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The Role of Complexity for Bank Risk during the Financial Crisis: Evidence from a Novel Dataset

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The Role of Complexity for Bank Risk during the Financial Crisis: Evidence from a Novel Dataset*

Abstract

We construct a novel dataset to measure banks' business and geographical complexity. Using these measures of complexity, we evaluate how they relate to banks' idiosyncratic and systemic riskiness. The sample covers stock listed banks in the euro area from 2007 to 2014. Our results show that banks have increased their total number of subsidiaries while business and geographical complexity have declined. Bank stability is significantly affected by our complexity measures, whereas the direction of the effect differs across the complexity measures: Banks with a higher degree of geographical complexity and a higher share of foreign subsidiaries seem to be less stable. In contrast, a higher share of non-bank subsidiaries significantly decreases the probability for a state aid request during the recent crisis period. This heterogeneity advises against the use of a single complexity measure when evaluating the implications of bank complexity.

Keywords: bank risk, complexity, globalization

JEL Classification: G01, G20, G33

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1. Motivation

Over recent years, the European banking system has become more financially integrated. Also, it has expanded its business activities toward sectors such as securitization or insurance (Cetorelli et al. 2014, Pozsar et al. 2010). This has increased banks' complexity. Geographical and business complexity can, on the one hand, dampen the impact of shocks emerging in one country or business sector. On the other hand, shocks are propagated and amplified in interlinked systems. This, in turn, might have adverse consequences for bank stability. Also, supervision and regulation, as well as the resolution of banks in distress become more difficult for banks with a more complex structure. In this context, it seems not surprising that recent proposals like the Liikanen report or Volcker rules suggest the separation of traditional lending business and investment banking (Krahnen et al. 2016). Further regulatory and supervisory changes apply a special treatment to complex banks, see e.g. the identification of systemically important banks by the Basel Committee on Banking Supervision or the supervision of selected banks by the Single Supervisory Mechanism.

Despite the relevance of the topic, there exists limited empirical research on the relationship between bank complexity and financial stability.¹ In this paper, we use a novel dataset to determine four different proxies for a bank's complexity and relate them to measures of bank risk. The dataset covers stock listed banks in the Euro area for the period 2007-2014. We exploit specific information on subsidiaries, their location and business area. In the vein of Cetorelli and Goldberg (2014), we compute measures for a parent bank's (i) business complexity, indicating the distribution of subsidiaries across business areas, (ii) geographical complexity, capturing the distribution of subsidiaries across regions, (iii) its share of non-bank subsidiaries, and (iv) its share of foreign subsidiaries.

The results of our paper show that banks have increased their number of subsidiaries over time. However, this has not translated into a higher degree of business and geographical complexity. Both of those complexity measures have declined following the financial and sovereign debt crisis. A decline can also be observed for the share of foreign subsidiaries in total subsidiaries owned by parent banks. One possible reason behind this declining trend could be flight home effects in response to the crisis and increased fragmentation in the financial sector. A closer look at our dataset tells another story: Banks have steadily increased their number of subsidiaries in different geographical regions or sectors. However, the increase has been more pronounced in some regions or sectors than in others. This disproportional increase caused a decline in business and geographical complexity. Also, banks have steadily increased their share of non-bank subsidiaries including, for example,

¹ Higher complexity can simultaneously imply a higher degree of diversification. For consistency, we make use of the term complexity throughout the whole paper.

mutual funds or insurance companies. This is in line with previous evidence that activities in the shadow banking sector gained in importance (Cetorelli et al. 2014, Pozsar et al. 2010).

Furthermore, we evaluate the effects on bank risk discriminating between idiosyncratic and systemic risk. Our results reveal that geographical complexity and a higher share of foreign subsidiaries increase both idiosyncratic default risk and banks' systemic risk. Business complexity seems to be of minor importance as, in most cases, we do not find significant effects on bank risk. However, a higher share of non-bank subsidiaries decreases the probability to request state aid during the period 2008-2014.

There are few papers that study bank complexity.² The evolution of banks' expansion into different business areas and resulting consequences are discussed by Herring and Carmassi (2010). Cetorelli et al. (2014) show that US bank holding companies have steadily increased their share of non-bank subsidiaries allowing them to become more active in securitization. Claessens and van Horen (2014, 2015) examine the international expansion of banks by constructing a comprehensive cross-country dataset on the maintenance of foreign-owned affiliates. The evolution of foreign ownership is studied by Mui and Niepmann (2015) using data on US banks' foreign affiliates. Similar to our results, which are based on domestic *and* foreign subsidiaries, they find that ownership of non-bank subsidiaries abroad has increased.

Descriptive evidence at the cross-country level for various types of complexity is provided by Cetorelli and Goldberg (2014). Using data from the Bankscope Ownership Module for the year 2012, they show that bank size is a weak predictor of complexity. While banks' degree of complexity varies across countries and institutions, a common feature is a high share of non-bank subsidiaries as well as a concentration of subsidiaries in the home country of the parent bank. Carmassi and Herring (2014) study the complexity of 29 global systemically important banks (G-SIBs) for the period 2002-2013. They show that for the G-SIBs complexity, approximated by the average number of majority-owned subsidiaries, has increased until 2011, and discuss resulting implications for regulation and resolvability. We extend this literature by computing different measures for banks' complexity *over time* for stock listed, Euro area banks and relate these measures to bank stability.

Research that focuses on banks' subsidiary structure and the effects on risk-taking is scarce. One recent paper by Gong et al. (2015) shows that effective capital ratios of US banks are lower than reported ones if minority-owned subsidiaries would be consolidated. A higher degree of undercapitalization increases banks' risk measured by the *Zscore* or earnings volatility suggesting that banks make use of minority-owned subsidiaries to arbitrage

² An abundant literature analyses the effects of banks' internationalization on shock spillovers, e.g., Cetorelli and Goldberg (2011), Buch and Goldberg (2015), De Haas and van Horen (2012), Giannetti and Laeven (2012), Hale et al. (2016), Ongena et al. (2015). A recent summary of the literature on contagion in interbank networks is provided by Hüser (2015).

regulation and increase risk-taking. The effect of US banks' branch network on bank performance is studied by Hirtle (2007). 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. Combining these results reveals that complexity can affect the behavior of the bank holding company, but also of institutes placed at the lower levels of the family tree, including branches and subsidiaries.

The paper closest to us is by Liu et al. (2015). Their analysis is based on a sample of US bank holding companies for the period 1986-2013. A bank's complexity increases the more diversified its activities, which are broken down in three main fields namely domestic, cross-border, and derivatives, and the less common its composition of activities compared to other banks. Their results suggest that higher complexity increases banks' idiosyncratic stability. This is in contrast to our results and might be driven by a different sample composition and calculation of the complexity measure. Regarding banks' systemic riskiness, they find a non-monotonic effect of complexity, suggesting that the impact on systemic risk is highest for banks with intermediate complexity.

The paper is structured as follows. Section 2 describes the data, the construction of the complexity measures, and the evolution of the complexity measures over time. Section 3 presents the regression framework and discusses results. The final section concludes.

2. Data description

2.1. Bank complexity

The analysis is based on a sample of stock listed banks in the Euro area over the period 2007-2014. We select bank-level data from Bankscope for all banks that are listed according to Datastream as of July 2014. We drop listed banks with a market capitalization smaller than 100 million Euros at the beginning of our sample period to exclude smaller and specialized banks with low trading frequency (Buch et al. 2016). For the remaining sample of banks, we have obtained data from the Bankscope Ownership Module, which contains information on banks' domestic and foreign subsidiaries including their business area, location, and percentage of ownership. We only consider majority-owned (>50%) subsidiaries that are directly owned by the parent bank ("level 1").³

³ With the most recent information provided by Bankscope, it is possible to construct a whole ownership tree exceeding "level one", that is, subsidiaries with direct ownership by the parent bank. However, this information is not available to us for previous years implying that we are rather underestimating the amount of relevant subsidiaries.

