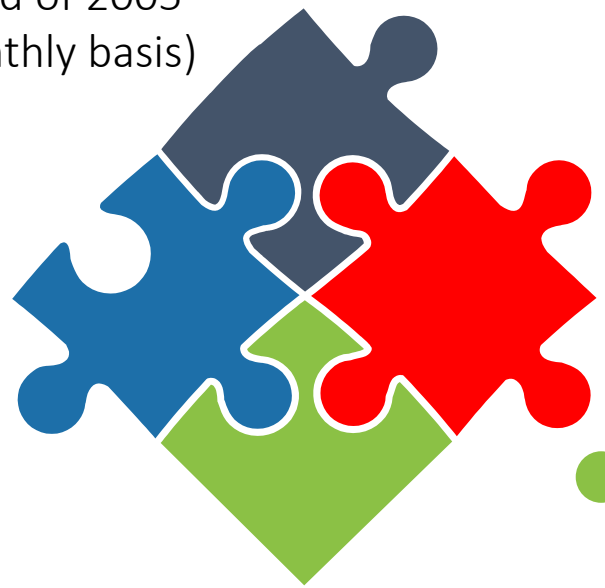
# 3 METHODOLOGY

## DATA

The data used in this study were the data of **high-value** payment transactions (RTGS) and **retail** transactions (clearing) of Bank Indonesia (BI) during the period of 2005-2016 (observed on a monthly basis)

## LOCAL CONSTRAINT (NULL MODEL)

The null model used consisted of Directed Random Graph (DRG) and Directed Configuration Model (DCM). The model was used to measure the differences between the link of the model estimation results and the link of the transaction data network used (z-score). Model estimates generate z-scores to see the early warning signals of crisis.



## DYADIC MOTIF

The network structure of the interbank exposure transaction used in this study was analyzed based on the dyadic motifs i.e. the motifs formed from the relationship between two nodes in the directed network. Dyadic motifs consist of single link, reciprocated link, and null link.

## CROSS CORRELATION FUNCTION

To further explore the patterns of interbank payment transaction movement, the cross-correlation (CCF) is used to determine whether a series includes lagging or leading indicator.

# 3 METHODOLOGY

## Local Constraint (Null Model)

The Hamiltonian DRG was formulated as follows:

$$H(A,\vec{\theta}) = \theta L$$

$$P(A|\vec{\theta}) = \prod_i \prod_{j(\neq i)} p^{a_{ij}} (1-p)^{1-a_{ij}} = p^L (1-p)^{N(N-1)-L}$$

where $p = \frac{x}{1+x}$ with $x \equiv e^{-0}$. Parameter $x$ can be changed to $x*$ that maximizes likelihood A*. in this case,

$$\langle L \rangle = \sum_i \sum_{j(\neq i)} \frac{x^*}{1+x^*} = L^*$$

The expected value of the adjacency matrix entry becomes $a_{ij} = p^* = \frac{x^*}{1+x^*}$. Then the P parameter formula i.e.:

$$p^* = \frac{L^*}{N(N-1)}$$

which is a link density. The DCM model has two-degree sequences for the local constraint i.e. out-degree sequence, $k_i^{out} = \sum_{j(\neq i)} a_{ij}$ *and* $k_i^{in} = \sum_{j(\neq i)} a_{ij}$. The DCM is obtained if in- and out-degree are entered as constraints in vector $\vec{C}$. The Hamiltonian DCM is formulated as follows:

$$H(A,\vec{\theta}) = \sum_{i=1}^{N} (\alpha_i k_i^{out} + \beta_i k_i^{in})$$

$$P(A|\vec{\theta}) = \prod_i \prod_{j(\neq i)} {p_{ij}}^{a_{ij}} \left(1 - p_{ij}\right)^{1-a_{ij}}$$

where $p_{ij} = \frac{x_i y_j}{1+x_i y_j}$ with $x_i \equiv e^{-\alpha_i}$ dan $y_i \equiv e^{-\beta_i}$. Parameters $\{x_i\}$ and $\{y_j\}$ can be replaced with values $\{{x_i}^*\}$ and $\{{y_i}^*\}$ which maximize likelihood A*. In the following case,

$$\begin{cases} \langle k_i^{out} \rangle = \sum_{j(\neq i)} \frac{{x_i}^* {y_j}^*}{1 + {x_i}^* {y_j}^*} \\ \langle k_i^{in} \rangle = \sum_{j(\neq i)} \frac{{x_j}^* {y_i}^*}{1 + {x_j}^* {y_i}^*} \end{cases}$$

