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From Organization to Activity in the US Collateralized Interbank Market

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This paper studies and connects market organization and activity in the US collateralized interbank market using an assumption-neutral approach. We apply cluster analysis to aggregate activity factors suggested by prior studies to support two market organizations: three-tier and core-periphery. We find that four bank-specific factors and one economic conditions factor explain interbank activity for both alternative organizations. We also find evidence that the interbank market organization affects institutions' borrowing and lending. While both organizations moderate interbank activity, the three-tier structure detects distinct market operations which are not represented in the core-periphery structure.

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CONTENTS

1. Introduction

The interbank market links financial intermediaries by a sophisticated network of multilateral exposures where risky activities of some institutions are financed using borrowed funds. Specifically, small financial intermediaries use customer deposits to make loans to large universal intermediaries that depend on wholesale short-term funds to finance a gamut of risky activities. While individually these exposures may appear safe, it is important to understand the drivers of this activity and how these risks behave in aggregate (Allen and Gale, 2000; Al-Suwailem, 2014). As financial asset values fall, financial institutions experience difficulty in repaying current obligations, raising funds, and remaining solvent and liquid. Through failed obligations in both collateralized (repo) and uncollateralized (federal funds) interbank market, distress and losses can be transmitted across institutions, markets, and economic sectors (Acharya and Yorulmazer, 2008; Iyer and Peydro, 2011; Tedeschi et al., 2012). Indeed, after the Lehman bankruptcy, repo haircuts ballooned some 43% (Gorton and Metrick, 2012) and the market retreated from $5.5 trillion in 2007 to $3.9 trillion in 2014 (Copeland et al., 2012; 2014).

Studies of interbank market organization generally focus on a set of rules which classify banks according to the individual trades they make. The interbank market organization that results is subject to the trading rules used for classification (Bech and Atalay, 2010; Craig and von Peter, 2014). A second strand of research seeks to shed light on the determinants of interbank market activity (e.g. King, 2008; Ashcraft et al., 2011). This paper connects these two strands of literature by completing an empirical study of interbank market organization and leveraging the results to understand the drivers of interbank activity. Focus is placed on answering three research questions. First, what is the organization of the US collateralized

interbank market? Second, what factors explain activity in this market? Third, how and to what extent do these factors and market organization interact?

The rest of this paper is structured as follows. Section 2 presents our research data and methods. Section 3 proposes falsifiable hypotheses regarding the organization of the interbank market and the principal functions of bank intermediaries relying on this market. The results in Section 4 identify market organization and connect it to the interbank activities. The discussion in Section 5 concludes.

We contribute three main findings. First, we find competing evidence of two alternative organizations of the US collateralized interbank market: core-periphery and three-tier. Second, we find that for both alternative organizations, interbank activities are associated with two exogenous factors—(1) economic conditions, (2) change in liquidity—and further mediated by three endogenous factors of institutional performance—(3) change in leverage, (4) change in return, and (5) balance sheet growth. Third, we demonstrate that the moderating effect of market organization on interbank activity results in different behavior between the tiers. In particular, we find that the three-tier partition marginally outperforms the core-periphery partition in explaining the variance in the US interbank market activity.

2. Research design

2.1. Data

The dataset consists of balance sheets drawn from the quarterly Federal Reserve Call Reports (031 and 041) between 3/31/1992 and 6/30/2014, supplemented by economic and monetary policy series from the Board of Governors releases (H.6 and H.15) and Federal Reserve Economic Data (FRED). We select the top 100 US bank holding companies (BHCs) by total assets as of June 30, 2014 (aggregated to the bank holding company level). For this sample,

the 22-year dataset comprises a 30-item measurement scale composed of quarterly data on the net interbank activities, institutional balance sheet stocks and flows, and macroeconomic conditions.

There are seven series we associate with the change in liquidity—change and growth in cash to liabilities, change and growth in cash equivalents to total expense, change in reserves, change in cash equivalents, and growth in short term liquidity to assets. There are four leverage series—change and growth in liabilities to assets, and change and growth in assets to capital. There are four growth series—growth in total assets, growth in total liabilities, growth in deposits, and growth of the mismatch between assets and liabilities maturing in the next six months. There are four series reflecting the change in return— change in pre- and post-tax return on equity, and change in pre- and post-tax return on assets. There are four series reflecting the growth in securities— change and growth in securities available for sale, and the change and growth in securities to assets. There are three series associated with the growth in profitability—growth in net interest margin, growth in revenue to assets, and growth in interest income to assets. There are four economic conditions series— inflation measured by personal consumption less energy and food, output measured by real GDP, money supply measured by M2, and the natural rate of unemployment.

2.2. Methods

We use cluster analysis of quarterly data to determine potential grouping of our population of banks into distinct tiers. [4] Cluster analysis is appropriate for such a study due to the assumption-neutral way it classifies observations. We employ the two-step methodology

[4] It should be noted that usage of quarterly balance sheet data to partition the interbank market is suggested as a viable alternative by studies of transactional data. For example, after partitioning institutions according to their transactions for the German interbank market, Craig and Von Peter (2014) find that the membership of banks could be predicted reasonably well based purely upon aggregate reporting of bank size.

proposed by Chiu et al. (2001) which extends the BIRCH algorithm developed by Zhang et al. (1996). The distance measure between two clusters (or observations) is related to the decrease in the log-likelihood function as they are combined into one cluster under the assumption that continuous variables and categorical variables follow the normal and multinomial distributions respectively. It is also assumed that variables and observations are independent. Appendix A in Supplements provides further mathematical details for cluster analysis.

We apply exploratory factor analysis (EFA) to investigate whether variables from the 30-item scale dataset of institutional balance sheets and macroeconomic conditions are adequately correlated and meet criteria of reliability and validity. Since EFA does not rely upon assumptions about how variables should be grouped, it is appropriate for an initial investigation of the effect that latent factors may exert on observable measures. Each factor "summarize[s] the interrelationships among [variables] in a concise but accurate manner as an aid in conceptualization" (Gorsuch, 1983: 2). We allow the common factors to be correlated and include idiosyncratic behavior through observation errors. To support meaningful interpretation from this measurement model we require that the factors are: common across observations, invariant to interbank organization during measurement, and significantly explain interbank activity.

To better understand the primary drivers of interbank activity we seek causal interpretation (Pearl, 2012) through a latent factor model (Bollen, 1989) (see Supplements, Appendix B for further mathematical details). We specify a latent factor model drawing upon literature to explain interbank activity through a set of falsifiable hypotheses. This model includes factors that may have direct influence on interbank activity alongside factors with a potential indirect (mediated) influence. The measurement of factors is invariant; however, we

allow interbank tiers to influence the strength and character of the estimated relationships among the model factors.

3. Hypothesis development

In this section, we build on current literature to develop a model of interbank activity wherein the change in leverage, change in return, and growth serve as measures of financial performance which mediate the effect of changes in liquidity and economic conditions on observable interbank activity. We develop three sets of testable hypotheses to address our research questions. First, the organization hypotheses (H1 and H2) examine the structure of the US interbank market. Second, the measurement model (H3), direct association (H4) and mediation hypotheses (H5 and H6) to connect economic conditions and bank specific factors to interbank market activity. Third, the moderation hypotheses (H8 – H11) examine the extent to which the model of interbank activity is affected by interbank market organization.

3.1. Interbank market organization

Several authors have studied the organization of interbank markets empirically. Craig and von Peter (2014) examine the organization of all institutions participating in the German interbank market using direct bilateral exposure data between Q1:1999 and Q4:2007. They posit the existence of a rule-defined core-periphery organization wherein core banks (small fraction of banks that borrow and lend) are assumed to trade between themselves and with the periphery. The distinguishing feature of periphery banks is that they can only interact with core banks.[5] In a similar study of the US federal funds market, Bech and Atalay (2010) apply the Furfine (1999) methodology to infer bilateral exposures using data from April 1997 to Dec. 2006. They propose

[5] Craig and von Peter (2014) find significant improvement upon Erdos-Renyi and scale-free networks and are able to generalize their method to consider a K-tier organizational scheme. For the German interbank system they find a 17% error rate in network link identification for 3 tiers compared to 12% for 2 tiers.

the existence of five groups, which trade according to several rules.[6] Unsurprisingly, the structural changes in the interbank market lead to alternative views of the US interbank market organization.[7] One persistent view of the US interbank market since the late 1980s is a three-tier organization (Allen and Saunders, 1986; Stigum and Crescenzi, 2007). Allen and Saunders (1986) differentiate the tiers as primary interdealer market banks, intermediary correspondents, and smaller banks lacking direct access to the primary market. Based on extensive interviews with market participants, Stigum and Crescenzi (2007) describe the interbank market in terms of money center banks, regional banks, and smaller banks. The three alternative models of interbank organization—core-periphery, five-group, and three-tier—are illustrated in Fig. 1.

Insert Fig. 1 about here

It is reasonable to expect that our dataset of the top 100 BHCs filters out the disconnected group with 1% of all participants (Bech and Atalay, 2010). Reconsidering Bech and Atalay (2010) findings (with the omission of transaction directionality but recognizing net transaction activity), the US interbank market may be represented as a core-periphery organization consistent with Craig and von Peter (2014). In this representation, the core component is likely coincident with the GSCC group (Bech and Atalay, 2010), while the periphery component is likely coincident with the combined GIN, GOUT, and Tendrils groups. Alternatively, the US interbank organization may be represented as a three-tier organization consistent with Allen and

[6] The giant strongly connected component (GSCC) composed of nodes that are connected to every other node in the GSCC through a directed path: the giant in-component (GIN) (resp. giant out-component (GOUT)) with nodes connected to the GSCC by a directed path in but not out (resp. from but not to) the GSCC; the tendrils that are connected to the GSCC only through a path of mixed lending and borrowing links; and the disconnected component with nodes, which participate in the federal funds market but are completely disconnected from the GSCC. Bech and Atalay (2010: 12-14) find the following allocation of institutions among the five groups: GSCC=10% (±1%), G-IN=58% (±5%), G-OUT=17% (±4%), Tendrils=14% (±3%); such that ~7.2% were borrowing from GIN, ~4.8% were lending to GOUT, and ~2.3% of tendrils were borrowing from GIN and lending to GOUT. The disconnected component contained less than 1% (±1%) of institutions.

[7] Furfine (1999), Soramaki et al. (2007), and Battiston et al. (2012) have also considered multi-tiered systems.

Saunders (1986) and Stigum and Crescenzi (2007), where the GSCC group is likely coincident with tier 1, while GIN, GOUT, and Tendrils (differentiate by interbank activity share) form tiers 2 and 3.

Exploratory analysis of characteristics of interbank market participants suggests that market organization exists as a latent construct that can be measured using relevant characteristics of financial intermediaries: interbank lending, interbank borrowing, interbank pass-through,[8] rank, and total assets. To establish the validity of this construct the institutional characteristics must both reliably converge on the latent construct (convergent validity) and be mutually distinct (discriminant validity) (Campbell and Fiske, 1959).

Hypothesis 1 (H1). A construct of core-periphery interbank market organization is formed by the five indicators of interbank lending, interbank borrowing, interbank pass-through, rank, and assets, such that the silhouette measure of cohesion and separation[9] exceeds 0.5.[10]

Hypothesis 2 (H2). A construct of three-tiered interbank market organization is formed by the five indicators of interbank lending, interbank borrowing, interbank pass-through, rank, and assets, such that the silhouette measure of cohesion and separation exceeds 0.5.

3.2. Formation of measurement, direct association, and mediation hypotheses

Measurement model hypotheses.

"Contemporary banking theory classifies banking functions into four main categories: offering liquidity and payment services, transforming assets, managing risks, processing information and monitoring" (Freixas and Rochet, 2008: 2). We consider the collected 30-item dataset in terms of these four functional categories. The risk management function reflects

[8] The interbank pass-through value is defined as the minimum of interbank borrowing and lending at quarterly time t. It measures the institution's role as a conduit of funding.

[9] See Rousseeuw (1987).

[10] See Kaufman and Rousseeuw (2009).

changing economic conditions, which may be handled through adjustment of the growth in securities, the change in leverage, the change in return, and profitability growth. The change in liquidity factor reflects the larger liquidity provision function. The growth factor reflects the larger asset transformation function. Information processing and monitoring may not be observable in the collected dataset.