Similar to Cetorelli and Goldberg (2014), we compute different complexity measures. In contrast to their paper, we can do this for the whole sample period and not only for the year 2012. Our complexity measures are defined as follows:

- **Business complexity:** We calculate a normalized Herfindahl index (*HHI*) that depends on the number of subsidiaries by business types relative to the total number of subsidiaries of the parent bank. The *HHI* for parent bank i at time t is defined as
$$HHI_{it} = \frac{T}{T-1} + \left(1 - \sum_{t=1}^T \left(\frac{count^{it}}{totalcount^{it}} \right)^2 \right)$$
 with T being the number of subsidiary types. The index is defined between zero and one, higher values reflect a higher degree of complexity, that is the parent bank has a wide range of subsidiaries being equally distributed across different types. Subsidiary types distinguish between banks, insurance companies, mutual and pension funds, other financial subsidiaries, non-financial subsidiaries (Cetorelli and Goldberg 2014, Herring and Carmassi 2010). A more complex subsidiary network might entail economies of scale, increase profitability, and buffer against the occurrence of losses in one sector. However, also transaction costs can increase if information is exchanged among different types of subsidiaries. These increased costs can, in turn, deteriorate bank performance. Similarly, losses in specialization can lead to reduced market power, depressed margins, which might incentivize banks to take more risks.⁴ A further aspect is that monitoring by shareholders can become more difficult providing incentives for increased risk-taking (Hirtle 2007).
- **Geographical complexity:** The normalized *HHI* depends on the number of subsidiaries by regional location relative to the total number of subsidiaries of the parent bank. The *HHI* for parent bank i at time t is defined as
$$HHI_{it} = \frac{R}{R-1} \left(1 - \sum_{t=1}^R \left(\frac{count^{it}}{totalcount^{it}} \right)^2 \right)$$
 with R being the number of geographical regions. Again, 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. While a higher degree of geographical complexity can help withstand local shocks and increase banking stability, it can also increase agency problems and exposure to global shock spillovers (Goetz et al. 2013). This would result into increased risk-taking before a crisis and higher vulnerability during a crisis.
- **Non-bank subsidiaries:** We compute the ratio of a parent bank's non-bank subsidiaries to total subsidiaries. Non-bank subsidiaries can be used as a tool to

⁴ Liu et al. (2015) argue that banks with a higher level of diversification and diversity across activities can distinguish themselves from their competitors and thus increase market shares.

become active in other activities than the traditional financial intermediation process such as securitization (Herring and Carmassi 2010). Like this, a parent bank can diversify its business model. At the same time, non-bank subsidiaries might be exposed to more lenient regulation offering incentives for the parent bank to place asset risk there.

- **Foreign subsidiaries:** We compute the ratio of a parent bank's foreign subsidiaries to total subsidiaries. A larger share of foreign subsidiaries might contain 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.

Figure 1 shows that banks have steadily increased their number of subsidiaries over recent years, which is mostly driven by the larger banks in our sample. This increase is consistent with related papers that partly used the same dataset or rely on country-specific data (Avraham et al. 2012, Carmassi and Herring 2014, Mui and Niepmann 2015). Also, Koch et al. (2011) show for the German banking system that while most banks conduct cross-border lending activities, the main share of foreign subsidiaries is maintained by the larger banks. For the largest US bank holding companies, Avraham et al. (2012) find a positive relation between size and the number of subsidiaries, which is their measure for complexity.

[Insert Figure 1 here]

How this increase in subsidiaries affects parent banks' complexity is depicted in Figure 2, in which we plot the complexity measures averaged across all banks by year. Similar to Herring and Carmassi (2010), we observe a decline for business complexity (upper, left panel). This might be driven by a relatively strong increase in the share of non-bank subsidiaries as depicted in the lower right panel. These observations reveal the difficulty to draw obvious conclusion about whether banks' complexity has increased or decreased. Depending on the definition of complexity and the related measures, opposite patterns can be observed.

[Insert Figure 2 here]

Geographical complexity (upper, right panel) and the share of foreign subsidiaries have declined (lower, left panel). The reason for this downward trend of geographical complexity is that banks have extended the ownership of domestic subsidiaries relatively more than the one of foreign subsidiaries. Furthermore, their presence through subsidiaries in the Euro area has increased relatively more than ownership of subsidiaries in other regions. This implies a higher degree of concentration in one region and thus a decline in geographical complexity. This finding is in line with Claessens and van Horen (2015), who illustrate that foreign bank presence does not become more fragmented during the crisis; it merely shows a tendency to have a focus on regional markets. Hence, flight-home effects during the recent crisis are a

phenomenon mostly related to cross-border lending, but not so much to the physical presence of foreign subsidiaries.

To illustrate the driving pattern behind the decline in business and geographical complexity, we depict the number of subsidiaries by type and location for the years 2007 and 2014. Figure 3a) shows the number of subsidiaries by type. It can be seen that, while the amount of subsidiaries being banks stayed almost the same, the number of non-financial subsidiaries increased strongly. Figure 3b) is based on the amount of subsidiaries by region. Obviously, the number of subsidiaries has increased across all regions, but the most so for the Euro area.

[Insert Figure 3 here]

2.2. Bank risk and control variables

To measure banks' riskiness, we rely on three different measures. First, we calculate the commonly used *Zscore*. For bank i at time t , it is defined as (see Lepetit and Strobel 2013):

$$Zscore_{it} = \log(1 + \widehat{Zscore}_{it})$$

The variable \widehat{Zscore}_{it} is calculated in the following way $\frac{\mu_{RoA,i} + equ_{it}}{\sigma_{RoA,i}}$, whereas $\mu_{RoA,i}$ is the mean of return on assets of bank i , $\sigma_{RoA,i}$ is the standard deviation of return on assets of bank i , and both are calculated over the full sample (2007-2014). The remaining element of the numerator equ_{it} denotes the equity to total assets ratio of bank i at time t . We use the log of $(1 + \widehat{Zscore}_{it})$ in our regression analysis to ensure linearity (Demirgüç-Kunt et al. 2008). Higher values of the *Zscore* indicate that a bank is more stable.

The evolution of the average *Zscore* is depicted in Figure 2. It can be seen that the *Zscore* declines on average with the start of the financial crisis in 2008. From then on, there is an upward trend in bank stability, the average *Zscore* increases again with small fluctuations. One reason behind this upward trend can be the announcement and implementation of higher capital requirements in the context of the re-regulation of the financial sector after the financial crisis. Also, the conduct of stress tests and asset quality reviews in the Euro area might have provided incentives for banks to increase their equity to assets ratio. Figure 4 provides a scatterplot of banks' *Zscore* against the complexity measures. This first visualization suggests a positive link between the share of non-bank subsidiaries and the *Zscore*. For all other complexity measures, the reverse can be observed.

[Insert Figure 4 here]

Second, we use an indicator variable that is one if a bank i has been exposed to failure risk and received state aid by the government at time t , e.g. recapitalization or asset guarantees, and zero otherwise. Information on the decision dates of state aid requests is obtained from the State Aid Register of the European Commission. In contrast to the *Zscore*, which is

similar to a distance to default measure, the state aid indicator is a more precise signal that a bank had serious problems during the recent time period.

Third, we use $\Delta CoVar$ by Adrian and Brunnermeier (2016). As a tail dependency indicator between the whole financial system and a particular institution, it measures a component of systemic risk that co-moves with the distress of a particular institution. Technically, $\Delta CoVar$ of bank i is defined as the difference between the VaR (value at risk) of the Euro area financial system conditional on this particular bank being in financial distress⁵ and the VaR of the financial system conditional on bank i being in its median state. In contrast to the $Zscore$ and the state aid indicator, $\Delta CoVar$ captures not only a bank's idiosyncratic risks but its systemic risks, or in other words risks that have negative externalities for the entire system.

In the regression analysis, we add control variables at the bank-level that are obtained from Bankscope.⁶ These include bank size (log of total assets) and the CAMEL variables including the equity ratio, the non-performing loans ratio, the cost-to-income ratio, return on assets, the liquid assets ratio (e.g., Buch et al. 2016, Cole and White 2012). At the country-level, we control for GDP growth and the inflation rate as provided by the International Monetary Fund. Also, we add a dummy variable that equals one if a country belongs to one of the GIIPS countries (Greece, Ireland, Italy, Portugal, Spain), and zero otherwise. Summary statistics for the full sample as well for the sample that is used for parts of the regression analysis can be found in Tables 1 and 2.