After all of the parameters have known values, the expected value of the adjacency matrix entry becomes:

$$\langle {a_{ij}}^* \rangle = {p_{ij}}^* = \frac{{x_i}^* {y_j}^*}{1+{x_i}^* {y_j}^*}.$$

## Dyadic motif

The number of occurrences of a particular motif was denoted by $N_m$ and $m = L^{\rightarrow}, L^{\leftarrow}, L^{\leftrightarrow}$, Formula $N_m$ for the dyadic motif i.e.:

$$N_{L^{\rightarrow}} = \sum_{j(\neq i)} a_{ij}(1-a_{ji}), N_{L^{\leftarrow}} = \sum_{j(\neq i)} a_{ji}(1-a_{ij}), N_{L^{\leftrightarrow}} = \sum_{j(\neq i)} a_{ij} a_{ji}$$

The original value information, the expected value, and the $N_m$ variant can be used to compare the observed value and the expected value, known as z-scores, i.e.:

$$z_m \equiv \frac{N_m(A^*) - \langle N_m \rangle^*}{\sigma^*[N_m]}$$

where $\sigma^*[N_m] \equiv \sqrt{\langle {N_m}^2 \rangle^* - (\langle N_m \rangle^*)^2}$ is the standard deviation of the null model.

# 4 RESULT OF THE RESEARCH

## Descriptive Analysis

**RTGS**

Null link motifs were more dominant compared to the other motifs, since a transactional relationship between banks occurs as a result of the need for liquidity or placement funds. It was being considered that there were selective process (including risk consideration) in RTGS which caused dominant null link.

**Clearing (SKN*)**

Reciprocated link motifs were more dominant compared to other motifs since the interbank transactions through the clearing are random, and the transactions are initiated by the customers.

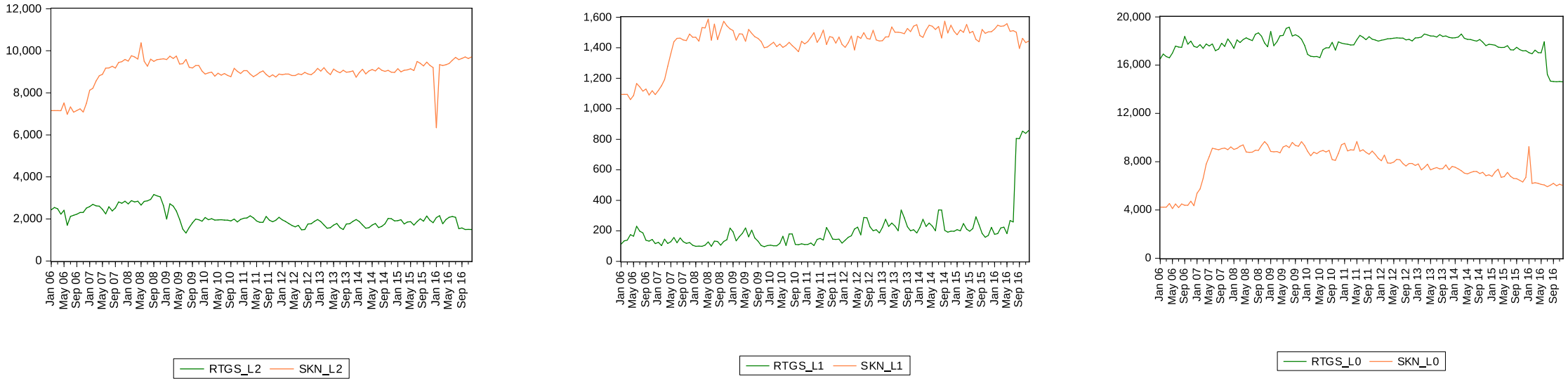



Figure 1. Series (a) Reciprocated, (b) Single, and (c) Null Links within the period of 2006-2016.

