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Complexity and bank risk during the financial crisis☆

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HIGHLIGHTS

- We construct a novel dataset to analyze the evolution of banks' complexity.
- We evaluate how complexity measures relate to bank stability during crisis times.
- The sample covers stock listed banks in the Euro area from 2007 to 2014.
- Bank stability is significantly affected by our complexity measures.
- However, the direction of the effect differs across the complexity measures.

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ABSTRACT

We construct a novel dataset to measure banks' complexity and relate it to banks' riskiness. The sample covers stock listed Euro area banks from 2007 to 2014. Bank stability is significantly affected by complexity, whereas the direction of the effect differs across complexity measures.

1. Motivation

Over recent years, the European banking system has becomemore financially integrated and expanded its business activities toward securitization or the insurance sector (Cetorelli et al., 2014; Pozsar et al., 2010). This has increased banks' complexity. Complexity can dampen the impact of shocks emerging in one country or business sector. However, shocks can be propagated in interlinked and complex systems. This might have adverse consequences for bank stability. Also, supervision and regulation, as well as the resolution of complex banks become more difficult.

Despite the relevance of the topic, there exists limited empirical research on the relationship between bank complexity and financial stability.[1] We use a novel dataset on parent banks' subsidiary structure to determine four proxies for banks' complexity and relate them to bank risk. The dataset covers stock listed banks in the Euro area for the period 2007–2014. Following Cetorelli and Goldberg (2014), we compute parent banks' business and geographical complexity. Hence, complexity is conceptually defined by the variety of business types and geographical regions of banks' subsidiaries: banks are more complex if they have subsidiaries across different business types/regions. We extend the set of complexity measures to cover the share of non-bank/foreign subsidiaries because these are useful complements in explaining key dynamics in the before mentioned measures.[2] The results show that banks have increased their number of

☆ All errors are our own.

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[1] Higher complexity can simultaneously imply a higher degree of diversification. We use the term complexity throughout the paper.

[2] A more detailed survey about the concept of complexity is provided by Carmassi and Herring (2014).

subsidiaries. However, this has not necessarily translated into higher complexity. The effect of complexity on bank stability depends on the choice of the complexity measure.

Cetorelli and Goldberg (2014) calculate complexity measures for the year 2012 and show that banks' degree of complexity varies across countries and institutions; a common feature is a concentration of subsidiaries in the home country of the parent bank. We extend this literature by computing complexity measures *over time* and relate them to bank stability. Gong et al. (2015) show that effective capital ratios of US banks are lower than reported ones if minority-owned subsidiaries would be consolidated. Undercapitalization increases bank risk, suggesting that banks arbitrage regulation. Cetorelli and Goldberg (2016) take the perspective of foreign branches in the US being part of a larger, global conglomerate. They find that the more complex the conglomerate, the lower is the lending sensitivity of branches to funding shocks. Liu et al. (2015), based on a sample of US bank holding companies, show that higher complexity increases banks' stability. This is in contrast to our results and might be driven by a different sample composition and calculation of complexity.

2. Bank complexity

The analysis is based on a sample of 80 stock listed banks in the Euro area over 2007–2014.[3] For these banks, we have obtained data from the *Bankscope Ownership Module* containing information on banks' domestic and foreign subsidiaries like their business area, location, and percentage of ownership. We only consider majority-owned (>50%) subsidiaries that are directly owned by the parent bank. We compute four complexity measures:

- ***Business complexity*** is a normalized Herfindahl index (*HHI*) depending on the number of subsidiaries by business types relative to the total number of subsidiaries: $HHI_{it} = \frac{T}{T-1}\left(1-\sum_{\tau=1}^{T}\left(\frac{count^{it\tau}}{totalcount^{it}}\right)^2\right)$ with T being the number of subsidiary types. The index is defined between zero and one, higher values reflect a higher degree of complexity. Subsidiary types include banks, insurance companies, mutual and pension funds, other financial subsidiaries, non-financial subsidiaries (Cetorelli and Goldberg, 2014). A more complex subsidiary network might entail economies of scale and buffer against the occurrence of losses in one sector. However, transaction and monitoring costs can increase, which might incentivize banks to take more risks.
- ***Geographical complexity*** is a normalized *HHI* depending on the number of subsidiaries by region relative to the total number of subsidiaries: $HHI_{it} = \frac{R}{R-1}\left(1-\sum_{r=1}^{R}\left(\frac{count^{itr}}{totalcount^{it}}\right)^2\right)$ with R being the number of geographical regions. Higher values indicate a higher degree of complexity in the sense that the parent bank's subsidiaries are equally distributed across various regions. Regions include the Euro area, the UK, Japan, South Korea, China, Canada, the USA, Taiwan, Middle East, other Americas, other Europe, Eastern Europe, other Asia, other. Higher geographical complexity can help withstand local shocks but it can also increase agency problems and exposure to global shock spillovers. This would result into increased risk-taking before a crisis and higher vulnerability during a crisis.
- ***Non-bank subsidiaries*** is the ratio of a parent bank's non-bank subsidiaries to total subsidiaries. Non-bank subsidiaries can be used to become active in other activities than the traditional financial intermediation process such as securitization.