[Insert Tables 1-2 here]

Simple correlations between the variables are shown in Table 3. Focusing on the correlations among the complexity measures shows that business (HHI Business) and geographical (HHI Geo) complexity are strongly correlated. A higher share of non-bank subsidiaries correlates negatively with the HHI Business, while a higher share of foreign subsidiaries correlates positively with the HHI Geo, which supports our explanations above. The link between the share of non-bank subsidiaries and the share of foreign subsidiaries is negative but rather weak. Also, in our dataset, bank size seems to be positively connected to the complexity measures, except for the share of non-bank subsidiaries.

[Insert Table 3 here]

Looking at the correlations between business or geographical complexity and the $Zscore$ ($\Delta CoVar$) points into a negative (positive) relationship. Hence, higher complexity is linked to increased riskiness of the standalone bank and its systemic relevance. Again, this is reversed

⁵ Distress is defined as the VaR_{α} of bank i at the 5% level.

⁶ 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 bank-level control variables are winsorized at the top and bottom percentile.

for the share of non-bank subsidiaries, for which a higher ratio correlates positively (negatively) with the *Zscore* ($\Delta CoVar$). Similarly, higher complexity measures seem to go hand in hand with the occurrence of a state aid request. This holds for all complexity measures, except for the share of non-bank subsidiaries.

In sum, these results provide preliminary evidence that, first, some dimensions of complexity might go hand in hand, while others can move independently from each other. Second, from the simple correlations, one might conclude that bank size is related to a bank's complexity. Third, no fast conclusion should be drawn regarding the relationship between complexity and bank risk. While some complexity measures show a negative correlation with bank stability, this does not hold true for all of them. In the following regression analysis, we test in a more sophisticated way whether these conclusions can be confirmed.

3. Regression results

3.1. Zscore

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

$$Zscore_{ij,average08-10} = \alpha + \beta_1 X_{ij,2007} + \beta_2 Country_{j,2007} + \beta_3 Complex_{ij,2007} + \varepsilon_{ij} \quad (1)$$

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. The explanatory variables include lagged, pre-crisis values of bank-level controls ($X_{ij,2007}$), country-level controls ($Country_{j,2007}$), and one of the complexity measures denoted by $Complex_{ij,2007}$. This estimation approach is similar to Laeven et al. (2016) and reduces simultaneity concerns. The bank-level controls include all CAMEL variables and bank size measured by the log of total assets. We exclude the equity ratio and the return on assets because these variables are part of our dependent variable.

The results in Table 4 show that two of the four complexity measures have a significant coefficient. A higher geographical complexity and a higher share of foreign subsidiaries before the crisis can be associated with higher bank risk (or a lower *Zscore*) during the crisis. This might be due to spillovers of shocks for banks with more international activities. In contrast, business complexity and the share of non-bank subsidiaries are insignificant.

[Insert Table 4 here]

To verify this result, we conduct a set of robustness test. First, based on equation (1), we run univariate regressions including only one of the complexity measures. Results can be found in Table 5, whereas all coefficients are significant (columns 1-4). As has already been indicated

by the correlations in Table 3, a higher value of business or geographical complexity, as well as a higher share of foreign subsidiaries relate negatively to banks' stability.

[Insert Table 5 here]

Second, we run cross-sectional regressions across all banks for each year, in which the *Zscore* is the dependent variable and all explanatory variables are included with a lag (Table 6). Interestingly, the HHI Business shows as before a negative coefficient, which is, however, only significant during recent years. In contrast, the HHI Geo and the share of foreign subsidiaries stand in a negative and significant relation to the *Zscore* for almost each year of the sample period. Only, the share of non-bank subsidiaries remains insignificant throughout.

[Insert Table 6 here]

Third, we make use of the time dimension of our sample in an alternative way than in Table 6 and run panel regressions. Again the *Zscore* is the dependent variable and the explanatory variables are included with a lag to reduce simultaneity concerns. In addition, we control for time and bank fixed effects. To evaluate whether the complexity measures played a different role for bank stability during the crisis years, we add an interaction term between a complexity measure and a crisis dummy, whereas the latter equals one during the years 2008-2010 and zero otherwise. Table 7 shows that we obtain consistent results for the signs of the coefficients of the complexity measures. For three of the complexity measures (HHI Geo, share of non-bank subsidiaries, share of foreign subsidiaries), we find that they show no significant effect in non-crisis times but significantly reduce bank stability during a crisis.

[Insert Table 7 here]

3.2. State aid

Alternatively, we estimate panel probit regressions to test whether bank complexity affected the probability to be close to failure and in the need of state aid during the period 2008-2014. In the spirit of Cole and White (2012) or Shaffer (2012), the model is specified as:

$$Stateaid_{ij,t} = \alpha + \beta_1 X_{ij,t-1} + \beta_2 Country_{j,t} + \beta_3 Complex_{ij,t-1} + \theta_t + \varepsilon_{ij,t} \quad (2)$$

where the dependent variable is a dummy variable that equals one if bank *i* has received state aid in period *t* and zero otherwise. The explanatory variables at the bank-level comprise the CAMEL variables and the log of total assets. Those variables are included with a lag to reduce simultaneity concerns. We again control for the country's GDP growth, inflation rate, and include a dummy that indicates whether a country belongs to the GIIPS countries. To

capture common developments over time that affect all banks similarly, we add time fixed effects θ_t .⁷

In Table 8, it can be seen that a higher level of geographical complexity and a higher share of foreign subsidiaries increase the probability for a state aid request. This is consistent with the results above (Table 4) because these variables showed a negative relation with bank stability during the crisis period, measured by the bank's average *Zscore*. However, a higher share of non-bank subsidiaries now significantly reduces the probability of state aid. This might suggest internal cross-funding possibilities within a bank holding company comprising a parent bank that owns different types of subsidiaries.

[Insert Table 8 here]

3.3. $\Delta CoVaR$

As a final robustness test, we use a stock market based measure for a bank's systemic riskiness as the dependent variable (Adrian and Brunnermeier 2016). The higher $\Delta CoVar$, the more systemic risk the bank imposes on the banking system. The regression estimation is pursued similar to model (1), whereas we only interchange the *Zscore* with the $\Delta CoVar$:

$$\Delta CoVar_{ij,average08-10} = \alpha + \beta_1 X_{ij,2007} + \beta_2 Country_{j,2007} + \beta_3 Complex_{ij,2007} + \varepsilon_{ij} \quad (3)$$

The results in Table 9 show that geographical complexity and the share of foreign subsidiaries to total subsidiaries affects $\Delta CoVar$ positively. This is in line with the previous results for the *Zscore* and the state aid indicator. Hence, complexity is not only likely to increase individual bank risk but also banks' systemic risk contributions. This might be due to increasing difficulties of resolving banks whose subsidiaries are more distributed across several regions. If banks with a high degree of internationalization fail, distress might spread within the system and affect interconnected banks. Thus, the failing bank is a source of systemic risk. Both business complexity and the share of non-bank subsidiaries do not enter significantly into the regression and seem to be of minor importance.

[Insert Table 9 here]

4. Concluding remarks

The recent financial crisis has brought the issue of bank complexity on the agenda of policymakers. Policy proposals aiming at separating traditional banking and investment banking target banks' business complexity. The geographical dimension of banks is, besides other criteria like size, considered by the Single Supervisory Mechanism in determining

⁷ Due to the incidental parameter problem, we cannot include bank-fixed effects. To test whether a random effects model is appropriate, we have also included Mundlak terms (available upon request).

which Euro area banks to supervise. However, empirical research on the drivers and consequences of bank complexity, which could provide insights for policymakers, is scarce. Reasons might be that no unique definition of complexity exists and data limitations hinder an evaluation of banks' complexity.