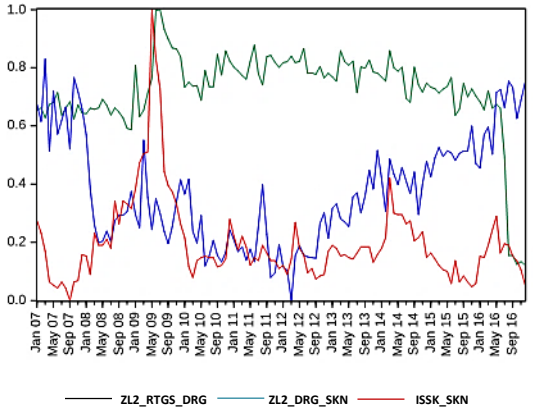
*) SKN: National Clearing System of Indonesia

# 4 RESULT OF THE RESEARCH

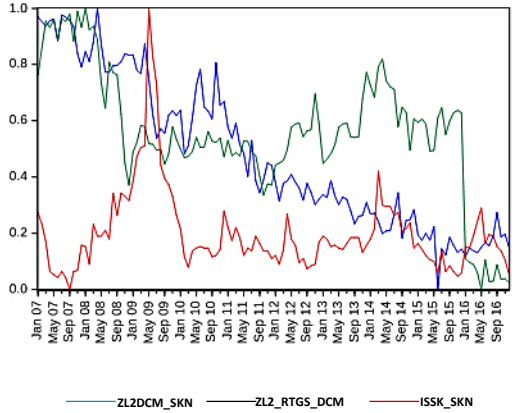
## Early Warning Signal Model

***Reciprocated Link***

DRG

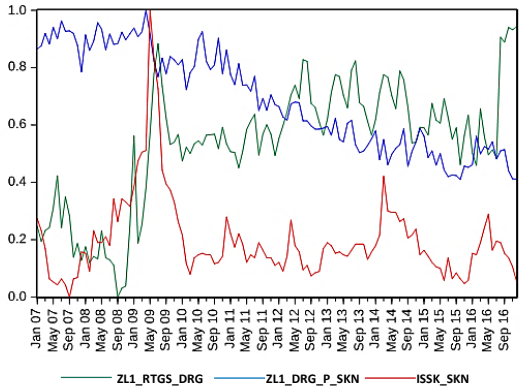


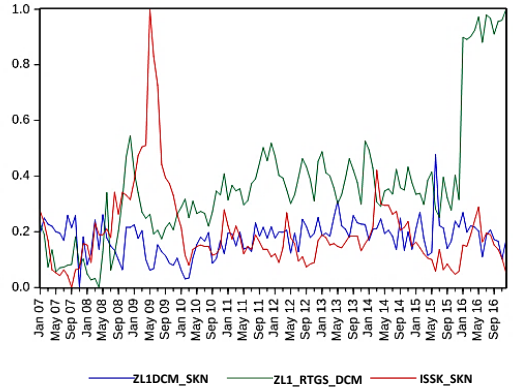

DCM




Either on RTGS or clearing transaction, z-score results from both models, the DCM produced smaller z-scores compared to the DRG. The results showed that the DCM approach, in both RTGS and clearing transactions, can estimate more accurately compared to the DRG approach.

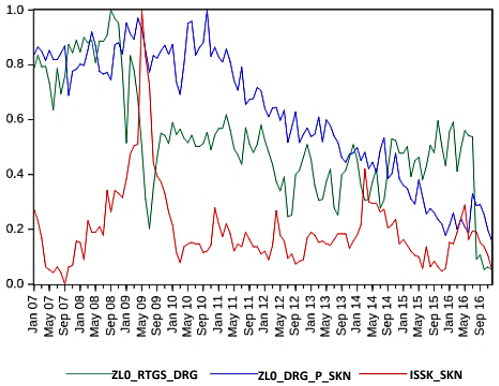
***Single Link***




***Null Link***

DRG




DCM

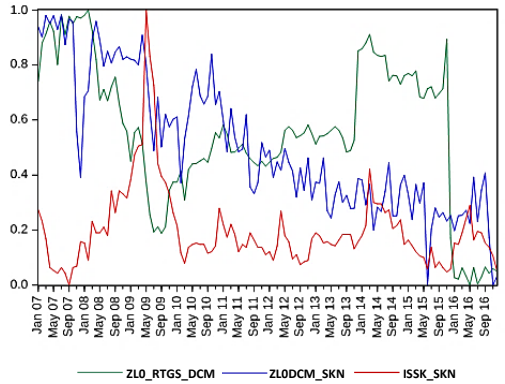



Figure 2. Z-score results normalization of the DRG and DCM at various link motifs.