We propose that seven latent factors of economic conditions, change in liquidity, change in leverage, change in return, growth, growth in securities, and profitability growth reliably measure the variance of our sample dataset. Accordingly, these seven latent factors should possess high correlation within each factor, low correlation between factors, and be consistently measured across all market participants.

Hypothesis 3 (H3a). Seven distinct factors of economic conditions, change in liquidity, change in leverage, change in return, growth, growth in securities, and profitability growth converge to a reliable measurement model such that each factor achieves[11]

- (H3b) reliability, such that each factor's composite reliability (CR) exceeds 0.70;
- (H3c) convergent validity, such that the unique one-to-one factor loading is shown by the factor components with average variance extracted (AVE) exceeding 0.50 and CR exceeding AVE;
- (H3d) discriminant validity, such that for each factor AVE exceeds maximum shared variance (MSV), and AVE exceeds average shared variance (ASV);
- (H3e) the factor measurement model is invariant, such that at 95% confidence there is no statistically significant difference in the factor construction between the interbank market structural groups or configural invariance can be demonstrated.

[11] See Hair et al., (2010). More detailed discussion of test statistics is provided in Section 4.2.

Direct association hypotheses.

We consider the direct effect that a change in monetary policy, economic conditions, leverage, liquidity, overall growth, or return would have upon interbank activity through three perspectives: 1) financial intermediation as delegated monitoring, 2) bank portfolio management, and 3) bank funding. First, interbank participants cross-monitor counterparty liquidity, leverage, return, and growth to inform pricing and collateral margins relative to economic conditions (Rochet and Tirole, 1996; Freixas and Rochet, 2008). Second, portfolio management determines the leverage banks use, the liquidity risk exposure, and the return banks eventually realize dependent on economic conditions (Farrugia et al., 2011; Moshirian and Wu, 2012; Bagliano and Morana, 2014). Portfolio management is generally considered a fundamental behavior of financial intermediaries (e.g. Hart and Jaffee, 1974; Koehn and Santomero, 1980).[12] From the third (funding) perspective, banks "finance their assets with interbank funds" (Rochet and Vives, 2004: 1117) and pledge assets as collateral in the interbank market (Freixas et al., 2004; Brunnermeier, 2009).[13] Thus, we make the simplifying hypothesis that direct associations between economic conditions, change in liquidity, change in leverage, change in return, growth and interbank activity are consistent with literature.

Hypothesis 4 (H4). At 95% confidence, the latent factors of economic conditions **(H4a)**, change in liquidity (H4b), change in leverage (H4c), change in return (H4d), and growth (H4e), in addition to monetary policy (H4f) are significantly associated with interbank borrowing.

[12] From this perspective, the extant banks can be viewed as successful portfolio managers, taking exogenous flows and choosing a return and growth rate "to maximize the expectation… of the bank's financial net worth" (Rochet, 1992: 1139).

[13] See also Heider et al., (2008: 2) who show how "banks' asset risks affects funding liquidity in the interbank market" in addition to Acharya and Skeie (2011) who study the effect that leverage of a bank has on its access to the interbank market in the presence of adverse economic conditions reflected by low market liquidity.

Hypothesis 5 (H5). At 95% confidence, the latent factors of economic conditions (H5a), change in liquidity (H5b), change in leverage (H5c), change in return (H5d), and growth (H5e), in addition to monetary policy (H5f) are significantly associated with interbank lending.

Mediation hypotheses.

Empirical studies of Goldsmith (1969), McKinnon (1973), Shaw (1973), and King and Levine (1993) find a positive association between economic growth and financial development. Bhattacharya and Fulghieri (1994) consider interbank activity as insurance against changes in returns and liquidity. Holmström and Tirole (2001) model assets as cushion against liquidity shocks that condition interbank activity. Heider et al. (2008) find that variation in economic conditions affects interbank activity through risk in counterparty assets. The financial accelerator effect (Bernanke et al., 1999) also plays a role in the connection between macroeconomic conditions and banking through the mediating influence of banks' balance sheets. Specifically, "as balance sheets strengthen with improved economic conditions, the external finance problem declines, which works to enhance borrower spending, thus enhancing the boom. … In this framework, a crisis is a situation where balance sheets of borrowers deteriorate sharply, possibly associated with a sharp deterioration in asset prices, causing the external finance premium to jump … [creating] strains in the interbank market" (Gertler and Kiyotaki, 2010). Pasiouras and Kosmidou (2006) and Chiabi and Ftiti (2014) find that economic conditions and leverage significantly impact return; through which they may in turn indirectly influence interbank positions. Finally, economic conditions are typically addressed by policy makers through monetary policy instruments such as the federal funds rate which acts as the reference price of much interbank activity (Stigum, 1989). Thus, both theoretical and empirical literature support the parsimonious view of monetary policy, growth, change in return, and change in leverage as

mediators of economic conditions, changes in liquidity, changes in leverage, and changes in return, and their effect on interbank activity.[14]

Hypothesis 6 (H6). At 95% confidence, the relationships of economic conditions (H6a), change in liquidity (H6b), change in leverage (H6c), and change in return (H6d) with interbank borrowing are mediated by the changes in leverage, change in return, growth, and monetary policy.

Hypothesis 7 (H7). At 95% confidence, the relationships of economic conditions (H7a), change in liquidity (H7b), change in leverage (H7c), and change in return (H7d) with interbank lending are mediated by changes in leverage, change in return, growth, and monetary policy.

3.3. Formation of moderation hypotheses: Multi-group boundary conditions

Multi-group structural variance.

A number of studies (Allen and Saunders, 1986; Allen et al., 1989; King, 2008; Ashcraft et al., 2011) find that interbank market activity varies with interbank market organization. Allen et al. (1989: 502-503) mention three ways size may impact bank participation in the interbank market.

First, Allen and Saunders (1986) posit that institutions that deal with each other frequently (e.g. Tier 1 or Core) set higher spreads on transactions with relatively unfamiliar institutions (e.g. Tier 2, Tier 3, or Periphery) due to counterparty information asymmetries. In a panel study of commercial bank data from 1986 to 2005, King (2008: 295) offers the supporting evidence "that high-risk banks have consistently paid more than safe banks for interbank loans and have been less likely to use these loans as a source of liquidity." While all banks are subject

[14] See also Pagano (1993), Coccorese (2004), and Baum et al. (2009).

to differentiated discount window rate,[15] many authors argue that money center banks benefit from implicit preferential liquidity backstop, a form of too-big-to-fail insurance by the Central Bank (e.g., Freixas et al., 2000: 627).

Second, Ho and Saunders (1985) propose that "managers of smaller regional banks may choose to rely on traditional "deposit-taking" techniques of funds production for reasons of risk aversion." An alternative is that due to a lack of competition smaller banks may serve regions in which they are able to collect deposits at below market rates (Rose and Kolari, 1985; Hannan and Hanweck, 1988).[16] Geographic expansion can be expected to pressure the expanding small banks to offer uniform rates across their branches, thus reducing their local deposit funding advantage and increasing the cost effectiveness of borrowing in the interbank market.

Third, Ashcraft et al. (2011: 26) build a model for intraday activity in the interbank market, according to which "Smaller banks hold larger average scaled amounts of nonborrowed reserves overnight than do large banks." Their model implies that small banks due to their relatively larger reserve balances will in general have weaker relationships with interbank borrowing and lending than large banks.

Therefore, we propose that the latent factor model relating economic conditions, the change in liquidity, change in leverage, change in return, and growth with interbank activity will vary significantly by market organization (hypothesis 8). Moreover, the theoretical and empirical studies above suggest that interbank market organization creates stronger association between the latent factors and interbank activity for money center banks than for smaller institutions (hypotheses 9 and 10).

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[15] The Federal Reserve Discount Window offers short-term credit at the prime or secondary rates, both above the federal funds rate.

[16] See Freixas and Rochet (2008: 81-84) and Salop (1979).

Hypothesis 8 (H8). At 95% confidence, the structural model of relationships of economic conditions, change in liquidity, change in leverage, change in return, and growth as they relate to interbank borrowing and lending activity is variant, such that there is a statistically significant difference in the latent factor model relationships between the interbank market structural groups.

Hypothesis 9 (H9). Interbank market organization will moderate the strength of the direct and mediated relationships between economic conditions (H9a), the change in liquidity (H9b), the change in leverage (H9c), the change in return (H9d), growth (H9e), and monetary policy (H9f) with interbank borrowing, such that the relationship will be stronger for lower Tiers (Tier 1 stronger than Tier2 which is in turn stronger than Tier 3, or Core stronger than Periphery).

Hypothesis 10 (H10). Interbank market organization will moderate the strength of the direct and mediated relationships between economic conditions (H10a), the change in liquidity (H10b), the change in leverage (H10c), the change in return (H10d), growth (H10e), and monetary policy (H9f) with interbank lending, such that the relationship will be stronger for lower Tier (Tier 1 stronger than Tier2 stronger than Tier 3, or Core stronger than Periphery).

Alternative interbank market organizations.

The dominant findings in recent literature suggest that the core-periphery organization found for the German interbank market by Craig and von Peter (2014) may be pervasive. The core-periphery organization has been verified as a "*stylized fact* of interbank markets" in Netherlands (in 't Veld and van Lelyveld, 2014: 27), UK (Langfield and Ota, 2014), and Italy (Fricke and Lux, 2014). At the same time, the authors find some room for alternative representations and acknowledge the common limitations of their network analysis. Langfield and Ota (2014) state "that the UK interbank market closely approximates a core-periphery

organization, but that the closeness of this approximation, and the composition of the optimal core, changes significantly across market instruments." Similarly, in 't Veld and van Lelyveld (2014) acknowledge that "While the core has a higher average size than the periphery, we observe that the group of core banks can be divided in the small set of the largest banks, and an additional group of medium-sized banks of a size similar to many periphery banks." Given the support for the core-periphery interpretation of the European interbank markets, we hypothesize that the core-periphery organization will also allow a superior explanation of the US interbank market than the alternative three-tier model observed.

Hypothesis 11 (H11). Core-periphery structural moderation is superior to three-tier structural moderation of the latent factor model relating economic conditions, change in liquidity, change in leverage, change in return, and growth to interbank activity, demonstrated by the sample multivariate goodness-of-fit statistics.

4. Results

4.1. Interbank market tiering

Propositions H1 and H2 are tested and supported by the silhouette measure of cohesion and separation (SMCS) value of 0.5298 for the core-periphery organization and SMCS of 0.5469 for the three-tier organization respectively, decomposed by the variables used for cluster analysis and discussed in Supplements (Appendix A). Descriptive statistics for total assets, asset ranking, interbank borrowing, interbank lending, and interbank pass-through are provided in Table 1.

Insert Table 1 about here

4.2. Measurement, direct association, and mediation

Structure in variable data.

Hypothesis H3 requires that seven distinct factors of the change in liquidity, change in leverage, change in return, growth, growth in securities, profitability growth and economic conditions adequately describe variation in our dataset. We test this through EFA using IBM SPSS Statistics software, then by examining overall model and multi-group fit through confirmatory factor analysis (CFA) in IBM SPSS AMOS.

EFA using principal component extraction, Promax rotation, and Kaiser normalization supports the identification of seven distinct factors among the observed items (pattern matrix for factors is provided in Supplements, Appendix B). Further support for H3a, correlative validity of the identified factors, is provided by examining the correlation matrix organized by factors. Items that load onto a particular factor should correlate strongly with each other, while correlations with other factors' loadings should not be strong. Visual examination of Table 2 supports the convergent validity of the factor definitions, evidenced by strong correlations among items that are expected to load distinctly into unique factors. Discriminant validity of the factor definitions is also supported, since fewer than 10% of all items exhibit medium-size (0.2 to 0.5 range) correlations.

Insert Table 2 about here

The EFA results are used to set up a first order CFA measurement model. Formal tests for reliability (H3b), convergent validity (H3c), discriminant validity (H3d), and measurement model invariance (H3e) are discussed below.