In this paper, we use a novel dataset for stock listed banks in the Euro area containing information on banks' subsidiaries. These data allow to compute four different measures to approximate banks' complexity over the period 2007-2014. Looking at the time pattern of these measures shows that banks have steadily increased their number of subsidiaries. However, this has not translated into higher complexity in terms of the diversification of these subsidiaries across regions and business types. Also, the share of foreign subsidiaries to total subsidiaries has declined, whereas this does not hold for the share of non-bank subsidiaries. This suggests that banks have focused more on home and regional markets regarding the presence of subsidiaries, but entered new business areas by increasing their share of non-bank subsidiaries. It also emphasizes that different dimensions of complexity can move into opposite directions, which advises against the use of a single measure of complexity.

This is also an important point when it comes to the evaluation of the relationship between bank complexity and stability. Thus, we use different complexity measures in our regression analysis and link them to banks' idiosyncratic and systemic riskiness. Higher complexity can, on the one hand, offer diversification possibilities and reduce the impact of local or sector-specific shocks. On the other hand, complexity might increase transaction and monitoring costs. This can reduce buffers and increase vulnerabilities, as well as reduced monitoring can result into moral hazard. The results show a heterogeneous picture. A higher degree of geographical complexity and a higher share of foreign subsidiaries increase banks' riskiness during the recent crisis. In contrast, a higher share of non-bank subsidiaries seems to have stabilizing effects.

References

- Adrian, T., and Brunnermeier, M.K. (2016). CoVar. *American Economic Review* (forthcoming).
- Avraham, D., Selvaggi, P., and Vickery, J.I. (2012). A Structural View of U.S. Bank Holding Companies. *Economic Policy Review* 18(2): 65-81.
- Benoit, S., Colliard, J.E., Hurlin, C., and Pérignon, C. (2016). Where the Risks Lie: A Survey on Systemic Risk. *Review of Finance* (forthcoming).
- Buch, C.M., and Goldberg, L.S. (2015). International Banking and Liquidity Risk Transmission: Lessons from Across Countries. *IMF Economic Review* 63: 377-410.
- Buch, C.M., Koch, C., and Koetter, M. (2011). Size, productivity, and international banking. *Journal of International Economics* 85(2): 329-334.
- Buch, C.M., Krause, T., and Tonzer, L. (2016). Drivers of Systemic Risk: Do National and European Perspectives Differ? Mimeo.
- Carmassi, J., and Herring, R.J. (2014). Corporate Structures, Transparency and Resolvability of Global Systemically Important Banks. Available at <http://fic.wharton.upenn.edu/fic/papers/15/p1510.html>.
- Cetorelli, N., and Goldberg, L.S. (2016). Organizational Complexity and Balance Sheet Management in Global Banks. NBER Working Paper No. 22169. NBER.
- Cetorelli, N., and Goldberg, L.S. (2014). Measures of Complexity of Global Banks. *Economic Policy Review* 20(2): 107-126. Federal Reserve Bank of New York.
- Cetorelli, N., and Goldberg, L.S. (2011). Global Banks and International Shock Transmission: Evidence from the Crisis. *IMF Economic Review* 59(1): 41-76.
- Cetorelli, N., McAndrews, J., and Traina, J. (2014). Evolution in Bank Complexity. *Economic Policy Review* 20(2): 85-106. Federal Reserve Bank of New York.
- Claessens, S., and van Horen, N. (2015). The impact of the global financial crisis on banking globalization. *IMF Economic Review* 63(4): 868-918.
- Claessens, S., and van Horen, N. (2014). Foreign Banks: Trends and Impact. *Journal of Money, Credit and Banking* 46(1): 295-326.
- Cole, R.A., and White, L.J. (2012). Déjà Vu All Over Again: The Causes of U.S. Commercial Bank Failures This Time Around. *Journal of Financial Services Research* 42: 5-29.

- De Haas, R., and van Horen, N. (2012). International Shock Transmission after the Lehman Brothers Collapse: Evidence from Syndicated Lending. *American Economic Review* 102(3): 231-37.
- Demirgüç-Kunt A., Detragiache E., and Tressel, T. (2008). Banking on the Principles: Compliance with Basel Core Principles and Bank Soundness. *Journal of Financial Intermediation* 17: 511-542.
- Giannetti, M., and Laeven, L. (2012). The Flight Home Effect: Evidence from the Syndicated Loan Market during Financial Crises. *Journal of Financial Economics* 104(1): 23-43.
- Goetz, M.R., Laeven, L., and Levine, R. (2013). Identifying the Valuation Effects and Agency Costs of Corporate Diversification: Evidence from the Geographic Diversification of U.S. Banks. *Review of Financial Studies* 26 (7): 1787-1823.
- Gong, D., Huizinga, H., and Laeven, L. (2015). Nonconsolidated Subsidiaries, Bank Capitalization and Risk Taking. CEPR Discussion Paper No. 10992, CEPR.
- Hale, G., Kapan, T., and Minoiu, C. (2016). Crisis transmission through the global banking network. Federal Reserve Bank of San Francisco Working Paper 2016-01.
- Herring, R., and Carmassi, J. (2010). The Corporate Structure of International Financial Conglomerates: Complexity and Its Implications for Safety and Soundness. **In A. Berger, P. Molyneux, and J. Wilson, eds., The Oxford Handbook of Banking.** Oxford: Oxford University Press.
- Hirtle, B. (2007). The impact of network size on bank branch performance. *Journal of Banking & Finance* 31(12): 3782-3805.
- Hüser, A.-C. (2015). Too interconnected to fail: a survey of the interbank networks literature. *Journal of Network Theory in Finance* 1(3): 1–50.
- Krahnen, J.-P., Noth, F., and Schüwer, U. (2016). Structural Reforms in Banking: The Role of Trading. IWH-Diskussionspapiere 9/2016: 1-30.
- Laeven, L., Ratnovski, L., and Tong, H. (2016). Bank Size, Capital, and Systemic Risk: Some International Evidence. *Journal of Banking & Finance* (forthcoming).
- Lepetit, L., and Strobel, F. (2013). Bank insolvency risk and time-varying Z-score measures. *Journal of International Financial Markets, Institutions and Money* 25: 73-87.
- Liu, H., Norden, L., and Spargoli, F. (2015). Why Banks Want to Be Complex. Available at SSRN: <http://ssrn.com/abstract=2697220>
- Mui, P., and Niepmann, F. (2015). Around the World in 8,379 Foreign Entities. <http://libertystreeteconomics.newyorkfed.org/2015/08/around-the-world-in-8379-foreign-entities.html>.

- Ongena, S., Peydro, J.L., and van Horen, N. (2015). Shocks Abroad, Pain at Home? Bank-Firm Level Evidence on the International Transmission of Financial Shocks. *IMF Economic Review* 63: 698–750.
- Pozsar, Z., Adrian, T., Ashcraft, A., and Boesky, H. (2010). Shadow Banking. Federal Reserve Bank of New York Staff Reports, no. 458.
- Shaffer (2012). Bank failure risk: Different now? *Economics Letters* 116(3): 613–616.

Figures and tables

Table 1: Summary statistics – Full sample

This table shows summary statistics for the dependent variables *Zscore*, *Stateaid* and ΔCoVaR , bank-level control variables, as well as macroeconomic control variables. The sample consists of 80 banks listed on the stock market in the Euro area and covers the years 2007-2014. *Zscore* is the log of the zscore calculated as in Lepetit and Strobil (2013). *Stateaid* denotes a dummy which equals one if the bank received state aid following the State Aid Register of the European Commission and zero otherwise. ΔCoVaR is calculated following Benoit et al. (2015) and market data are obtained from Datastream. *HHI Business* indicates diversification of banks across different business activities, *HHI Geo* indicates diversification of banks across geographical regions, *Ratio Nonbanks* gives the number of nonbank subsidiaries over the total number of subsidiaries, and *Ratio Foreign* is the number of subsidiaries that are located in a different country than the bank holding company over the total number of subsidiaries. *Log assets* denotes the logarithm of bank assets in thousands of USD. *Equity* is the equity to total assets ratio (in %). In order to measure asset quality, *NPL* is used which is defined as the fraction of impaired loans relative to gross loans (in %). *Cost-to-income* is a measurement of the management quality defined as the cost to income ratio (in %). Earnings are measured by the return on assets (*RoA*) which is the ratio of operating profits to total assets (in %). *Liquid assets* is the share of liquid assets in total assets (in %). The *inflation* rate (in %) and *GDP* growth (in %) of the bank holding's country of location are used as macroeconomic controls.