*) SKN: National Clearing System of Indonesia; *) FSI: Indonesia Financial System Stability Indicator (ISSK)

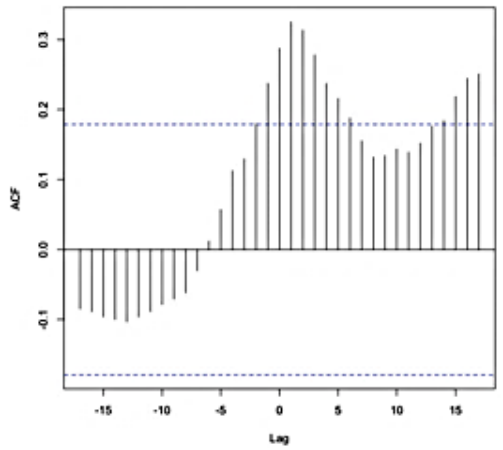
# 4 RESULT OF THE RESEARCH

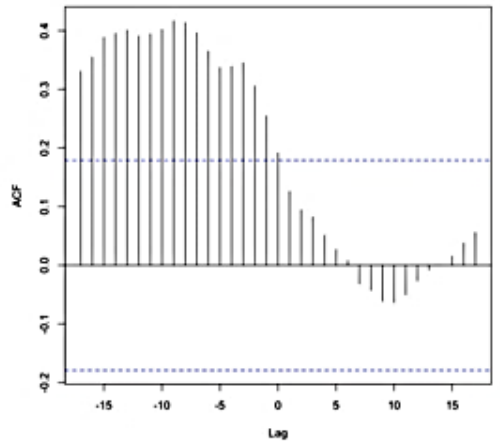
## Early Warning Signal Model

DRG

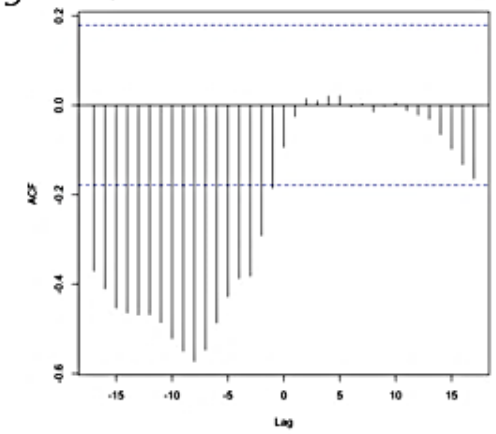
DCM

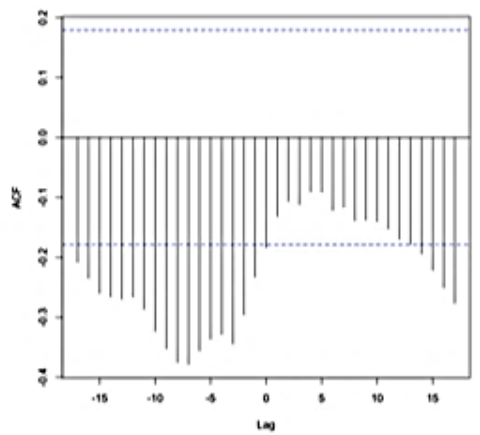
*Reciprocated Link*




*Single Link*



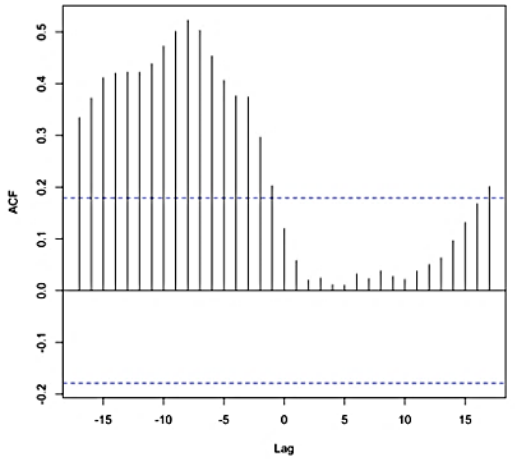




Most of the CCFs between RTGS transactions and the FSI (Financial Stability Index) showed significant results prior to lag 0, indicating that the RTGS transaction is leading towards the FSI. In addition, the transaction motif, of the reciprocated link on the DCM z-score, had the highest correlation with the FSI. This indicated that the DCM approach, using the reciprocated motifs, had the best results in terms of capturing the crisis signal compared to the FSI.