The reliability of each factor is supported by a Cronbach Alpha (CA) statistic[17] satisfying the 0.7 threshold (Peterson and Kim, 2013) in Table 3. The composite reliability for factor F (CR_F), a measure of aggregate factor reliability, following Fornell and Larcker (1981) is defined according to equation (1) where λ_j is the loading of component j, and $\sigma_{\varepsilon_j}^2$ is the variance of the measurement error of component j. Bagozzi and Yi (1988) suggest 0.7 as an adequate threshold for CR_F. We test for convergent validity, defined by Krippendorff (2012) as the "extent to which results correlate with variables known to measure the same phenomena and considered valid", using the Average Variance Extracted of factor F (AVE_F) following equation (2). Convergent validity is supported if AVE_F is greater than 0.5 (Fornell and Larcker, 1981) and if AVE_F is greater than CR_F (Byrne, 2013). We analyze the discriminant validity, the idea that the variances of latent factor F and any other sample do not overlap, through the Maximum Shared Variance (MSV_F) and the Average Shared Variance of factor F (ASV_F), following equations (3) and (4) respectively. The hypothesis test criteria that AVE_F is greater than MSV_F, and AVE_F is greater than ASV_F can be found in Hair et al. (2010).

$$CR_F = \frac{\left(\sum_{j=1}^{C} \lambda_j\right)^2}{\left(\sum_{j=1}^{C} \lambda_j\right)^2 + \sum_{j=1}^{C} \sigma_{\varepsilon_j}^2} \tag{1}$$

$$AVE_F = \frac{\left(\sum_{j=1}^{C} \lambda_j^2\right)}{\left(\sum_{i=1}^{C} \lambda_j^2\right) + \sum_{j=1}^{C} \sigma_{\varepsilon_j}^2} \tag{2}$$

$$MSV_F = \max_{\mathrm{J}\neq\mathrm{K}}\left(\rho_{J,K}^2\right) = \max_{\mathrm{J}\neq\mathrm{K}}\left[\left(\frac{cov(J,K)}{\sigma_J \sigma_K}\right)^2\right] = \max_{\mathrm{J}\neq\mathrm{K}}\left[\left(\frac{E[(J-\mu_J)(K-\mu_K)}{\sigma_J \sigma_K}\right)^2\right] \tag{3}$$

$$ASV_F = \max_{\mathrm{J,K}\in\mathrm{F}}\left(\rho_{J,K}^2\right) \tag{4}$$

[17] Cronbach Alpha (CA) statistic of factor reliability is measured as $CA = \frac{k}{k-1}\frac{\sigma_x^2 - \sum \sigma_i^2}{\sigma_x^2}$ where σ_i^2 is variance of individual k factor items and σ_x^2 is the factor variance (e.g., Crocker & Algina, 1986).

In Table 3 we show that the composite reliability metrics for each factor are well above the threshold of 0.7 required, supporting factor reliability (H3b). The average variance extracted is between 0.5 and the composite reliability for each factor which supports convergent validity (H3c). Furthermore, we find that the average variance extracted is greater than both the maximum shared variance and the average shared variance for each factor supporting the discriminant validity of the latent factors (H3d).

Insert Table 3 about here

Next, we consider the configural invariance for the measurement model by comparing its goodness of fit statistics in the context of the model's multi-group partitions, as summarized in Table 4. Hair et al. (2010) state that "One key point across the results is that simpler models and smaller samples should be subject to more strict evaluation than are more complex models with larger samples." The measurement model in this study satisfies both the complexity (30 variables and 7 factors) and large sample size (over 6000 observations) considerations. The comparative fit index (CFI) (Bentler, 1990) decreases when the sample is partitioned along either the core-periphery or three-tier interbank market organization, and in each case it fails to meet the 0.9 threshold suggested by Hu and Bentler (1999). The root-mean square error of approximation (RMSEA) (Steiger & Lind, 1980) metrics for each model are close or satisfy (for the three-tier model) the 0.1 threshold suggested by Hu and Bentler (1999). Finally, the standardized root mean square residual (SRMR) is close to but does not meet the 0.05 threshold suggested by Byrne (2013) for well-fitting models.[18] Allowing for flexibility when determining adequate thresholds for the goodness-of-fit statistics due to model complexity and the large sample size,

[18] The χ^2/df metric is not considered since Satorra and Bentler (2001) find that it is sensitive to non-normal data which is present in this dataset.

we suggest that the CFA measurement model is close but does not support configural invariance. However, as an alternative to configural invariance we test for and are able to support metric invariance following Gaskin (2012; 2014) thereby satisfying hypothesis H3e (Supplements, Appendix B).

Insert Table 4 about here

Direct associations.

We test the direct association of the five latent factors and monetary policy with interbank borrowing and interbank lending through a straightforward estimation of the structural equation model presented in Fig. 2 (Panel A) using the entire sample. Table 5 indicates that several portions of hypotheses 4 and 5 are supported, particularly the significance of return, growth, and economic conditions.

Insert Fig. 2 about here

Insert Table 5 about here

Mediated associations.

We test the mediation relationships proposed in hypotheses 6 and 7 using the Baron and Kenny (1986) approach (estimating the model without and then with mediators) which are illustrated in Fig. 2 Panel B. Results are provided in Table 6. Mediation hypotheses are tested via bootstrapping (2000 samples with 95% bias-corrected confidence level). We find that hypotheses 5 and 6 are both supported for several relationships; however, the nature of intermediation varies.

Insert Table 6 about here

4.3. Moderation

Moderation of interbank market organization.

We incorporate the interbank market organization as a consideration of interbank activity in the latent factor model described in Fig. 2. We test for significant differences in model coefficients between groups using the $\Delta\chi^2$ test with H_0 expecting model invariance. The results are presented in Table 7. There is significant difference in the chi-squared values between constrained and unconstrained versions of the model for both the core-periphery and three-tier interbank market organizations supporting hypothesis 8. In Table 8 we explore the moderation of direct relationships and find significant evidence in support of moderation for several direct relationships. The results of testing moderation for the mediated relationships are detailed in Supplements, Appendix B3.

Insert Table 7 about here

Insert Table 8 about here

Comparison of alternative interbank market organizations.

Motivated by the desire for a better structural representation of the interbank market, we attempt to determine which decomposition of the interbank market is a more useful. To this end we compare the goodness of fit for the latent factor model presented in Fig. 2 Panel B for individual partitions of the interbank market and provide the results in Table 9. Model fit is best when all observations are included simultaneously. This is not surprising, since the latent factor model was selected to optimize the model fit for the entire sample. Interestingly, the fit of each segment of the three-tier model is superior to any segment of the core-periphery model. Tier 2

appears to behave significantly differently from tiers 1 and 3.[19] Therefore, a possible cause of the decrease in model fit is that the core and periphery each contain portions of tier 2 which behaves distinctly. This result must be taken with some discretion, since it is also natural to expect that a model which allows calibration with more groups may achieve a better fit.

Insert Table 9 about here

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5. Discussion

This study combines two distinct strands of literature which investigate the organization of the interbank market and the determinants of institutions' interbank activity. In contrast to prior studies of interbank market organization that focus on transactional data to connect specific borrowers and lenders, this paper utilizes aggregate institutional activity in the collateralized interbank market. Cluster analysis of bank data leads to competing evidence of core-periphery and three-tier market organizations.

Our second empirical finding is that five latent factors, as hypothesized, explain the variance in the interbank activity data across tiers. Specifically, three factors—economic conditions, change in return, and balance sheet growth—are significantly and directly associated with interbank activity. In addition, two factors—change in liquidity and change in leverage—have a mediated relationship with interbank activity via growth and change in return. Moreover, we find that interbank market organization significantly moderates interbank activity.

To determine whether the core-periphery partition, proposed for several European countries, is superior to the three-tier partition as an organizational representation of the US collateralized interbank market, we first examine whether the moderating effect of these

[19] The distinct behavior of Tier 2 can be seen in Table 8 through the coefficient difference tests in Panel B. Also, in Appendix B we test for the moderation of mediated relationships and find that the three-tier organization recognizes less moderation of mediated relationships than the core-periphery organization.

alternative organizations is reasonable and useful for interpretation. Second, we analyze which organization achieves superior model fit in explaining the variance in the interbank market activities. Contrary to the literature findings in the European interbank markets, we find that the three-tier organization marginally outperforms the core-periphery organization in explaining the US collateralized interbank market activity largely by capturing the distinct behavior of tier 2 compared to tiers 1 and 3.

Supplements

Supplementary data in Appendixes A, B, and C can be found in the online version of the article.

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Figures

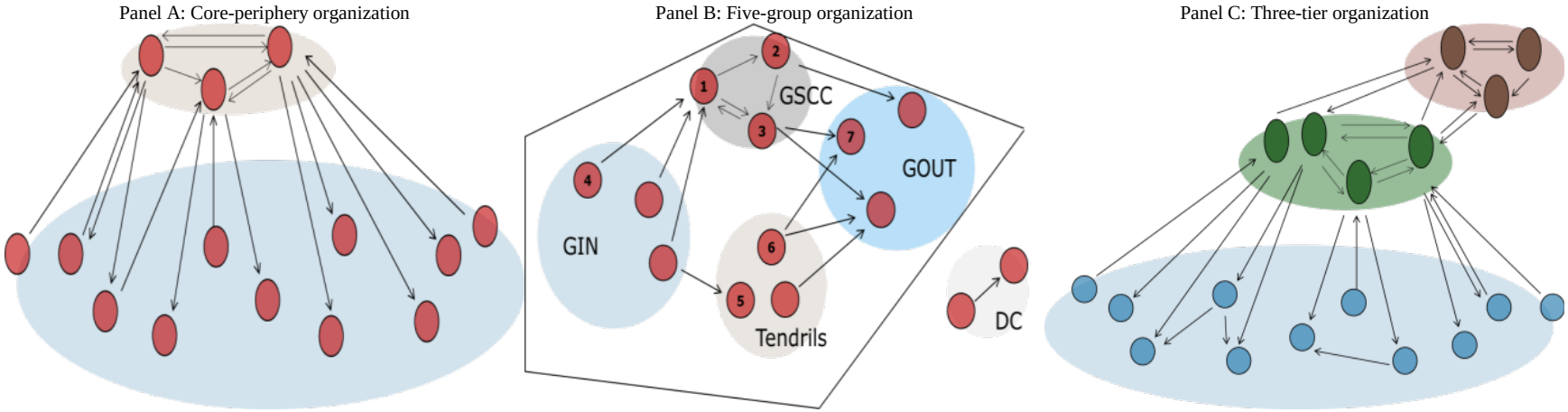

Fig. 1. Models of interbank organization.

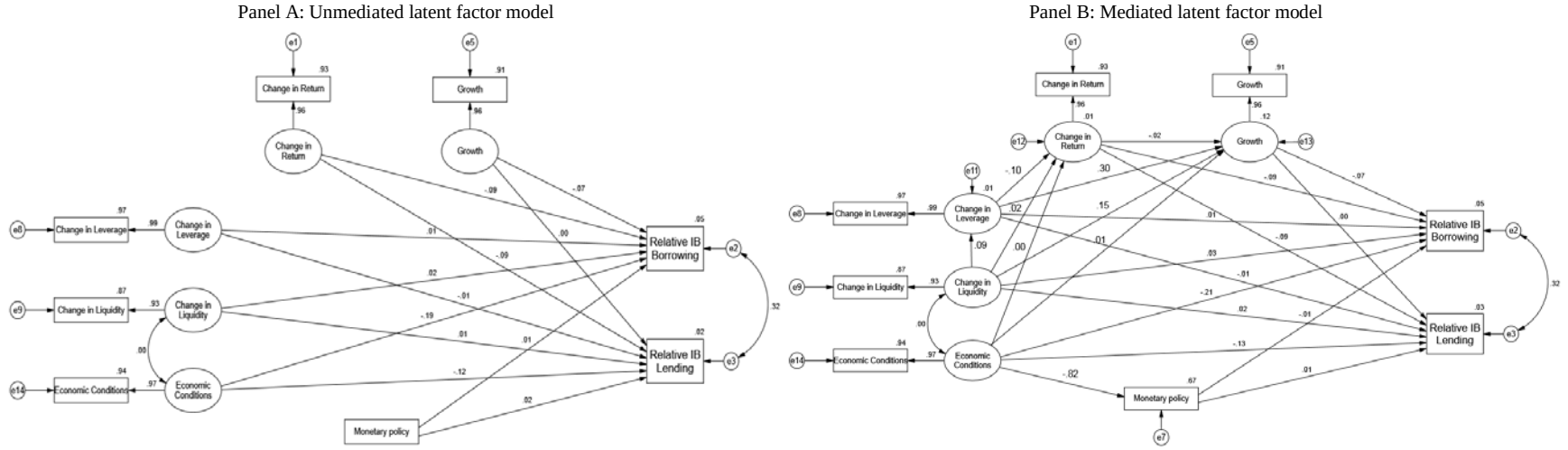

Fig. 2. Latent factor model for direct association and mediation testing.