VARIABLES	N	mean	sd	skewness	kurtosis	min	max
<i>Dependent variables</i>							
<i>Zscore</i>	608	2.82	1.07	0.18	2.43	0.25	5.11
<i>Stateaid</i>	610	0.05	0.21	4.34	19.83	0.00	1.00
ΔCoVaR	601	0.01	0.01	0.62	3.02	0.00	0.05
<i>Complexity measures</i>							
<i>HHI Business</i>	587	0.74	0.24	-1.82	5.84	0.00	0.99
<i>HHI Geo</i>	589	0.28	0.27	0.41	1.78	0.00	0.85
<i>Ratio Nonbanks</i>	587	0.85	0.16	-1.40	5.70	0.00	1.00
<i>Ratio Foreign</i>	589	0.30	0.26	0.50	2.26	0.00	1.00
<i>Bank-level controls</i>							
<i>Log assets</i>	610	17.80	1.97	0.07	2.46	13.28	21.66
<i>Equity</i>	610	7.34	3.50	1.28	6.73	1.45	24.60
<i>NPL</i>	520	7.94	8.32	2.24	8.29	0.41	42.58
<i>Cost-to-income</i>	579	60.93	12.01	0.60	3.11	36.73	96.01
<i>RoA</i>	610	0.30	1.26	-2.69	12.65	-5.98	2.36
<i>Liquid assets</i>	610	15.22	11.64	1.71	6.09	2.51	61.56
<i>Macroeconomic variables</i>							
<i>Inflation</i>	610	1.85	1.29	-0.11	2.88	-1.71	5.65
<i>GDP</i>	610	0.03	2.70	-0.59	3.74	-8.86	10.68

Table 2: Summary statistics – Regression sample (equation (1))

This table shows summary statistics for the dependent variables *Zscore* and *Stateaid*, bank-level control variables, as well as macroeconomic control variables. The sample consists of 74 banks listed on the stock market in the Euro area. Explanatory variables are from the year 2007. *Zscore* (in logs) is calculated as in Lepetit and Strobel (2013) as a mean of the crisis years 2008-2010. ΔCoVaR is calculated following Benoit et al. (2015) and market data are obtained from Datastream. *HHI Business* indicates diversification of banks across different business activities, *HHI Geo* indicates diversification of banks across geographical regions, *Ratio Nonbanks* gives the number of nonbank subsidiaries over the total number of subsidiaries, and *Ratio Foreign* is the number of subsidiaries that are located in a different country than the bank holding company over the total number of subsidiaries. *Log assets* denotes the logarithm of bank assets in thousands of USD. *Equity* is the equity to total assets ratio (in %). In order to measure asset quality, *NPL* is used which is defined as the fraction of impaired loans relative to gross loans (in %). *Cost-to-income* is a measurement of the management quality defined as the cost to income ratio (in %). Earnings are measured by the return on assets (*RoA*) which is the ratio of operating profits to total assets (in %). *Liquid assets* is the share of liquid assets in total assets (in %). The *inflation* rate (in %) and *GDP* growth (in %) of the bank holding's country of location are used as macroeconomic controls.

	N	mean	sd	skewness	kurtosis	min	max
<i>Dependent variable</i>							
<i>Zscore</i>	74	2.72	1.07	0.24	2.39	0.56	4.94
ΔCoVaR	72	0.01	0.01	-0.01	1.83	0.00	0.02
<i>Complexity measures</i>							
<i>HHI Business</i>	70	0.74	0.26	-1.77	5.42	0.00	0.99
<i>HHI Geo</i>	70	0.30	0.28	0.31	1.60	0.00	0.80
<i>Ratio Nonbanks</i>	70	0.82	0.21	-1.91	7.61	0.00	1.00
<i>Ratio Foreign</i>	70	0.32	0.27	0.47	2.24	0.00	1.00
<i>Bank-level controls</i>							
<i>Log assets</i>	74	17.82	1.98	0.16	2.42	13.28	21.66
<i>Cost-to-income</i>	73	57.10	9.98	0.71	5.08	36.73	96.01
<i>NPL</i>	57	3.22	2.86	2.00	8.32	0.41	15.27
<i>Equity</i>	74	7.71	3.98	1.40	6.11	2.04	24.60
<i>RoA</i>	74	1.06	0.66	-1.75	10.64	-2.24	2.36
<i>Liquid assets</i>	74	19.25	13.36	1.57	5.36	2.51	61.56
<i>Macroeconomic variables</i>							
<i>Inflation</i>	74	2.12	0.56	0.31	3.50	0.70	3.61
<i>GDP</i>	74	3.08	1.55	1.94	9.59	1.47	10.68

Table 3: Correlations

This table shows pairwise correlations between the log of the *Zscore*, calculated as in Lepetit and Strobel (2013), the dummy *Stateaid* which equals one if the bank received state aid following the State Aid Register of the European Commission and zero otherwise and bank-level data from 2007-2014. ΔCoVaR is calculated following Benoit et al. (2015) and market data are obtained from Datastream. Bank-level data are obtained from the *Bankscope Ownership Module: HHI Business*, indicating diversification of banks across different business activities, *HHI Geo* indicating diversification of banks across geographical regions, number of nonbank subsidiaries over the total number of subsidiaries (*Ratio Nonbanks*), and the number of subsidiaries that are located in a different country than the bank holding company over the total number of subsidiaries (*Ratio Foreign*). Further bank characteristics are obtained from *Bankscope* and comprise: *Log assets* denotes the logarithm of bank assets in thousands of USD. *Equity* is the equity to total assets ratio (in %). In order to measure asset quality, *NPL* is used which is defined as the fraction of impaired loans relative to gross loans (in %). *Cost-to-income* is a measurement of the management defined as the cost to income ratio (in %). Earnings are measured by the return on assets (*RoA*) which is the ratio of operating profits to total assets (in %). *Liquid assets* is the share of liquid assets in total assets (in %).

	Zscore	Stateaid	ΔCoVaR	HHI Business	HHI Geo	Ratio Nonbanks	Ratio Foreign	Log Assets	Equity	NPL	Cost-to-income	RoA	Liquid assets
Zscore	1.00												
Stateaid	-0.20	1.00											
ΔCoVaR	-0.35	0.06	1										
HHI Business	-0.43	0.11	0.53	1.00									
HHI Geo	-0.33	0.20	0.51	0.52	1.00								
Ratio Nonbanks	0.24	-0.01	-0.26	-0.31	-0.22	1.00							
Ratio Foreign	-0.31	0.19	0.44	0.40	0.87	-0.15	1.00						
Log assets	-0.05	0.16	0.52	0.53	0.66	-0.22	0.58	1.00					
Equity	0.41	-0.20	-0.29	-0.52	-0.48	0.15	-0.42	-0.56	1.00				
NPL	-0.37	0.25	-0.06	-0.05	-0.11	-0.03	-0.05	-0.12	0.00	1.00			
Cost-to-income	-0.25	0.12	-0.08	0.15	0.13	-0.18	0.10	0.06	-0.27	0.21	1.00		
RoA	0.41	-0.28	0.05	-0.13	-0.10	0.08	-0.14	-0.03	0.25	-0.65	-0.51	1.00	
Liquid assets	-0.13	-0.09	0.06	0.15	0.26	-0.01	0.20	0.10	-0.12	-0.20	0.16	-0.02	1.00