DRG

DCM

*Null Link*



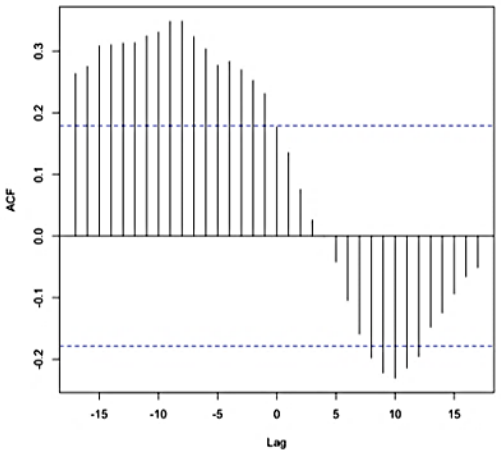



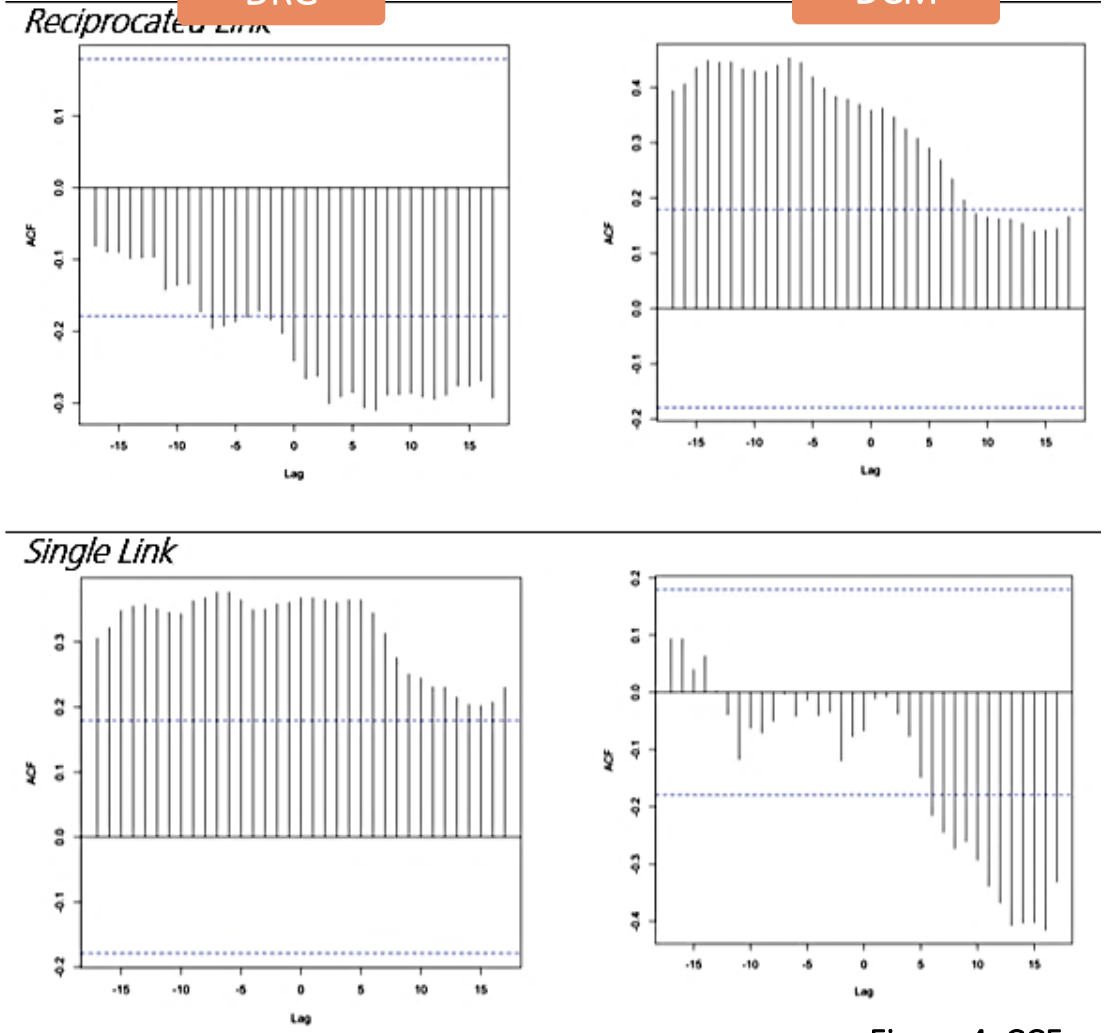

Figure 3. CCF results from RTGS to FSI.