Tables

Table 1
Descriptive statistics of cluster analysis dataset.

	N	Min.	Max.	Mean	S.E.	Std.	Variance	Skewness	S.E.	Kurtosis	S.E	ρ(1)	ρ(2)	ρ(3)	ρ(4)	ρ(5)
(1) Ranking	6774	1.00	100.00	42.56	0.30	25.02	625.99	0.14	0.03	-1.03	0.06	1				
(2) Assets^{+}	6774	-9.25	-1.25	-6.02	0.02	1.56	2.45	0.87	0.03	0.38	0.06	-0.92***	1			
(3) IB lending^{+}	6774	-20.79	-0.64	-10.26	0.06	5.03	25.34	-0.85	0.03	0.11	0.06	-0.60***	0.58***	1		
(4) IB borrowing^{+}	6774	-20.86	-0.94	-7.80	0.05	4.01	16.08	-1.79	0.03	3.55	0.06	-0.62***	0.65***	0.40***	1	
(5) IB Pass-through^{+}	6774	-20.62	-0.64	-10.77	0.06	5.30	28.07	-0.64	0.03	-0.46	0.06	-0.65***	0.65***	0.91***	0.65***	1

Note: The properties describe the fully (share- and log-) transformed data, denoted $^{+}$. ρ is the Pearson correlation which is significant at the 0.01 level (2-tailed), denoted by ***.

Table 2
Correlative validity.

		Factor 1 (F1) Change in Liquidity							Factor 2 (F2) Economic Conditions				Factor 3 (F3) Change in Leverage				Factor 4 (F4) Change in return				Factor 5 (F5) Growth				Factor 6 (F6) Growth in Securities				Factor 7 (F7) Profitability Growth		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
F1	(1) Δ Cash to Lia.	1.00	0.78	0.46	0.74	0.30	0.66	0.58	0.00	0.00	0.00	0.00	0.01	0.00	0.06	0.05	0.01	0.05	0.02	0.06	0.10	0.12	0.09	-0.13	-0.02	-0.01	-0.32	-0.26	-0.02	-0.03	-0.04
	(2) G. Cash to Lia	0.78	1.00	0.43	0.93	0.31	0.60	0.62	0.00	0.00	0.00	0.00	0.05	0.04	0.06	0.06	-0.01	-0.01	0.00	0.00	0.11	0.13	0.11	-0.07	0.00	0.03	-0.26	-0.21	-0.03	-0.03	-0.05
	(3) Δ Cash to Exp.	0.46	0.43	1.00	0.47	0.14	0.34	0.31	0.00	0.00	0.00	0.00	0.04	0.04	0.05	0.05	0.04	0.06	0.04	0.06	0.09	0.07	0.09	-0.07	0.00	0.02	-0.16	-0.13	-0.09	-0.09	-0.12
	(4) G. Cash to Exp.	0.74	0.93	0.47	1.00	0.30	0.58	0.57	0.00	0.00	0.00	0.00	0.10	0.09	0.11	0.11	0.02	0.01	0.02	0.02	0.23	0.19	0.22	0.00	0.05	0.08	-0.23	-0.19	-0.15	-0.18	-0.20
	(5) Δ Reserves	0.30	0.31	0.14	0.30	1.00	0.50	0.23	0.00	0.00	0.00	0.00	0.07	0.06	0.07	0.07	0.00	-0.01	0.00	-0.01	0.15	0.15	0.15	0.04	0.02	0.01	-0.10	-0.09	-0.02	0.01	-0.01
	(6) Δ Cash	0.66	0.60	0.34	0.58	0.50	1.00	0.42	0.00	0.00	0.00	0.00	0.11	0.11	0.11	0.11	-0.02	-0.02	-0.01	-0.01	0.25	0.22	0.25	0.03	0.13	0.09	-0.19	-0.17	-0.06	-0.05	-0.07
	(7) G. STL to assets	0.58	0.62	0.31	0.57	0.23	0.42	1.00	0.00	0.00	0.00	0.00	0.08	0.08	0.07	0.08	0.00	-0.01	0.00	-0.01	0.05	0.01	0.05	-0.15	0.00	0.00	-0.18	-0.14	-0.05	-0.04	-0.04
F2	(8) PCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.96	0.99	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
	(9) Output	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	1.00	0.93	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00
	(10) Money stock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.93	1.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(11) Unemployment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.53	0.78	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F3	(12) Δ Lia. to assets	0.01	0.05	0.04	0.10	0.07	0.11	0.08	0.00	0.00	0.00	0.00	1.00	0.97	0.87	0.95	-0.02	-0.11	-0.04	-0.13	0.29	0.20	0.40	0.14	0.11	0.12	0.04	0.04	-0.15	-0.12	-0.11
	(13) G. Lia. to assets	0.00	0.04	0.04	0.09	0.06	0.11	0.08	0.00	0.00	0.00	0.00	0.97	1.00	0.79	0.88	-0.01	-0.13	-0.04	-0.15	0.27	0.20	0.39	0.13	0.09	0.10	0.03	0.02	-0.14	-0.11	-0.11
	(14) Δ Assets to Capital	0.06	0.06	0.05	0.11	0.07	0.11	0.07	0.00	0.00	0.00	0.00	0.87	0.79	1.00	0.98	-0.02	-0.06	-0.05	-0.09	0.29	0.19	0.37	0.15	0.12	0.13	0.05	0.05	-0.15	-0.13	-0.12
	(15) G. Assets to Capital	0.05	0.06	0.05	0.11	0.07	0.11	0.08	0.00	0.00	0.00	0.00	0.95	0.88	0.98	1.00	-0.02	-0.08	-0.05	-0.10	0.29	0.20	0.38	0.15	0.12	0.12	0.05	0.04	-0.15	-0.13	-0.12
F4	(16) Δ Pre-tax ROE	0.01	-0.01	0.04	0.02	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	-0.02	-0.01	-0.02	-0.02	1.00	0.72	0.93	0.67	-0.03	-0.05	-0.04	-0.06	-0.03	-0.04	0.00	-0.01	0.04	0.16	0.00
	(17) Δ Pre-tax ROA	0.05	-0.01	0.06	0.01	-0.01	-0.02	-0.01	0.00	0.00	0.00	0.00	-0.11	-0.13	-0.06	-0.08	0.72	1.00	0.66	0.95	-0.04	-0.04	-0.06	-0.06	-0.04	-0.05	-0.01	-0.01	0.07	0.14	0.03
	(18) Δ Post-tax ROE	0.02	0.00	0.04	0.02	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.04	-0.04	-0.05	-0.05	0.93	0.66	1.00	0.72	-0.04	-0.06	-0.05	-0.07	-0.02	-0.02	0.00	0.00	0.05	0.18	0.01
	(19) Δ Post-tax ROA	0.06	0.00	0.06	0.02	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	-0.13	-0.15	-0.09	-0.10	0.67	0.95	0.72	1.00	-0.05	-0.05	-0.07	-0.06	-0.03	-0.04	0.00	0.00	0.08	0.16	0.04
F5	(20) G. Assets	0.10	0.11	0.09	0.23	0.15	0.25	0.05	0.01	0.01	0.01	0.00	0.29	0.27	0.29	0.29	-0.03	-0.04	-0.04	-0.05	1.00	0.77	0.98	0.60	0.34	0.39	-0.01	-0.03	-0.23	-0.18	-0.25
	(21) G. Deposits	0.12	0.13	0.07	0.19	0.15	0.22	0.01	0.01	0.01	0.01	0.00	0.20	0.20	0.19	0.20	-0.05	-0.04	-0.06	-0.05	0.77	1.00	0.76	0.66	0.22	0.26	-0.07	-0.07	-0.14	-0.12	-0.16
	(22) G. Liabilities	0.09	0.11	0.09	0.22	0.15	0.25	0.05	0.01	0.01	0.01	0.00	0.40	0.39	0.37	0.38	-0.04	-0.06	-0.05	-0.07	0.98	0.76	1.00	0.59	0.34	0.38	0.00	-0.03	-0.23	-0.18	-0.24
	(23) G. Current AL Miss	-0.13	-0.07	-0.07	0.00	0.04	0.03	-0.15	0.00	0.00	0.00	0.00	0.14	0.13	0.15	0.15	-0.06	-0.06	-0.07	-0.06	0.60	0.66	0.59	1.00	0.22	0.26	0.02	-0.01	-0.10	-0.07	-0.10
F6	(24) Δ Sec. AFS	-0.02	0.00	0.00	0.05	0.02	0.13	0.00	0.00	0.00	0.00	0.00	0.11	0.09	0.12	0.12	-0.03	-0.04	-0.02	-0.03	0.34	0.22	0.34	0.22	1.00	0.67	0.45	0.42	-0.08	-0.06	-0.08
	(25) G. Sec AFS	-0.01	0.03	0.02	0.08	0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.12	0.10	0.13	0.12	-0.04	-0.05	-0.02	-0.04	0.39	0.26	0.38	0.26	0.67	1.00	0.49	0.56	-0.13	-0.08	-0.12
	(26) Δ Sec. to Assets	-0.32	-0.26	-0.16	-0.23	-0.10	-0.19	-0.18	-0.01	-0.01	0.00	0.00	0.04	0.03	0.05	0.05	0.00	-0.01	0.00	0.00	-0.01	-0.07	0.00	0.02	0.45	0.49	1.00	0.87	-0.05	-0.05	-0.03
	(27) G. Sec. to Assets	-0.26	-0.21	-0.13	-0.19	-0.09	-0.17	-0.14	0.00	-0.01	0.00	0.00	0.04	0.02	0.05	0.04	-0.01	-0.01	0.00	0.00	-0.03	-0.07	-0.03	-0.01	0.42	0.56	0.87	1.00	-0.03	-0.03	-0.01
F7	(28) G. Net Int. Margin	-0.02	-0.03	-0.09	-0.15	-0.02	-0.06	-0.05	0.00	0.00	0.00	0.00	-0.15	-0.14	-0.15	-0.15	0.04	0.07	0.05	0.08	-0.23	-0.14	-0.23	-0.10	-0.08	-0.13	-0.05	-0.03	1.00	0.60	0.87
	(29) G. Rev. to Assets	-0.03	-0.03	-0.09	-0.18	0.01	-0.05	-0.04	0.00	0.00	0.00	0.00	-0.12	-0.11	-0.13	-0.13	0.16	0.14	0.18	0.16	-0.18	-0.12	-0.18	-0.07	-0.06	-0.08	-0.05	-0.03	0.60	1.00	0.70
	(30) G. Int. Inc. to Assets	-0.04	-0.05	-0.12	-0.20	-0.01	-0.07	-0.04	0.00	0.00	0.00	0.00	-0.11	-0.11	-0.12	-0.12	0.00	0.03	0.01	0.04	-0.25	-0.16	-0.24	-0.10	-0.08	-0.12	-0.03	-0.01	0.87	0.70	1.00

Table 3
Reliability and validity.

	Reliability and validity metrics					Factor correlation matrix						
	CA	CR	AVE	MSV	ASV	Change in Liquidity	Economic Conditions	Change in Leverage	Change in Return	Growth	Growth in Securities	Profitability Growth
Change in Liquidity	0.87	0.97	0.90	0.09	0.02	*0.95*						
Economic Conditions	0.95	0.91	0.73	0.09	0.03	0.31	*0.85*					
Change in Leverage	0.98	0.96	0.86	0.00	0.00	0.00	0.01	*0.92*				
Change in Return	0.93	0.87	0.52	0.05	0.01	0.08	0.15	0.00	*0.72*			
Growth	0.92	0.92	0.74	0.01	0.00	-0.09	-0.05	0.00	0.01	*0.86*		
Growth in Securities	0.85	0.82	0.56	0.05	0.01	0.05	-0.02	-0.01	-0.22	0.00	*0.75*	
Profitability Growth	0.89	0.87	0.70	0.05	0.01	-0.15	-0.23	0.01	-0.07	0.08	-0.04	*0.84*

Note: Italicized diagonal of the factor correlation matrix shows square root of AVE.

Table 4
Goodness of fit metrics.

Sample	CFI	RMSEA	standardized RMR
All Observations	0.819	0.141	0.0650
Core-periphery partition	0.817	0.102	0.0686
Three-tiered partition	0.815	0.085	0.0698

Table 5
Direct association results.