Table 4: Regression results – Zscore

This table reports cross section regressions that are based on yearly data of stock listed banks of Euro area countries. The dependent variable is a bank's average *Zscore* over the years 2008-2010. Explanatory variables are from the year 2007 and include bank-level controls: *Log assets* is the log of total assets, *NPL* is the ratio of non-performing loans to total loans (in %), the *cost-to-income* ratio (in %), and *liquid assets* to total assets (in %). Macro controls of the bank holding's country of location include: *GDP* growth (in %), the *inflation* rate (in %) and a dummy that equals one if the bank holding is located in a *GIIPS Country*, i.e. Portugal, Italy, Ireland, Greece or Spain. The complexity measures are also from year the 2007 and include: *HHI Business* indicates diversification of banks across different business activities, *HHI Geo* indicates diversification of banks across geographical regions, the ratio of nonbank subsidiaries over the total number of subsidiaries (*Ratio Nonbanks*), and the ratio of subsidiaries that are situated in a foreign country over the total number of subsidiaries (*Ratio Foreign*). Robust standard errors are depicted in parentheses. The p-values are as follows: *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
Log assets	0.027 (0.065)	0.121 (0.090)	0.020 (0.066)	0.096 (0.087)
NPL	-0.080 (0.049)	-0.084** (0.040)	-0.076 (0.047)	-0.075* (0.042)
Cost-to-income	0.002 (0.010)	0.006 (0.009)	0.002 (0.011)	0.005 (0.008)
Liquid assets	-0.005 (0.010)	-0.002 (0.009)	-0.008 (0.011)	-0.005 (0.010)
GDP	0.038 (0.137)	0.030 (0.132)	0.020 (0.153)	0.017 (0.135)
Inflation	-0.870*** (0.264)	-0.725*** (0.233)	-0.895*** (0.266)	-0.784*** (0.257)
GIIPS Country	0.259 (0.423)	0.238 (0.430)	0.227 (0.435)	0.181 (0.417)
HHI Business	-0.206 (0.511)			
HHI Geo		-1.057** (0.442)		
Ratio Nonbanks			0.221 (0.485)	
Ratio Foreign				-0.853* (0.487)
Constant	3.964** (1.654)	1.897 (2.148)	3.918** (1.592)	2.609 (2.031)
Observations	54	54	54	54
R-squared	0.316	0.371	0.316	0.356

Table 5: Univariate cross-sectional regression results – Zscore

This table reports cross section regressions that are based on yearly data of stock listed banks of Euro area countries. The dependent variable is a bank's average *Zscore* over the years 2008-2010. The complexity measures are from the year 2007 and include: *HHI Business* indicates diversification of banks across different business activities, *HHI Geo* indicates diversification of banks across geographical regions, the ratio of nonbank subsidiaries over the total number of subsidiaries (*Ratio Nonbanks*), and the ratio of subsidiaries that are situated in a foreign country over the total number of subsidiaries (*Ratio Foreign*). Robust standard errors are depicted in parentheses. The p-values are as follows: *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)
HHI Business	-1.691*** (0.586)				-1.473*** (0.454)
HHI Geo		-1.311*** (0.385)			-0.942 (0.657)
Ratio Nonbanks			1.062** (0.463)		1.116** (0.542)
Ratio Foreign				-0.986** (0.463)	0.409 (0.769)
Constant	3.976*** (0.488)	3.106*** (0.187)	1.850*** (0.324)	3.033*** (0.204)	3.050*** (0.497)
Observations	70	70	70	70	70
R-squared	0.165	0.119	0.044	0.063	0.250

Table 6: Cross-sectional regression results by year – Zscore

This table reports cross section regressions that are based on yearly data of stock listed banks of Euro area countries by year as indicated in the column head. The dependent variable is a bank's *Zscore*. Explanatory variables include bank-level controls: *Log assets* is the log of total assets, *NPL* is the ratio of non-performing loans to total loans (in %), the *cost-to-income* ratio (in %), and *liquid assets* to total assets (in %). Macro controls of the bank holding's country of location include: *GDP* growth (in %), the *inflation* rate (in %), and a dummy that equals one if the bank holding is located in a *GIIPS Country*, i.e. Portugal, Italy, Ireland, Greece or Spain. The complexity measures comprise: *HHI Business* indicates diversification of banks across different business activities (Panel a), *HHI Geo* indicates diversification of banks across geographical regions (Panel b), the ratio of nonbank subsidiaries over the total number of subsidiaries (*Ratio Nonbanks*, Panel c), and the ratio of subsidiaries that are situated in a foreign country over the total number of subsidiaries (*Ratio Foreign*, Panel d). Bank-level variables are lagged by one period. Robust standard errors are depicted in parentheses. The p-values are as follows: *** p<0.01, ** p<0.05, * p<0.1.

a) HHI Business							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	2008	2009	2010	2011	2012	2013	2014
Log assets	0.046 (0.080)	0.136** (0.063)	0.081 (0.061)	0.108** (0.050)	0.128** (0.056)	0.097** (0.042)	0.083* (0.042)
NPL	-0.049 (0.059)	-0.102* (0.053)	-0.074* (0.037)	-0.065** (0.027)	-0.104*** (0.020)	-0.087*** (0.018)	-0.056*** (0.010)
Cost-to-income	-0.005 (0.015)	0.007 (0.007)	-0.015* (0.008)	-0.003 (0.007)	-0.009 (0.007)	-0.019*** (0.007)	-0.018*** (0.006)
Liquid assets	0.007 (0.015)	0.028* (0.015)	-0.002 (0.015)	-0.007 (0.008)	-0.017** (0.008)	-0.018** (0.009)	-0.023*** (0.007)
GDP	0.207 (0.139)	0.126* (0.069)	0.184** (0.079)	0.158*** (0.042)	0.190** (0.071)	0.024 (0.059)	-0.062 (0.055)
Inflation	-0.432** (0.188)	0.333** (0.158)	0.071 (0.174)	0.431** (0.172)	0.474** (0.200)	-0.035 (0.189)	-0.069 (0.145)
GIIPS Country	0.432 (0.400)	0.205 (0.266)	0.136 (0.262)	0.137 (0.201)	0.188 (0.193)	-0.396** (0.198)	-0.645*** (0.215)
HHI Business	-0.855 (0.566)	-2.159 (1.285)	-1.333 (0.896)	-1.943** (0.760)	-1.414** (0.566)	-1.349*** (0.482)	-0.744* (0.435)
Constant	3.719* (1.993)	1.594 (1.389)	3.075** (1.448)	1.418 (1.176)	1.963 (1.423)	4.678*** (0.824)	4.558*** (0.680)
Observations	54	52	55	55	50	62	69
R-squared	0.194	0.335	0.344	0.607	0.657	0.678	0.722

b) HHI Geo

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	2008	2009	2010	2011	2012	2013	2014
Log assets	0.204** (0.098)	0.172*** (0.061)	0.102 (0.067)	0.116** (0.053)	0.084 (0.052)	0.120** (0.048)	0.096** (0.046)
NPL	-0.047 (0.041)	-0.100** (0.044)	-0.073** (0.031)	-0.075** (0.029)	-0.112*** (0.018)	-0.096*** (0.017)	-0.058*** (0.008)
Cost-to-income	0.002 (0.011)	0.006 (0.007)	-0.016* (0.009)	-0.003 (0.007)	-0.007 (0.007)	-0.014** (0.007)	-0.017*** (0.006)
Liquid assets	0.009 (0.012)	0.027** (0.011)	0.004 (0.014)	-0.000 (0.010)	-0.012 (0.010)	-0.018* (0.009)	-0.020*** (0.008)
GDP	0.240** (0.118)	0.162** (0.070)	0.121 (0.098)	0.138*** (0.044)	0.218*** (0.068)	0.052 (0.066)	-0.050 (0.049)
Inflation	-0.480*** (0.152)	0.272* (0.143)	-0.016 (0.195)	0.320 (0.215)	0.216 (0.207)	-0.178 (0.160)	-0.158 (0.142)
GIIPS Country	0.536 (0.380)	0.059 (0.260)	-0.022 (0.290)	-0.033 (0.241)	0.165 (0.191)	-0.611*** (0.195)	-0.766*** (0.189)
HHI Geo	-1.928*** (0.451)	-1.469*** (0.464)	-0.953 (0.599)	-1.175** (0.441)	-0.803* (0.437)	-1.216*** (0.432)	-0.790** (0.338)
Constant	0.478 (2.366)	-0.014 (1.285)	2.196 (1.514)	0.507 (1.585)	2.483* (1.413)	3.664*** (0.976)	3.960*** (0.813)
Observations	54	52	55	55	51	62	69
R-squared	0.364	0.397	0.339	0.552	0.622	0.684	0.725