[3] Details on the sample composition are available in Table A1 in the supplementary appendix.

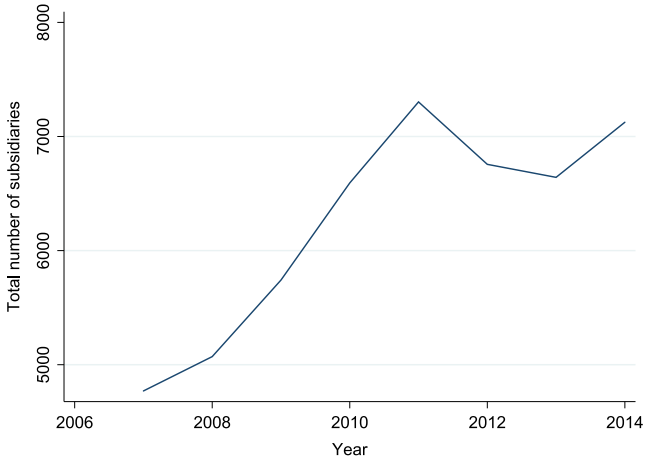

Fig. 1. Number of banks' subsidiaries. This graph shows the number of majority-owned subsidiaries by parent banks.

- ***Foreign subsidiaries*** is the ratio of a parent bank's foreign subsidiaries to total subsidiaries. A larger share of foreign subsidiaries contains possibilities for regulatory arbitrage – in general, subsidiaries fall under the regulation of their host country – and cause coordination problems among regulators from different countries in case a bank has to be resolved.

Fig. 1 shows that banks have increased their number of subsidiaries (like in Carmassi and Herring, 2014). However, this has not resulted in an increase of all complexity measures (Fig. 2). Business and geographical complexity, and the share of foreign subsidiaries have declined. The reason for this downward trend is that banks have extended the ownership of non-bank/local subsidiaries relatively more than the one of bank/foreign subsidiaries.[4] This implies a higher degree of concentration in one sector/region and thus a decline in the HHIs.

3. Regression results

3.1. Zscore

To evaluate the relationship between banks' complexity and riskiness during the recent crisis period, we estimate the following model:

$$Zscore_{ij,average\ 08-10} = \alpha + \beta_1 X_{ij,2007} + \beta_2 Country_{j,2007} + \beta_3 Complex_{ij,2007} + \varepsilon_{ij} \quad (1)$$

where $Zscore_{ij,average08-10}$ is the average *Zscore* for bank *i* located in country *j* during the financial crisis period from 2008 to 2010. To ensure linearity, the *Zscore* is defined as $Zscore_{it} = \log(1+\widehat{Zscore}_{it})$, whereas higher values indicate higher stability.[5]

We add pre-crisis values of bank-level controls ($X_{ij,2007}$) obtained from *Bankscope* including the log of total assets, the CAMEL variables (Cole and White, 2012), and a complexity measure ($Complex_{ij,2007}$).[6][7] At the country-level ($Country_{j,2007}$), we

[4] For illustration, see Figure A1 in the supplementary appendix.

[5] $\widehat{Zscore}_{it}$ is calculated as $\frac{\mu_{RoA,i}+equ_{it}}{\sigma_{RoA,i}}$, with $\mu_{RoA,i}$ being the mean and $\sigma_{RoA,i}$ being the standard deviation of return on assets over 2007–2014, equ_{it} denotes the equity to assets ratio (Lepetit and Strobel, 2013). The pattern of the *Zscore* is depicted in Fig. 2.

[6] We exclude the equity ratio and return on assets because they are part of our dependent variable.

[7] To correct for outliers, we keep only observations with non-missing assets. We drop observations with negative values for assets, equity, or loans, and if ratios take implausible values (e.g. greater than 100%). All CAMEL variables are winsorized at the top and bottom percentile. For summary statistics, see the supplementary appendix (Tables A2–A4).