Hypothesis	Proposition	Direct Beta	Hypothesis outcome
H4a	Economic Conditions↗ Relative Interbank borrowing	-0.191***	Supported
H5a	Economic Conditions↗ Relative Interbank lending	-0.120***	Supported
H4b	Change in Liquidity↗ Relative Interbank borrowing	0.025*	Not Supported
H5b	Change in Liquidity ↗ Relative Interbank lending	0.015	Not Supported
H4c	Change in Leverage↗ Relative Interbank borrowing	0.008	Not Supported
H5c	Change in Leverage ↗ Relative Interbank lending	-0.014	Not Supported
H4d	Change in Return↗ Relative Interbank borrowing	-0.088***	Supported
H5d	Change in Return ↗ Relative Interbank lending	-0.095***	Supported
H4e	Growth↗ Relative Interbank borrowing	-0.071***	Supported
H5e	Growth ↗ Relative Interbank lending	0.005	Not Supported
H4f	Monetary Policy↗ Relative Interbank borrowing	0.013	Not Supported
H5f	Monetary Policy ↗ Relative Interbank lending	0.023*	Not Supported

Note: * significant at 10%; ** significant at 5%; *** significant at 1%

Table 6
Mediation testing results.

Hypothesis	Proposition	Direct Beta w/o Med.	Direct Beta w/ Med.	Indirect Beta	Mediation observed	Hypothesis outcome
H6a-1	Economic Conditions ↗Change in Return ↗ Relative Interbank borrowing	-0.191***	-0.191***	0.000	No Mediation	Not Supported
H7a-1	Economic Conditions ↗Change in Return ↗ Relative Interbank lending	-0.120***	-0.120***	0.000	No Mediation	Not Supported
H6a-2	Economic Conditions ↗ Growth ↗ Relative Interbank borrowing	-0.191***	-0.191***	-0.001	No Mediation	Not Supported
H7a-2	Economic Conditions ↗Growth ↗ Relative Interbank lending	-0.120***	-0.120***	0.000	No Mediation	Not Supported
H6a-3	Economic Conditions ↗ Monetary Policy ↗ Relative Interbank borrowing	-0.191***	-0.211***	0.011	No Mediation	Not Supported
H7a-3	Economic Conditions ↗ Monetary Policy ↗ Relative Interbank lending	-0.120***	-0.133***	-0.006	No Mediation	Not Supported
H6b-1	Change in Liquidity ↗Change in Leverage ↗ Relative Interbank borrowing	0.024*	0.024*	0.000	No Mediation	Not Supported
H7b-1	Change in Liquidity ↗Change in Leverage ↗ Relative Interbank lending	0.015	0.015	0.000	No Mediation	Not Supported
H6b-2	Change in Liquidity ↗Change in Return ↗ Relative Interbank borrowing	0.024*	0.024*	-0.002	No Mediation	Not Supported
H7b-2	Change in Liquidity ↗Change in Return ↗ Relative Interbank lending	0.015	0.015	-0.002	No Mediation	Not Supported
H6b-3	Change in Liquidity ↗ Growth ↗ Relative Interbank borrowing	0.024*	0.025*	-0.011***	Full Mediation	Supported
H7b-4	Change in Liquidity ↗Growth ↗ Relative Interbank lending	0.015	0.015	0.001	No Mediation	Not Supported
H6c-1	Change in Leverage ↗Change in Return ↗ Relative Interbank borrowing	0.008	0.007	0.008***	Full Mediation	Supported
H7c-1	Change in Leverage↗Change in Return ↗ Relative Interbank lending	-0.014	-0.015	0.009***	Full Mediation	Supported
H6c-2	Change in Leverage ↗Growth ↗ Relative Interbank borrowing	0.008	0.010	-0.022***	Full Mediation	Supported
H7c-2	Change in Leverage↗Growth ↗ Relative Interbank lending	-0.014	-0.014	0.001	No Mediation	Not Supported
H6d-1	Change in Return ↗ Growth ↗ Relative Interbank borrowing	-0.088***	-0.088***	0.002***	Partial Mediation	Supported
H7d-1	Change in Return ↗ Growth ↗ Relative Interbank lending	-0.095***	-0.094***	0.000	No Mediation	Not Supported

Note: * significant at 10%; ** significant at 5%; *** significant at 1%

Table 7
Invariance to interbank market organization (H8).

Panel A: Core-periphery organization	Chi-square	df	p-val	Invariant?
Unconstrained	1.855	10		
Fully constrained	245.807	31		
Number of groups		2		
Difference	243.952	21	0.00	No
Panel A: Three-tier organization	Chi-square	df	p-val	Invariant?
Unconstrained	0.932	15		
Fully constrained	383.523	57		
Number of groups		3		
Difference	382.591	42	0.00	No

Table 8

Multi-group moderation.

Panel A: Core-periphery moderation			Unconstrained Std. Coefficients		Direct Moderation	
					z-score	
Hyp.	Path	Predicted	Core	Periphery	Core vs. Periphery	Hypothesis outcome
H9a-d	Economic Conditions↗ Relative Interbank borrowing	Core > Periphery	-0.346***	-0.099***	4.47***	Supported
H10a-d	Economic Conditions↗ Relative Interbank lending	Core > Periphery	0.015	-0.251***	-2.461**	Supported
H9b-d	Change in Liquidity↗ Relative Interbank borrowing	Core > Periphery	-0.002	0.035**	1.435	Not Supported
H10b-d	Change in Liquidity ↗ Relative Interbank lending	Core > Periphery	0.025	-0.003	-1.145	Not Supported
H9c-d	Change in Leverage↗ Relative Interbank borrowing	Core > Periphery	-0.001	0.014	0.583	Not Supported
H10c-d	Change in Leverage ↗ Relative Interbank lending	Core > Periphery	-0.011	-0.026	0.123	Not Supported
H9d-d	Change in Return↗ Relative Interbank borrowing	Core > Periphery	-0.141***	-0.065***	2.209**	Supported
H10d-d	Change in Return ↗ Relative Interbank lending	Core > Periphery	-0.168***	0.007	7.832***	Supported
H9e-d	Growth↗ Relative Interbank borrowing	Core > Periphery	-0.009	-0.1***	-3.516***	Supported
H10e-d	Growth ↗ Relative Interbank lending	Core > Periphery	-0.013	0.066***	1.399	Not Supported
H9f-d	Effective Federal Funds↗ Relative Interbank borrowing	Core > Periphery	-0.033	-0.011	0.416	Not Supported
H10f-d	Effective Federal Funds ↗ Relative Interbank lending	Core > Periphery	0.019	-0.009	-0.569	Not Supported

Panel B:Three-tier moderation			Unconstrained Std. Coefficients			Direct Mediation			
						z-score			
Hyp.	Path	Predicted	Tier 1	Tier 2	Tier 3	Tier 1 vs. Tier 2	Tier 1 vs. Tier 3	Tier 2 vs. Tier 3	Hypothesis outcome
H9a-d	Economic Conditions↗ Relative Interbank borrowing	Tier 1 >Tier 2 > Tier 3	-0.357***	-0.094***	-0.099*	4.651***	2.598***	-0.329	Partially Supported
H10a-d	Economic Conditions↗ Relative Interbank lending	Tier 1 >Tier 2 > Tier 3	0.02	-0.196***	-0.284***	-1.718*	-3.036***	-2.971***	Partially Supported
H9b-d	Change in Liquidity↗ Relative Interbank borrowing	Tier 1 >Tier 2 > Tier 3	0.003	0.04**	0.016	1.278	0.400	-0.522	Not Supported
H10b-d	Change in Liquidity ↗ Relative Interbank lending	Tier 1 >Tier 2 > Tier 3	0.03	0.005	-0.008	-1.177	-1.254	-0.359	Not Supported
H9c-d	Change in Leverage↗ Relative Interbank borrowing	Tier 1 >Tier 2 > Tier 3	-0.013	0.031	-0.016	1.476	-0.178	-1.306	Not Supported
H10c-d	Change in Leverage ↗ Relative Interbank lending	Tier 1 >Tier 2 > Tier 3	-0.012	0.004	-0.054**	0.531	-0.307	-1.885*	Not Supported
H9d-d	Change in Return↗ Relative Interbank borrowing	Tier 1 >Tier 2 > Tier 3	-0.154***	-0.055***	-0.082***	2.977***	1.231	-0.936	Partially Supported
H10d-d	Change in Return ↗ Relative Interbank lending	Tier 1 >Tier 2 > Tier 3	-0.193***	-0.022	0.039	8.106***	8.351***	1.798*	Partially Supported
H9e-d	Growth↗ Relative Interbank borrowing	Tier 1 >Tier 2 > Tier 3	-0.023	-0.092***	-0.093***	-2.377**	-2.075**	-0.349	Not Supported
H10e-d	Growth ↗ Relative Interbank lending	Tier 1 >Tier 2 > Tier 3	-0.024	0.033	0.081***	1.209	1.962**	1.924*	Partially Supported
H9f-d	Effective Federal Funds↗ Relative Interbank borrowing	Tier 1 >Tier 2 > Tier 3	-0.035	-0.008	-0.079	0.506	-0.977	-1.293	Not Supported
H10f-d	Effective Federal Funds ↗ Relative Interbank lending	Tier 1 >Tier 2 > Tier 3	0.016	-0.055*	0.054	-0.753	0.195	1.604	Not Supported

Note: * significant at 10%; ** significant at 5%; *** significant at 1%

Table 9

Comparative goodness of fit (H11).

Sample	CMIN / DF	CFI	RMSEA	SRMR
All observations	0.028	1.000	0.000	0.0008
Core	0.116	1.000	0.000	0.0031
Periphery	0.255	1.000	0.000	0.0038
Tier 1	0.049	1.000	0.000	0.0017
Tier 2	0.074	1.000	0.000	0.0012
Tier 3	0.063	1.000	0.000	0.0016

Appendix A: Cluster analysis

A1. Specification.

The distance between clusters i and j is defined as[20]:

$$d^{log}(i,j) = \xi_i + \xi_j - \xi_{<i,j>} \quad \text{(A1)}$$

$$\xi_v = N_v \left[\sum_{k=1}^{K} \frac{1}{2} \log(\hat{\sigma}_k^2 + \hat{\sigma}_{vk}^2) \right] \quad \text{(A2)}$$

Above, $\hat{\sigma}_k^2$ is the estimated variance of the k^{th} continuous variable across the entire dataset, $\hat{\sigma}_{vk}^2$ is the estimated variance of the k^{th} continuous variable in cluster v, and N_v denotes the number of data records in cluster v. Moreover, K is the total number of continuous variables used in the procedure, and $<i, j>$ is the index of the cluster obtained by combining clusters i and j. If $\hat{\sigma}_k^2$ is ignored in the expression for ξ_v, the distance between clusters i and j would be exactly the decrease in log-likelihood when the two clusters are combined. The $\hat{\sigma}_k^2$ term is added to solve the problem caused by $\hat{\sigma}_{vk}^2 = 0$, which would result in the natural logarithm being undefined.[21] The result of this cluster analysis is that each observation i is assigned to one of M tiers, denoted $m(i) \in \{1, \dots, M\}$ where m is a membership function.

We measure the goodness of the predicted tier membership produced by the cluster analysis in terms of the average silhouette coefficient ρ. The latter balances the desire for each observation in a cluster to be "close" to the other observations in that cluster (similarity within a cluster) against the need for an observation to be "distant" from observations which are not in that cluster (distinction between clusters). It is calculated as:

$$\rho = \frac{1}{n} \sum \rho_i = \frac{1}{n} \sum_i \frac{B_i - A_i}{\max(A_i, B_i)} \quad \text{(A3)},$$

[20] The distance measure proposed by Chiu et al. (2001) also allows for the use of categorical variables which is slightly more involved and therefore a simpler version is outlined here.

[21] Initially, each cluster contains only a single observation leading to a variance of zero for that cluster which would make the logarithm term undefined if $\hat{\sigma}_k^2$ was not included.

$$A_i = d^{\log}(i, C(i)) \quad \text{(A4)},$$

$$B_i = \min_{j \neq i}\left[d^{log}\left(i, C(j)\right)\right] \quad \text{(A5)},$$

where $d(i,j)$ is the distance between observations i and j and $C(i)$ denotes the centroid of the cluster to which observation i belongs. Kaufman and Rousseeuw (2009) find that a silhouette greater than 0.5 indicates reasonable partitioning while a silhouette less than 0.2 implies that the dataset does not exhibit a cluster structure.

A2. Data suitability and results.