c) Ratio Nonbanks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	<i>2008</i>	<i>2009</i>	<i>2010</i>	<i>2011</i>	<i>2012</i>	<i>2013</i>	<i>2014</i>
Log assets	0.007 (0.080)	0.072 (0.056)	0.009 (0.050)	0.013 (0.042)	0.021 (0.043)	0.019 (0.041)	0.051 (0.040)
NPL	-0.056 (0.059)	-0.097* (0.052)	-0.064** (0.030)	-0.064* (0.033)	-0.110*** (0.021)	-0.089*** (0.019)	-0.056*** (0.009)
Cost-to-income	-0.001 (0.015)	0.005 (0.007)	-0.018** (0.008)	-0.005 (0.007)	-0.009 (0.007)	-0.017** (0.008)	-0.021*** (0.006)
Liquid assets	0.008 (0.015)	0.032** (0.014)	0.001 (0.016)	-0.010 (0.011)	-0.022** (0.009)	-0.026*** (0.009)	-0.024*** (0.008)
GDP	0.219 (0.150)	0.089 (0.069)	0.183** (0.078)	0.181*** (0.045)	0.263*** (0.069)	0.092 (0.067)	-0.064 (0.059)
Inflation	-0.391* (0.203)	0.276* (0.160)	0.027 (0.177)	0.292 (0.231)	0.255 (0.223)	-0.185 (0.203)	-0.023 (0.152)
GIIPS Country	0.361 (0.450)	0.032 (0.280)	-0.003 (0.285)	0.028 (0.257)	0.224 (0.197)	-0.607*** (0.216)	-0.651*** (0.240)
Ratio Nonbanks	-0.832 (0.553)	-0.634 (0.551)	-0.486 (0.523)	0.143 (0.572)	-0.181 (0.484)	-0.064 (0.613)	0.832 (0.714)
Constant	4.054* (2.080)	1.465 (1.163)	3.920*** (1.385)	2.055 (1.645)	3.778** (1.682)	5.497*** (1.109)	3.987*** (0.959)
Observations	54	52	55	55	50	62	69
R-squared	0.199	0.299	0.314	0.512	0.606	0.634	0.712

d) Ratio Foreign

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	2008	2009	2010	2011	2012	2013	2014
Log assets	0.134 (0.106)	0.162*** (0.053)	0.083 (0.056)	0.092* (0.054)	0.070 (0.058)	0.124** (0.048)	0.066 (0.046)
NPL	-0.036 (0.047)	-0.090** (0.038)	-0.049 (0.030)	-0.057* (0.033)	-0.108*** (0.018)	-0.090*** (0.015)	-0.057*** (0.009)
Cost-to-income	-0.000 (0.012)	0.005 (0.007)	-0.017* (0.009)	-0.005 (0.007)	-0.007 (0.007)	-0.016** (0.007)	-0.018*** (0.006)
Liquid assets	0.006 (0.014)	0.026** (0.010)	0.007 (0.013)	-0.001 (0.011)	-0.014 (0.010)	-0.018** (0.009)	-0.024*** (0.007)
GDP	0.189 (0.129)	0.155** (0.063)	0.094 (0.100)	0.143*** (0.048)	0.212*** (0.066)	0.038 (0.066)	-0.048 (0.052)
Inflation	-0.409** (0.178)	0.267* (0.151)	-0.068 (0.209)	0.339 (0.208)	0.153 (0.212)	-0.159 (0.156)	-0.132 (0.140)
GIIPS Country	0.329 (0.385)	-0.035 (0.242)	-0.167 (0.290)	-0.115 (0.238)	0.110 (0.171)	-0.712*** (0.188)	-0.813*** (0.193)
Ratio Foreign	-1.258** (0.563)	-1.738*** (0.500)	-1.173** (0.502)	-1.064** (0.473)	-0.843 (0.556)	-1.392*** (0.470)	-0.446 (0.363)
Constant	1.546 (2.443)	0.370 (1.167)	2.744* (1.481)	0.893 (1.527)	3.017* (1.515)	3.713*** (0.959)	4.522*** (0.806)
Observations	54	52	55	55	51	62	69
R-squared	0.256	0.444	0.378	0.545	0.622	0.689	0.711

Table 7: Panel regression results – Zscore

This table reports fixed effects regressions that are based on yearly data of stock listed banks of Euro area countries for the period 2007-2014. The dependent variable is a bank's *Zscore* (in logs). Explanatory variables include bank-level controls: *Log assets* is the log of total assets, *NPL* is the ratio of non-performing loans to total loans (in %), the *cost-to-income* ratio (in %), and *liquid assets* to total assets (in %). Macro controls of the bank holding's country of location include: *GDP* growth (in %), the *inflation* rate (in %), and a dummy that equals one if the bank holding is located in a *GIIPS Country*, i.e. Portugal, Italy, Ireland, Greece or Spain. The complexity measures are standardized and include: *HHI Business* indicates diversification of banks across different business activities, *HHI Geo* indicates diversification of banks across geographical regions, the ratio of nonbank subsidiaries over the total number of subsidiaries (*Ratio Nonbanks*), and the ratio of subsidiaries that are situated in a foreign country over the total number of subsidiaries (*Ratio Foreign*). All bank-level variables are lagged by one period. The complexity measures are interacted with the dummy variable *Crisis*, which equals one in the years 2008, 2009 and 2010, and zero otherwise. The regressions take into account bank and year fixed effects. Cluster-robust standard errors are depicted in parentheses. The p-values are as follows: *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
Log assets	-0.621*** (0.149)	-0.605*** (0.140)	-0.597*** (0.123)	-0.573*** (0.125)
NPL	-0.003 (0.005)	-0.003 (0.005)	-0.003 (0.004)	-0.004 (0.004)
Cost-to-income	0.000 (0.002)	0.000 (0.002)	-0.000 (0.001)	0.000 (0.001)
Liquid assets	0.003 (0.004)	0.002 (0.004)	0.001 (0.003)	0.001 (0.004)
GDP	0.030*** (0.009)	0.029*** (0.010)	0.023** (0.009)	0.023** (0.009)
Inflation	0.021 (0.019)	0.016 (0.020)	0.009 (0.017)	0.004 (0.017)
Crisis	-0.389*** (0.089)	-0.347*** (0.088)	0.211*** (0.056)	0.228*** (0.053)
HHI Business	-0.066* (0.035)			
Crisis*HHI Business	0.007 (0.030)			
HHI Geo		-0.007 (0.051)		
Crisis*HHI Geo		-0.057** (0.024)		
Ratio Nonbanks			0.019 (0.023)	
Crisis*Ratio Nonbanks			-0.070*** (0.022)	
Ratio Foreign				0.017 (0.032)
Crisis*Ratio Foreign				-0.048** (0.022)
Constant	14.056*** (2.745)	13.764*** (2.576)	13.229*** (2.250)	12.792*** (2.270)
Bank fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Observations	397	398	443	444
R-squared	0.347	0.354	0.349	0.326
Number of banks	75	75	75	75