*) FSI: Indonesia Financial System Stability Indicator (ISSK)

# 4 RESULT OF THE RESEARCH

## Early Warning Signal Model

DRG DCM




In the clearing transactions, the CCF results revealed a significant correlation before and after the lag 0, signifying that the lagging status or the clearing leading z-score status towards the FSI is unknown. The z-score values of the clearing transactions are not as good as those of the RTGS transaction in capturing the crisis signal.

DRG DCM

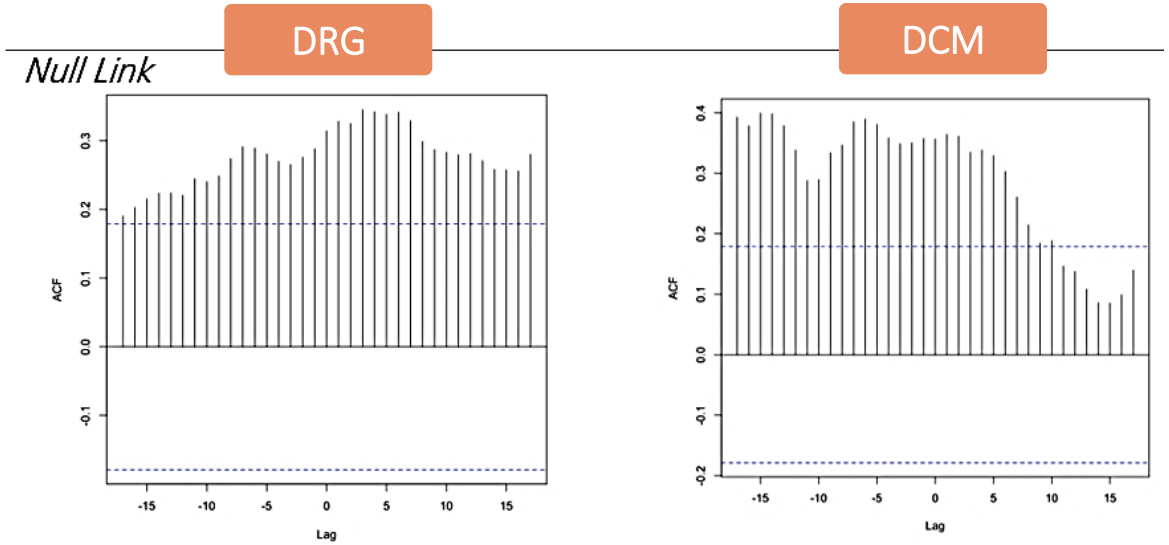



Figure 4. CCF results from clearing to FSI.

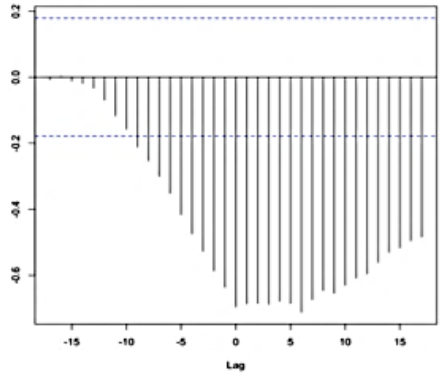
*) FSI: Indonesia Financial System Stability Indicator (ISSK)