Hair et al. (2010) point out that not every dataset is appropriate for cluster analysis and propose three features that suitable data should possess. First, "variables with larger dispersion (i.e., larger standard deviation) have more impact on the final similarity value" so the scale of variables should be similar. Therefore, we convert each observation of interbank lending, interbank borrowing, interbank pass-through, and total assets to reflect the share of that variable controlled at that time.[22] Second, Hair et al. (2010) point out that there is no statistical basis to infer the properties of a large population from a small sample so the sample should adequately represent the population. Our dataset of the 100 largest banks accounts for 90% of assets as well as 95% of the interbank activity reported by the 900 largest bank holding companies between 2013 and 2014 supporting the representativeness of our sample.[23] Third, multicollinearity in the data may bias the classification towards one concept over the others. We are not attempting to cluster around several competing traits (e.g. interbank activity, risk profile, geographic presence) so any multicollinearity present should not severely impair the procedure.

[22] The asset (size-based) ranking is not transformed to a share basis due to its ordinal nature. However, the asset ranking is standardized which places it at the same scale as other variables.

[23] Due to the method of tracing back a firm through time our sample may become progressively less representative as we move backwards historically.

Finally, while clustering methods based on Euclidean distance measures do not make assumptions about the distributions of underlying variables, the log-likelihood measure of distance described in Section 2 assumes normality for all continuous variables. Therefore, a logarithmic transformation is applied to the data restoring moderately acceptable skewness and kurtosis values. To avoid complications with the logarithmic transformation for banks which do not participate as lenders and borrowers in a given period we add a very small value to the lending and borrowing positions of each observation. The standardized versions of these logarithmic and share transformed variables are used in cluster analysis. Descriptive statistics for the data are provided for the entire sample in Table 1 and by market segment in Table A1.

Table A1
Data suitability statistics of logarithm and share transformed data used for cluster analysis.

Variable	Tier	N	Mean	Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error	Statistic	Std. Error
Assets	All	6774	-6.02	1.56	0.87	0.03	0.38	0.06
	Core	4316	-4.36	1.20	0.85	0.05	0.04	0.10
	Periphery	2458	-6.96	0.75	0.36	0.04	1.49	0.07
	1	2133	-4.14	1.14	0.93	0.05	-0.01	0.11
	2	3218	-6.76	0.7	-0.21	0.04	-0.20	0.09
	3	1423	-7.16	0.89	1.17	0.06	2.93	0.13
IB lending	All	6774	-10.26	5.03	-0.85	0.03	0.11	0.06
	Core	4316	-6.33	2.45	0.48	0.05	0.10	0.10
	Periphery	2458	-12.50	4.75	-0.81	0.04	-0.87	0.07
	1	2133	-6.05	2.47	0.38	0.05	-0.07	0.11
	2	3218	-9.79	1.92	-0.58	0.04	-0.08	0.09
	3	1423	-17.64	4.65	1.27	0.06	0.02	0.13
IB borrowing	All	6774	-7.80	4.01	-1.79	0.03	3.55	0.06
	Core	4316	-4.96	1.62	0.60	0.05	0.26	0.10
	Periphery	2458	-9.42	4.06	-1.86	0.04	2.30	0.07
	1	2133	-4.72	1.59	0.57	0.05	0.18	0.11
	2	3218	-7.93	1.71	-1.19	0.04	1.84	0.09
	3	1423	-12.10	5.78	-0.55	0.06	-1.51	0.13
IB Pass-through	All	6774	-10.77	5.30	-0.64	0.03	-0.46	0.06
	Core	4316	-6.31	2.42	0.52	0.05	0.12	0.10
	Periphery	2458	-13.30	4.79	-0.52	0.04	-1.35	0.07
	1	2133	-6.03	2.44	0.41	0.05	-0.06	0.11
	2	3218	-9.96	1.90	-0.48	0.04	-0.28	0.09
	3	1423	-19.67	1.53	2.03	0.06	3.29	0.13

Fig. A1 describes the ranking, interbank borrowing, interbank lending, and interbank pass-through probability distributions of observations shown to belong to the core-periphery and three-tier organizations. For the core-periphery organization, there is a clear dichotomy between low rank firms which have high interbank participation and high rank firms with lower interbank

participation.[24] Similarly, the three-tier vignettes depict a clear distinction between the largest banks that take on large interbank positions (tier 1), medium to small banks with significant interbank activity (tier 2), and generally small banks with low interbank positions and very low pass-through activity.

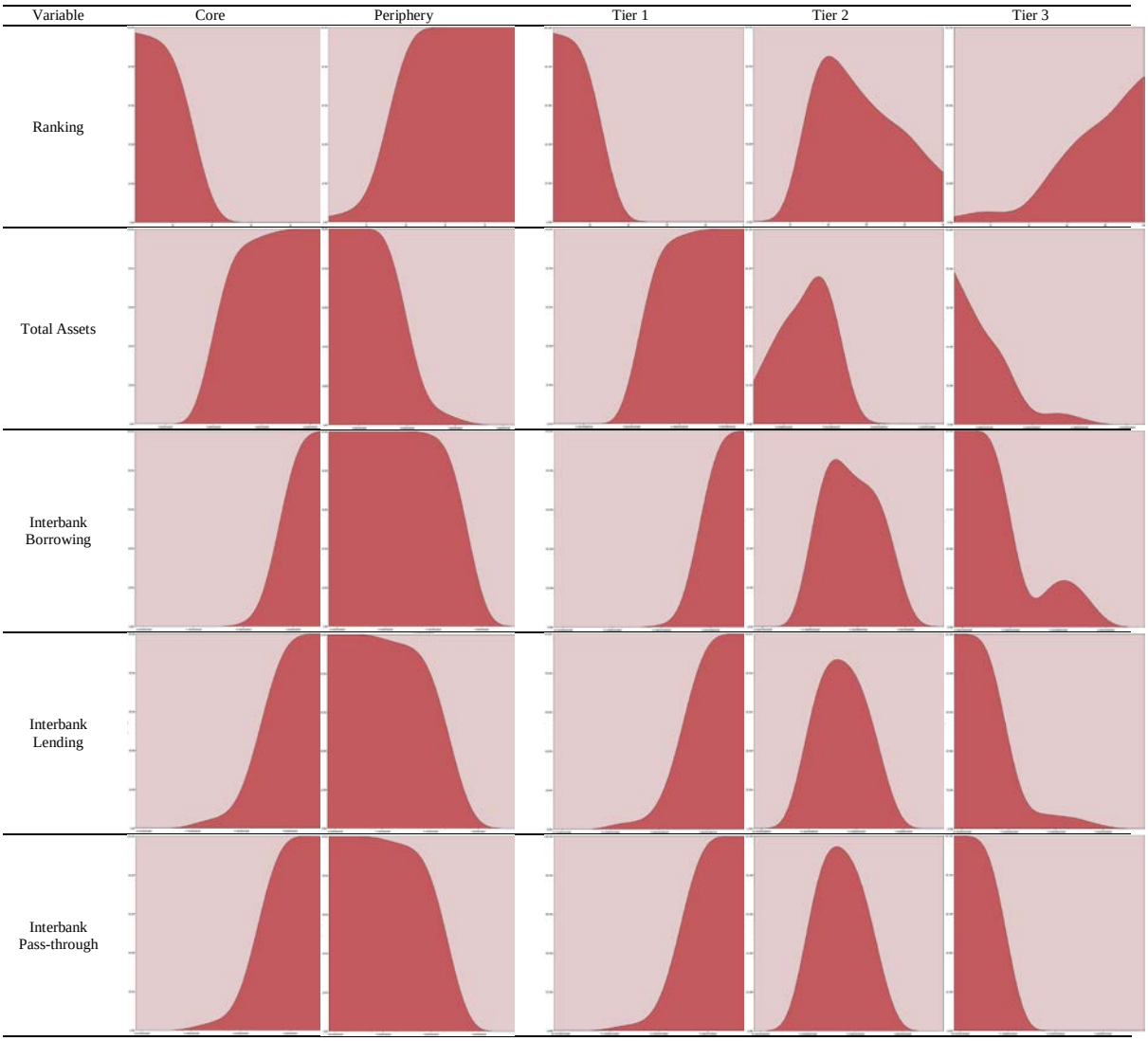

Fig. A1. Variable distributions for core-periphery and three-tier organizations.

[24] For asset ranking, the bank with the most assets has rank one and the lowest assets has rank 100 at each point in time.

Appendix B: Factor model

B1. Methodology.

Following Bollen (1989), we set up a factor model to estimate the factors collectively. Given observable variables X and Y, our objective is to estimate the coefficient matrices $E_K \in \mathbb{R}^{s\times r}$, $E_\xi \in \mathbb{R}^{s\times n}$, and $E_\eta \in \mathbb{R}^{s\times m}$ in the below equation

$$Q = E_k K + E_\xi \Xi + E_\eta H + U.^{25} \quad \text{(B1)}$$

Here $K \in \mathbb{R}^r$ is a vector of control variables and $U \in \mathbb{R}^s$ is a zero mean disturbance term which is assumed to be uncorrelated with Ξ, H, and K. The exogenous and endogenous latent factor vectors, Ξ and H respectively, are estimated using the system of equations below

$$X = \Lambda_x \Xi + \Delta \quad \text{(B2)},$$

$$Y = \Lambda_y H + E \quad \text{(B3)},$$

$$H = BH + \Gamma\Xi + Z. \quad \text{(B4)}$$

In above equations, $X \in \mathbb{R}^q$ and $Y \in \mathbb{R}^p$ are observed variables from the sample panel dataset. $\Lambda_x \in \mathbb{R}^{q\times n}$ and $\Lambda_y \in \mathbb{R}^{p\times m}$ are the given coefficient matrices describing the respective relationships of X to Ξ and of Y to H .The measurement errors for X, Y, and H are given by vectors Δ, E , and Z respectively. They are assumed to be zero mean and uncorrelated with the systematic factors Ξ, H, and each other. The coefficient matrix $B \in \mathbb{R}^{m\times m}$ shows the effect of endogenous variables on each other such that $(I - B)$ is nonsingular. The coefficient matrix $\Gamma \in \mathbb{R}^{m\times n}$ specifies the dependence of H on exogenous latent factors Ξ. We estimate Ξ and H by

[25] In the model implementation, Q contains a vector of institutional interbank borrowing and lending (relative to assets) and K controls for the monetary policy via effective federal funds rate. The exogenous latent factors Ξ are economic conditions and the change in liquidity, while the endogenous latent factors H include the change in leverage, change in return, and growth.

using the maximum likelihood method which minimizes the distance function between the sample and the factor covariance matrices.

Robustness.

The EFA model's core assumptions include that factors ξ and η, as well as idiosyncratic residuals δ and ϵ do not exhibit serial correlation. Referring to the assumption of serial correlation, Geweke (1977: 365) raises the point that "if the $x_i(t)$ are time series this assumption is almost always inappropriate since $x_i(t)$ and $x_i(t+s)$ will in general be correlated." Stock and Watson (2011: 2) provide the analogy that residuals pick up on issues unique to an individual indicator, like the impact of a salmonella scare which affects restaurant employment but not the pet store next door. Anderson (1963: 7) agrees that shocks in the time dimension may persist across multiple time periods leading to serial correlation issues. However, Anderson concludes that the "day-to-day correlation may be of no greater disadvantage than if the observations were independent". As shown in Table B1, serial correlation testing on the time-ordered data showed the presence of some serial correlation. Table B2 indicates that the data significantly differs from the normal distribution. Descriptive statistics for each data series analyzed in EFA is provided in Table B3.

Table B1
Serial correlation testing of data series used in EFA.

	Original	
	$LM\ Obs * R^2$ (at –1 lags)	H_0 no serial autocorrelation
Change in cash to liabilities	0.84(ns)	fail to reject the null at *
Growth in cash to liabilities	0.45(ns)	fail to reject the null at *
Change in cash to total expenses	5.13(**)	reject the null at **
Growth in cash to total expenses	0.07(ns)	fail to reject the null at *
Change in reserves	0.95(ns)	fail to reject the null at *
Change in cash	2.18(ns)	fail to reject the null at *
Growth in short term liquidity to assets	4.67(**)	reject the null at **
Inflation	0.83(ns)	fail to reject the null at *
Output	0.25(ns)	fail to reject the null at *
Money supply	0.52(ns)	fail to reject the null at *
Unemployment	0.00(ns)	fail to reject the null at *
Change in liabilities to assets	0.11(ns)	fail to reject the null at *
Growth in liabilities to assets	0.22(ns)	fail to reject the null at *
Change in assets to capital	1.10(ns)	fail to reject the null at *
Growth in assets to capital	0.89(ns)	fail to reject the null at *
Change in pre-tax return on equity	10.39(***)	reject the null at ***
Change in pre-tax return on assets	3.69(*)	reject the null at *
Change in post-tax return on equity	7.43(***)	reject the null at ***
Change in post-tax return on assets	1.35(ns)	fail to reject the null at *
Growth in asset	0.02(ns)	fail to reject the null at *
Growth in deposit	0.13(ns)	fail to reject the null at *
Growth in liabilities	0.00(ns)	fail to reject the null at *
Growth in current asset-liability mismatch	0.28(ns)	fail to reject the null at *
Change in securities available for sale	1.23(ns)	fail to reject the null at *
Growth in securities available for sale	0.25(ns)	fail to reject the null at *
Change in securities to assets	2.60(ns)	fail to reject the null at *
Growth in securities to assets	2.04(ns)	fail to reject the null at *
Growth in the net interest margin	0.50(ns)	fail to reject the null at *
Growth in revenue to assets	1.06(ns)	fail to reject the null at *
Growth in interest income to assets	0.28(ns)	fail to reject the null at *

Note: * significant at 10%; ** significant at 5%; *** significant at 1%

Table B2
Normality testing of standardized data series used in EFA.

Variable	Lilliefors	Cramer-von Mises	Watson	Anderson-Darling
Change in cash to liabilities	0.11***	31.72***	31.67***	175.25***
Growth in cash to liabilities	0.05***	8.30***	8.27***	49.03***
Change in cash to total expenses	0.10***	25.94***	24.87***	160.09***
Growth in cash to total expenses	0.06***	8.81***	8.77***	52.04***
Change in reserves	0.15***	55.58***	55.51***	303.16***
Change in cash	0.16***	64.12***	63.94***	342.84***
Growth in short term liquidity to assets	0.06***	9.62***	9.61***	56.20***
Inflation	0.10***	15.32***	15.31***	99.70***
Output	0.16***	30.47***	27.06***	177.64***
Money supply	0.07***	9.72***	9.03***	73.79***
Unemployment	0.25***	131.10***	123.13***	749.50***
Change in liabilities to assets	0.09***	23.25***	23.25***	132.00***
Growth in liabilities to assets	0.11***	32.16***	32.14***	178.15***
Change in assets to capital	0.09***	22.74***	22.71***	129.07***
Growth in assets to capital	0.08***	18.18***	18.17***	104.52***
Change in pre-tax return on equity	0.06***	8.74***	8.52***	52.28***
Change in pre-tax return on assets	0.12***	37.77***	37.72***	205.09***
Change in post-tax return on equity	0.07***	12.87***	12.57***	76.78***
Change in post-tax return on assets	0.13***	45.70***	45.68***	249.07***
Growth in asset	0.15***	49.97***	43.88***	266.11***
Growth in deposit	0.14***	50.60***	45.67***	276.73***
Growth in liabilities	0.14***	45.45***	41.00***	248.26***
Growth in current asset-liability mismatch	0.12***	32.74***	30.72***	183.13***
Change in securities available for sale	0.16***	67.51***	66.81***	359.28***
Growth in securities available for sale	0.10***	25.46***	24.93***	146.45***
Change in securities to assets	0.07***	15.01***	15.01***	86.87***
Growth in securities to assets	0.08***	18.26***	18.23***	105.29***
Growth in the net interest margin	0.10***	29.42***	29.21***	165.04***
Growth in revenue to assets	0.10***	26.87***	26.81***	153.81***
Growth in interest income to assets	0.09***	26.66***	26.50***	151.65***

Notes: Null hypothesis is that the data is normally distributed.* significant at 10%; ** significant at 5%; *** significant at 1%

Table B3
Descriptive statistics of data used for EFA analysis.

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
						Statistic	Std. Error	Statistic	Std. Error
Change in cash to liabilities	6424	-6.91	7.15	0.00	0.97	0.29	0.03	7.10	0.06
Growth in cash to liabilities	6424	-5.90	6.12	0.00	0.98	0.12	0.03	2.90	0.06
Change in cash to total expenses	6424	-6.69	6.24	0.00	0.98	-0.65	0.03	6.63	0.06
Growth in cash to total expenses	6424	-6.10	6.44	0.00	0.98	0.15	0.03	3.21	0.06
Change in reserves	6424	-6.52	6.32	0.00	0.99	0.24	0.03	8.56	0.06
Change in cash	6424	-6.72	6.39	0.00	0.99	0.31	0.03	8.88	0.06
Growth in short term liquidity to assets	6424	-4.73	6.26	0.00	0.98	0.07	0.03	2.74	0.06
Inflation	6424	-1.75	1.62	0.02	0.99	-0.05	0.03	-1.28	0.06
Output	6424	-2.15	1.43	0.02	0.98	-0.65	0.03	-0.68	0.06
Money supply	6424	-1.46	1.99	0.02	0.99	0.29	0.03	-1.00	0.06
Unemployment	6424	-0.79	1.82	0.00	1.00	0.83	0.03	-1.08	0.06
Change in liabilities to assets	6424	-7.03	6.33	0.00	0.97	-0.15	0.03	5.43	0.06
Growth in liabilities to assets	6424	-7.18	6.58	0.00	0.97	-0.26	0.03	8.39	0.06
Change in assets to capital	6424	-6.69	5.48	0.00	0.98	-0.29	0.03	4.97	0.06
Growth in assets to capital	6424	-6.93	5.95	0.00	0.98	-0.22	0.03	4.62	0.06
Change in pre-tax return on equity	6424	-5.74	4.98	0.01	0.97	-0.36	0.03	3.30	0.06
Change in pre-tax return on assets	6424	-7.03	7.05	0.00	0.97	0.72	0.03	12.76	0.06
Change in post-tax return on equity	6424	-6.11	5.91	0.00	0.97	-0.43	0.03	4.69	0.06
Change in post-tax return on assets	6424	-7.06	7.08	0.00	0.97	0.69	0.03	13.88	0.06
Growth in asset	6424	-4.46	5.94	-0.01	0.98	1.77	0.03	6.71	0.06
Growth in deposit	6424	-5.38	6.03	-0.01	0.97	1.65	0.03	6.82	0.06
Growth in liabilities	6424	-4.82	5.94	-0.01	0.97	1.63	0.03	6.42	0.06
Growth in current asset-liability mismatch	6424	-6.18	6.03	0.00	0.98	1.05	0.03	6.03	0.06
Change in securities available for sale	6424	-6.53	6.29	0.00	0.99	0.54	0.03	8.86	0.06
Growth in securities available for sale	6424	-6.70	5.99	0.00	0.98	0.42	0.03	5.63	0.06
Change in securities to assets	6424	-5.82	6.02	0.00	0.98	-0.10	0.03	3.74	0.06
Growth in securities to assets	6424	-6.21	6.27	0.00	0.98	-0.07	0.03	4.67	0.06
Growth in the net interest margin	6424	-7.13	7.02	0.01	0.94	-0.30	0.03	6.94	0.06
Growth in revenue to assets	6424	-7.13	6.74	0.00	0.95	-0.07	0.03	6.84	0.06
Growth in interest income to assets	6424	-7.13	7.02	0.00	0.94	-0.20	0.03	6.67	0.06

B2. Exploratory and confirmatory factor analysis.

The pattern matrix in Table B4 demonstrates consistently high loadings between each factor and relevant variables in addition to no cross-loading. The results provide preliminary support for Hypothesis 3 for the presence of factors which incorporate variables of economic conditions, change in liquidity, change in leverage, change in return, growth, growth in securities, and profitability growth. We then construct and solve the corresponding first order measurement model in IBM SPSS AMOS using maximum likelihood estimation. It is important that the factors are estimated consistently for a given partition of the sample, so that each factor can be measured invariantly across interbank characteristics. Following Gaskin (2012; 2014), metric invariance requires that the loading of at least one variable for each factor does not significantly vary across subsamples. We establish metric invariance in Table B5 where grayed cells indicate stable loadings across interbank market segments.

Table B4

Exploratory factor analysis: Pattern matrix.

	Factor						
Variables	1	2	3	4	5	6	7
Change in cash to liabilities	0.891						
Growth in cash to liabilities	0.929						
Change in cash to total expenses	0.571						
Growth in cash to total expenses	0.883						
Change in reserves	0.454						
Change in cash	0.764						
Growth in short term liquidity to assets	0.750						
Inflation		0.992					
Output		0.929					
Money supply		0.995					
Unemployment		0.800					
Change in liabilities to assets			0.985				
Growth in liabilities to assets			0.948				
Change in assets to capital			0.939				
Growth in assets to capital			0.983				
Change in pre-tax return on equity				0.912			
Change in pre-tax return on assets				0.909			
Change in post-tax return on equity				0.910			
Change in post-tax return on assets				0.910			
Growth in asset					0.900		
Growth in deposit					0.911		
Growth in liabilities					0.868		
Growth in current asset-liability mismatch					0.858		
Change in securities available for sale						0.728	
Growth in securities available for sale						0.791	
Change in securities to assets						0.872	
Growth in securities to assets						0.902	
Growth in the net interest margin							0.909
Growth in revenue to assets							0.833
Growth in interest income to assets							0.954

Note: Principal Component Analysis extraction was used. Rotation Method: Promax with Kaiser Normalization.

Table B5

Metric invariance of the factor model with respect to interbank market organization (H3e).

Panel A: Core-periphery invariance			z-score
Path	Core	Periphery	Core vs. Periphery
Change in Liquidity→Change in cash to liabilities	0.794***	0.786***	-0.409
Change in Liquidity→Growth in cash to liabilities	0.912***	0.982***	3.865***
Change in Liquidity→Change in cash to total expenses	0.392***	0.499***	4.331***
Change in Liquidity→Growth in cash to total expenses	0.879***	0.961***	4.334***
Change in Liquidity→Change in reserves	0.387***	0.282***	-3.784***
Change in Liquidity→Change in cash	0.719***	0.567***	-6.079***
Change in Liquidity→Growth in short term liquidity to assets	0.595***	0.639***	1.973**
Economic Conditions→Inflation	0.997***	0.951***	-2.581***
Economic Conditions→Output	1.024***	0.863***	-8.378***
Economic Conditions→Money Supply	0.963***	0.967***	0.229
Economic Conditions→Unemployment	0.575***	0.832***	12.253***
Change in Leverage→Change in liabilities to assets	0.948***	0.907***	-2.227**
Change in Leverage→Growth in liabilities to assets	0.927***	0.808***	-6.239***
Change in Leverage→Change in assets to capital	0.945***	0.959***	0.806
Change in Leverage→Growth in assets to capital	0.971***	0.976***	0.292
Change in Return→Change in pre-tax return on equity	0.885***	0.617***	-12.729***
Change in Return→Change in pre-tax return on assets	0.959***	0.948***	-0.57
Change in Return→Change in post-tax return on equity	0.876***	0.630***	-11.718***
Change in Return→Change in post-tax return on assets	0.948***	0.961***	0.707
Growth→Growth in asset	0.970***	0.987***	0.977
Growth→Growth in deposit	0.726***	0.768***	1.978**
Growth→Growth in liabilities	0.956***	0.971***	0.864
Growth→Growth in current asset-liability mismatch	0.559***	0.607***	2.101**
Growth in Securities→Change in securities available for sale	0.466***	0.395***	-2.719***
Growth in Securities→Growth in securities available for sale	0.551***	0.552***	0.051
Growth in Securities→Change in securities to assets	0.810***	0.875***	3.264***
Growth in Securities→Growth in securities to assets	0.956***	0.999***	2.423**
Profitability Growth→Growth in the net interest margin	0.976***	0.982***	0.293
Profitability Growth→Growth in revenue to assets	0.595***	0.565***	-1.313
Profitability Growth→Growth in interest income to assets	0.828***	0.860***	1.585