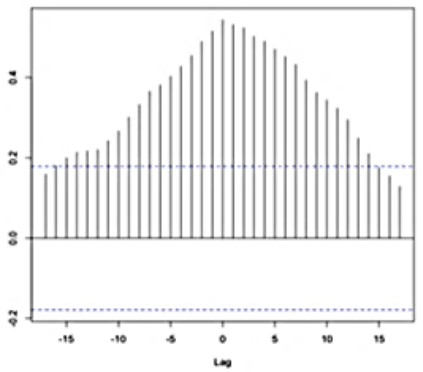
# 4 RESULT OF THE RESEARCH

## Early Warning Signal Model

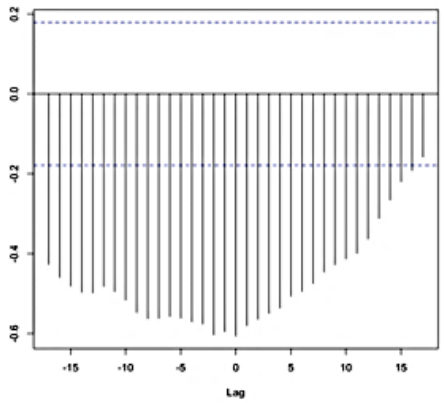
DRG | DCM

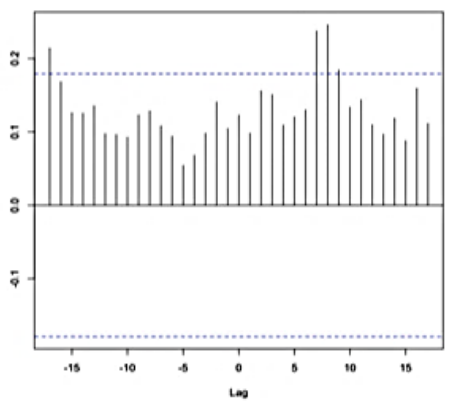
*Reciprocated Link*




*Single Link*

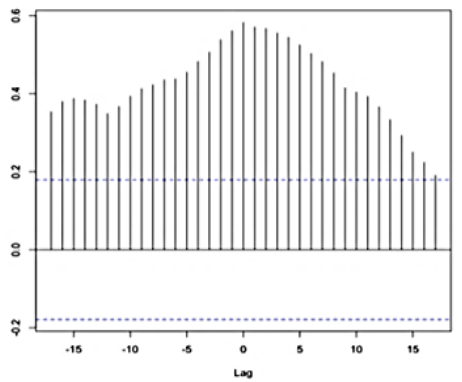



There was a leading signal from the z-score in the clearing towards the RTGS transactions due to the clearing transaction is the beginning of the emergence of a bank liquidity needs. At the end of clearing transactions settlement, a bank in a negative clearing net position will seek funds on the interbank market through the RTGS system to cover its shortfall. The clearing transaction becomes one of the sources affecting liquidity needs in the RTGS.

DRG | DCM

*Null Link*



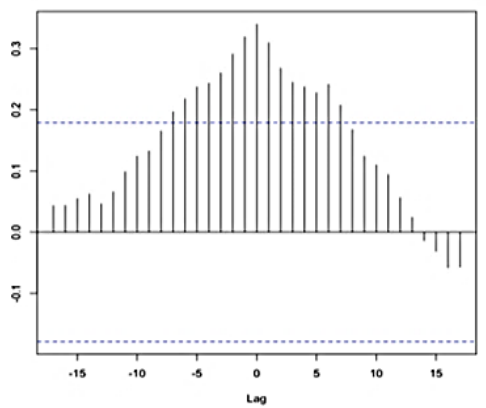




Figure 5. CCF results from RTGS to SKN.

*) SKN: National Clearing System of Indonesia; *) FSI: Indonesia Financial System Stability Indicator (ISSK)

# 5 CONCLUSIONS AND POLICY IMPLICATIO

- The null link motif dominates the RTGS transactions, while the reciprocal link motif commands the clearing transactions in the SKN*. This occurs because, in RTGS transactions, the interbank relation is more concentrated in some banks only and do not spread to other banks.
- The estimation of the DCM approach is more accurate than that of the DRG approach in both types of transactions. This showed that the DCM model, in the RTGS transaction, has a potential as an early warning signal for the liquidity crisis conditions.
- The presence of leading signals from the z-score of the clearing towards RTGS transaction, indicating that a clearing transaction may affect the liquidity requirement of an RTGS transaction. *Thus, although the clearing transactions do not have the potential to reflect the liquidity conditions, they precisely and firstly signal the RTGS transactions.*
- The RTGS payment transactions can be an indicator of the occurrence of financial liquidity. The DCM model and interbank reciprocal relationship can be used as an early warning signal of the liquidity crisis.
- The next study can be more focused on the z-score threshold measurement. In addition, the payment motif between the three banks (triadic motif) can be an alternative to better understand the interbank payment transaction motifs.



*) SKN: National Clearing System of Indonesia

# THANK YOU FOR YOUR ATTENTION