Panel B: Three-tier invariance				z-score		
Path	Tier 1	Tier 2	Tier 3	Tier 1 vs. 2	Tier 1 vs. 3	Tier 2 vs. 3
Change in Liquidity→Change in cash to liabilities	0.789***	0.783***	0.804***	-0.272	0.524	0.774
Change in Liquidity→Growth in cash to liabilities	0.919***	0.977***	0.966***	2.877***	1.864*	-0.499
Change in Liquidity→Change in cash to total expenses	0.360***	0.503***	0.515***	5.369***	4.726***	0.403
Change in Liquidity→Growth in cash to total expenses	0.885***	0.959***	0.940***	3.555***	2.128**	-0.799
Change in Liquidity→Change in reserves	0.362***	0.248***	0.425***	-3.852***	1.691*	5.772***
Change in Liquidity→Change in cash	0.656***	0.591***	0.635***	-2.429**	-0.604	1.539
Change in Liquidity→Growth in short term liquidity to assets	0.606***	0.573***	0.774***	-1.311	5.608***	7.184***
Economic Conditions←Inflation	0.991***	0.929***	0.870***	-3.142***	-5.162***	-2.788***
Economic Conditions←Output	1.022***	0.893***	0.743***	-6.05***	-11.967***	-7.471***
Economic Conditions←Money Supply	0.953***	0.916***	0.926***	-1.951*	-1.152	0.428
Economic Conditions←Unemployment	0.553***	0.671***	0.912***	5.319***	12.212***	8.571***
Change in Leverage←Change in liabilities to assets	0.947***	0.914***	0.905***	-1.646	-1.602	-0.332
Change in Leverage←Growth in liabilities to assets	0.935***	0.819***	0.795***	-5.529***	-5.108***	-0.896
Change in Leverage←Change in assets to capital	0.942***	0.967***	0.943***	1.279	0.074	-1
Change in Leverage←Growth in assets to capital	0.966***	0.979***	0.978***	0.685	0.5	-0.049
Change in Return←Change in pre-tax return on equity	0.865***	0.639***	0.665***	-9.761***	-6.808***	0.906
Change in Return←Change in pre-tax return on assets	0.956***	0.940***	0.976***	-0.768	0.8	1.503
Change in Return←Change in post-tax return on equity	0.861***	0.652***	0.659***	-9.055***	-6.917***	0.239
Change in Return←Change in post-tax return on assets	0.949***	0.945***	0.990***	-0.23	1.648	1.937*
Growth←Growth in asset	0.981***	0.981***	0.980***	-0.04	-0.072	-0.043
Growth←Growth in deposit	0.731***	0.800***	0.672***	2.958***	-1.952*	-4.582***
Growth←Growth in liabilities	0.976***	0.962***	0.957***	-0.707	-0.798	-0.251
Growth←Growth in current asset-liability mismatch	0.547***	0.658***	0.491***	4.429***	-1.766*	-5.645***
Growth in Securities←Change in securities available for sale	0.433***	0.418***	0.408***	-0.512	-0.676	-0.322
Growth in Securities←Growth in securities available for sale	0.572***	0.497***	0.655***	-2.934***	2.709***	5.481***
Growth in Securities←Change in securities to assets	0.803***	0.893***	0.826***	4.156***	0.819	-2.614***
Growth in Securities←Growth in securities to assets	0.968***	0.996***	0.980***	1.422	0.492	-0.688
Profitability Growth←Growth in the net interest margin	0.979***	0.977***	0.988***	-0.084	0.377	0.474
Profitability Growth←Growth in revenue to assets	0.585***	0.573***	0.570***	-0.5	-0.497	-0.111
Profitability Growth←Growth in interest income to assets	0.843***	0.839***	0.880***	-0.203	1.341	1.624

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Shading indicates measurement model group variance.

B3. Moderated mediation.

Following Hypotheses 9 and 10, we expect to find differences in how factors indirectly contribute to interbank positions. Therefore, we investigate whether interbank market organization moderates the mediating relationship that change in leverage, change in return, growth, and monetary policy exert on relationships with interbank borrowing and lending. This is undertaken by estimating the nature of mediation for each segment in isolation and comparing these to determine changes in the nature, significance, and direction of association. Results are presented in Tables B6 and B7 for core-periphery and three-tier organizations respectively. We find that the three-tier interbank market organization moderates the mediating role of:

- growth between liquidity and borrowing,
- growth between leverage and borrowing/lending,
- change in return between leverage and lending.

However, the core-periphery interbank market organization moderates the mediating role of:

- growth between liquidity and borrowing as well as lending,
- change in return between leverage and lending,
- growth between leverage and borrowing/lending,
- growth between change in return and borrowing/lending.

Many of these moderating influences that are significant from the core-periphery perspective fail to be significant from the three-tier perspective. These results suggest that the core-periphery organization, by not recognizing the distinct behavior of tier 2, finds moderated relationships that may not be truly present.

Table B6

Multi-group moderation for core-periphery organization.

		Core				Periphery			
Hypothesis	Association Path	Direct Beta w/o Med	Direct Beta w/ Med	Indirect Beta	Mediation Type Observed	Direct Beta w/o Med	Direct Beta w/ Med	Indirect Beta	Mediation Type Observed
H9a-1m	Economic Conditions ↗Change in Return ↗ Interbank borrowing	-0.309***	-0.310***	0.004	NM	-0.090***	-0.090***	-0.001	NM
H10a-1m	Economic Conditions ↗Change in Return ↗ Interbank lending	0.014	0.014	0.005	NM	-0.227***	-0.227***	0.000	NM
H9a-2m	Economic Conditions ↗ Growth ↗ Interbank borrowing	-0.309***	-0.309***	0.000	NM	-0.090***	-0.090***	-0.001	NM
H10a-2m	Economic Conditions ↗Growth ↗ Interbank lending	0.014	0.014	0.000	NM	-0.227***	-0.227***	0.001	NM
H9a-3m	Economic Conditions ↗ Effective Federal Funds Rate ↗ Interbank borrowing	-0.309***	-0.345***	0.027	NM	-0.090***	-0.100***	0.008	NM
H10a-3m	Economic Conditions ↗ Effective Federal Funds Rate ↗ Interbank lending	0.014	0.016	-0.016	NM	-0.227***	-0.250***	0.008	NM
H9b-1m	Change in Liquidity ↗Change in Leverage ↗ Interbank borrowing	-0.003	-0.003	0.001	NM	0.033**	0.033**	-0.001	NM
H10b-1m	Change in Liquidity ↗Change in Leverage ↗ Interbank lending	0.025	0.025	0.000	NM	-0.002	-0.002	-0.001	NM
H9b-2m	Change in Liquidity ↗Change in Return ↗ Interbank borrowing	-0.003	-0.002	-0.001	NM	0.033**	0.033**	0.000	NM
H10b-2m	Change in Liquidity ↗Change in Return ↗ Interbank lending	0.025	0.025	-0.002	NM	-0.002	-0.002	-0.001	NM
H9b-3m	Change in Liquidity ↗ Growth ↗ Interbank borrowing	-0.003	-0.002	-0.001	NM	0.033**	0.035**	-0.014***	PM
H10b-3m	Change in Liquidity ↗Growth ↗ Interbank lending	0.025	0.025	-0.002	NM	-0.002	-0.003	0.010***	FM
H9c-1m	Change in Leverage ↗Change in Return ↗ Interbank borrowing	0.000	-0.001	0.016***	FM	0.012	0.011	0.005***	FM
H10c-1m	Change in Leverage↗Change in Return ↗ Interbank lending	-0.010	-0.012	0.019***	FM	-0.025	-0.024	0.000	NM
H9c-2m	Change in Leverage ↗Growth ↗ Interbank borrowing	0.000	-0.140***	-0.003	NM	0.012	0.014	-0.026***	FM
H10c-2m	Change in Leverage↗Growth ↗ Interbank lending	-0.010	-0.168***	-0.005	NM	-0.025	-0.026	0.017***	FM
H9d-1m	Change in Return ↗ Growth ↗ Interbank borrowing	-0.140***	-0.141***	0.000	NM	-0.065***	-0.065***	0.004***	PM
H10d-1m	Change in Return ↗ Growth ↗ Interbank lending	-0.168***	-0.168***	0.000	NM	0.007	0.007	-0.002***	FM

Note: * significant at 10%; ** significant at 5%; *** significant at 1%

There is either no mediation (NM), full mediation (FM), or partial mediation (PM) for each relationship.

Table B7

Multi-group moderation using the three-tier organization.

		Tier 1				Tier 2				Tier 3			
Hyp.	Association Path	Direct Beta w/o Med	Direct Beta w/ Med	Indirect Beta	Mediation Type Observed	Direct Beta w/o Med	Direct Beta w/ Med	Indirect Beta	Mediation Type Observed	Direct Beta w/o Med	Direct Beta w/ Med	Indirect Beta	Mediation Type Observed
H9a-1m	Economic Conditions ↗Change in Return ↗ Interbank borrowing	-0.321***	-0.321***	0.000	NM	-0.086***	-0.086***	0.000	NM	-0.086***	-0.086***	0.001	NM
H10a-1m	Economic Conditions ↗Change in Return ↗ Interbank lending	0.018	0.018	0.000	NM	-0.178***	-0.178***	0.000	NM	-0.253***	-0.253***	0.000	NM
H9a-2m	Economic Conditions ↗ Growth ↗ Interbank borrowing	-0.321***	-0.321***	0.000	NM	-0.086***	-0.086***	-0.001	NM	-0.086***	-0.086***	-0.002	NM
H10a-2m	Economic Conditions ↗Growth ↗ Interbank lending	0.018	0.018	0.000	NM	-0.178***	-0.179***	0.000	NM	-0.253***	-0.253***	0.001	NM
H9a-3m	Economic Conditions ↗ Effective Federal Funds Rate ↗ Interbank borrowing	-0.321***	-0.357***	0.029	NM	-0.086***	-0.094***	0.006*	NM	-0.086***	-0.099*	0.065	NM
H10a-3m	Economic Conditions ↗ Effective Federal Funds Rate ↗ Interbank lending	0.018	0.020	-0.013	NM	-0.178***	-0.196***	0.042	NM	-0.253***	-0.283***	-0.044	NM
H9b-1m	Change in Liquidity ↗Change in Leverage ↗ Interbank borrowing	0.002	0.002	-0.001	NM	0.038**	0.038**	0.001	NM	0.015	0.015	-0.002	NM
H10b-1m	Change in Liquidity ↗Change in Leverage ↗ Interbank lending	0.029	0.029	0.000	NM	0.005	0.005	0.001	NM	-0.007	-0.007	-0.003*	NM
H9b-2m	Change in Liquidity ↗Change in Return ↗ Interbank borrowing	0.002	0.002	-0.001	NM	0.038**	0.038**	-0.002*	NM	0.015	0.015	0.000	NM
H10b-2m	Change in Liquidity ↗Change in Return ↗ Interbank lending	0.029	0.029	-0.001	NM	0.005	0.005	-0.001	NM	-0.007	-0.007	0.000	NM
H9b-3m	Change in Liquidity ↗ Growth ↗ Interbank borrowing	0.002	0.002	-0.004	NM	0.038**	0.040**	-0.013***	PM	0.015	0.016	-0.011	NM
H10b-3m	Change in Liquidity ↗Growth ↗ Interbank lending	0.029	0.030	-0.004	NM	0.005	0.005	0.004*	NM	-0.007	-0.008	0.012*	NM
H9c-1m	Change in Leverage ↗Change in Return ↗ Interbank borrowing	-0.013	-0.014	0.018***	FM	0.029	0.028	0.004***	FM	-0.017	-0.018	0.007***	FM
H10c-1m	Change in Leverage↗Change in Return ↗ Interbank lending	-0.012	-0.014	0.022***	FM	0.005	0.005	0.002	NM	-0.054**	-0.052*	-0.004*	NM
H9c-2m	Change in Leverage ↗Growth ↗ Interbank borrowing	-0.013	-0.012	-0.009	NM	0.029	0.031*	-0.026***	FM	-0.017	-0.016	-0.018***	FM
H10c-2m	Change in Leverage↗Growth ↗ Interbank lending	-0.012	-0.011	-0.010	NM	0.005	0.004	0.009*	NM	-0.054**	-0.054**	0.016***	PM
H9d-1m	Change in Return ↗ Growth ↗ Interbank borrowing	-0.154***	-0.154***	0.000	NM	-0.055***	-0.055***	0.000	NM	-0.082***	-0.082***	-0.002	NM
H10d-1m	Change in Return ↗ Growth ↗ Interbank lending	-0.193***	-0.193***	0.000	NM	-0.022	-0.022	0.000	NM	0.040	0.039	0.002	NM

Note: * significant at 10%; ** significant at 5%; *** significant at 1%

There is either no mediation (NM), full mediation (FM), or partial mediation (PM) for each relationship.

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