Table 8: Regression results – State aid

This table reports random effects probit regressions that are based on yearly data of stock listed banks of Euro area countries for the period 2007-2014. The dependent variable is a dummy for state aid, which equals one if the bank received state aid that year following the State Aid Register of the European Commission, and zero otherwise. Explanatory variables include bank-level controls: *Log assets* is the log of total assets, *equity* is the ratio of equity to total assets (in %), *NPL* is the ratio of non-performing loans to total loans (in %), the *cost-to-income* ratio (in %), return on assets (*RoA*, in %), and *liquid assets* to total assets (in %). Macro controls of the bank holding's country of location include: *GDP* growth (in %), the *inflation* rate (in %), and a dummy that equals one if the bank holding is located in a *GIIPS Country*, i.e. Portugal, Italy, Ireland, Greece or Spain. The complexity measures comprise: *HHI Business* indicates diversification of banks across different business activities, *HHI Geo* indicates diversification of banks across geographical regions, the ratio of nonbank subsidiaries over the total number of subsidiaries (*Ratio Nonbanks*), and the ratio of subsidiaries that are situated in a foreign country over the total number of subsidiaries (*Ratio Foreign*). All bank-level variables are lagged by one period. Regressions include time fixed effects. Standard errors clustered at the bank level are depicted in parentheses. The p-values are as follows: *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
Log assets	0.513** (0.257)	0.316 (0.238)	0.632** (0.311)	0.427* (0.245)
Equity	-0.297*** (0.112)	-0.297*** (0.109)	-0.350*** (0.105)	-0.291*** (0.101)
NPL	0.135*** (0.046)	0.143*** (0.036)	0.149*** (0.051)	0.128*** (0.033)
Cost-to-income	-0.009 (0.020)	-0.015 (0.019)	-0.011 (0.022)	-0.009 (0.020)
RoA	-0.210 (0.211)	-0.342 (0.218)	-0.311 (0.238)	-0.207 (0.214)
Liquid assets	-0.103** (0.049)	-0.112** (0.050)	-0.119** (0.053)	-0.116** (0.052)
GDP	0.138 (0.105)	0.145 (0.104)	0.166 (0.115)	0.166 (0.108)
Inflation	-1.021** (0.402)	-0.794** (0.348)	-1.161*** (0.395)	-0.927** (0.376)
GIIPS Country	-1.083 (0.693)	-0.943 (0.605)	-1.386** (0.707)	-0.860 (0.602)
HHI Business	0.788 (1.614)			
HHI Geo		3.452*** (1.140)		
Ratio Nonbanks			-3.738*** (1.189)	
Ratio Foreign				2.505** (1.010)
Constant	-5.543 (5.777)	-2.791 (5.027)	-9.044 (6.127)	-9.528* (5.175)
Time fixed effects	Yes	Yes	Yes	Yes
Observations	399	400	399	400
Number of banks	75	75	75	75

Table 9: Regressions results – ΔCoVaR

This table reports cross section regressions that are based on yearly data of stock listed banks of Euro area countries. The dependent variable is a bank's average ΔCoVaR over the years 2008-2010. Explanatory variables are from the year 2007 and include bank-level controls: *Log assets* is the log of total assets, *equity* is the ratio of equity to total assets (in %), *NPL* is the ratio of non-performing loans to total loans (in %), the *cost-to-income* ratio (in %), return on assets (*RoA*, in %), and *liquid assets* to total assets (in %). Macro controls of the bank holding's country of location include: *GDP* growth (in %), the *inflation* rate (in %), and a dummy that equals one if the bank holding is located in a *GIIPS Country*, i.e. Portugal, Italy, Ireland, Greece or Spain. The complexity measures are also from year the 2007 and include: *HHI Business* indicates diversification of banks across different business activities, *HHI Geo* indicates diversification of banks across geographical regions, the ratio of nonbank subsidiaries over the total number of subsidiaries (*Ratio Nonbanks*), and the ratio of subsidiaries that are situated in a foreign country over the total number of subsidiaries (*Ratio Foreign*). Robust standard errors are depicted in parentheses. The p-values are as follows: *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
Log assets	0.002*** (0.000)	0.002*** (0.001)	0.003*** (0.000)	0.002*** (0.001)
Equity	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
NPL	0.001 (0.001)	0.001* (0.000)	0.001 (0.001)	0.001* (0.000)
Cost-to-income	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
RoA	0.003 (0.003)	0.006** (0.003)	0.006* (0.003)	0.005* (0.003)
Liquid assets	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
GDP	-0.000 (0.001)	-0.000 (0.001)	-0.001 (0.001)	0.000 (0.001)
Inflation	0.004 (0.003)	0.003 (0.002)	0.004 (0.002)	0.003 (0.002)
GIIPS Country	0.003 (0.003)	0.004 (0.003)	0.004 (0.003)	0.005*** (0.003)
HHI Business	0.008 (0.006)			
HHI Geo		0.012*** (0.004)		
Ratio Nonbanks			0.007 (0.004)	
Ratio Foreign				0.013*** (0.004)
Constant	-0.046*** (0.016)	-0.030 (0.019)	-0.059*** (0.017)	-0.029 (0.018)
Observations	54	54	54	54
R-squared	0.582	0.641	0.580	0.682

Figure 1: Number of banks' subsidiaries

This graph shows the evolution of the total number of majority-owned subsidiaries by parent banks included in our sample over the period 2007-2014.

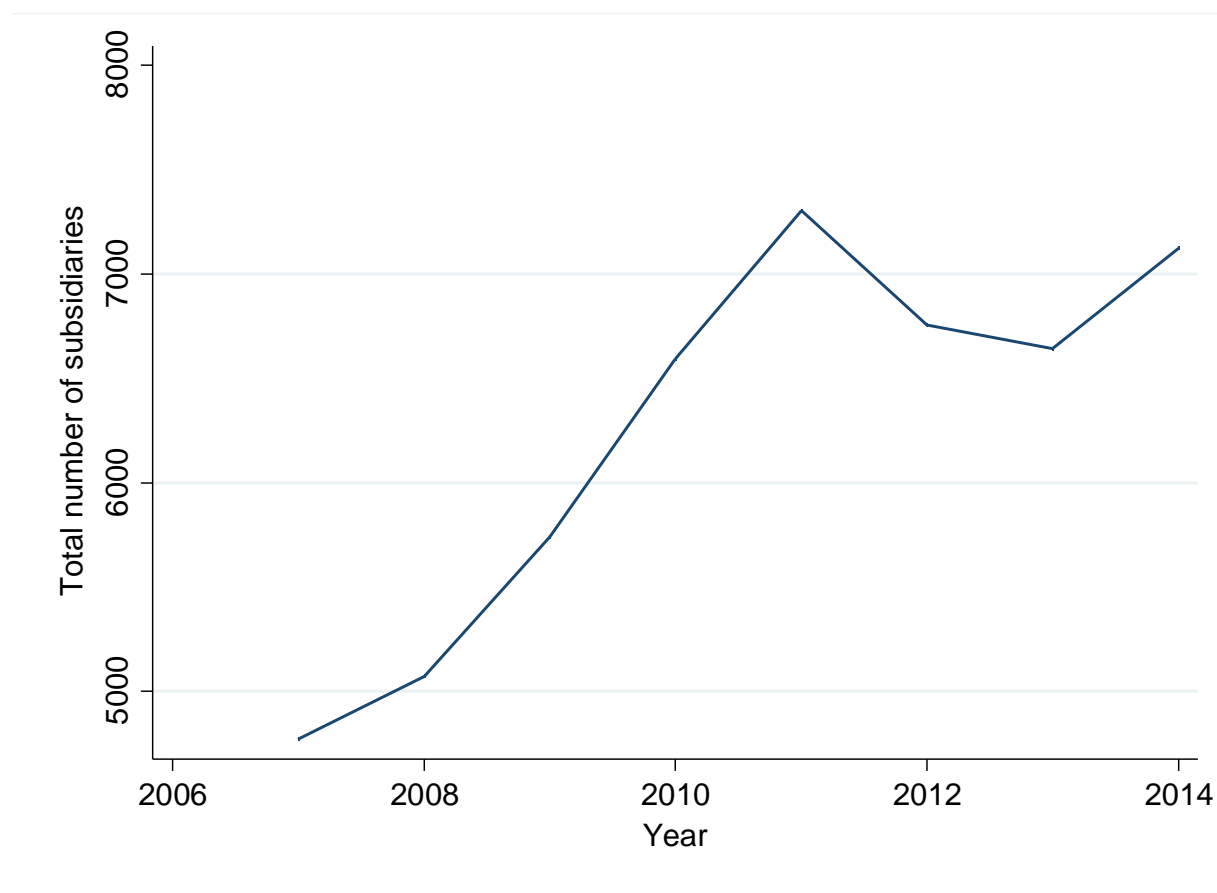


Figure 2: Complexity measures and Zscore

This graph shows the pattern of a complexity measure (left axis; blue solid line) and the *Zscore* (right axis; red dotted line) over the period 2007-2014. The complexity measures include the HHI Business, HHI Geo, Ratio foreign, and Ratio Nonbanks as described in Section 2.1.

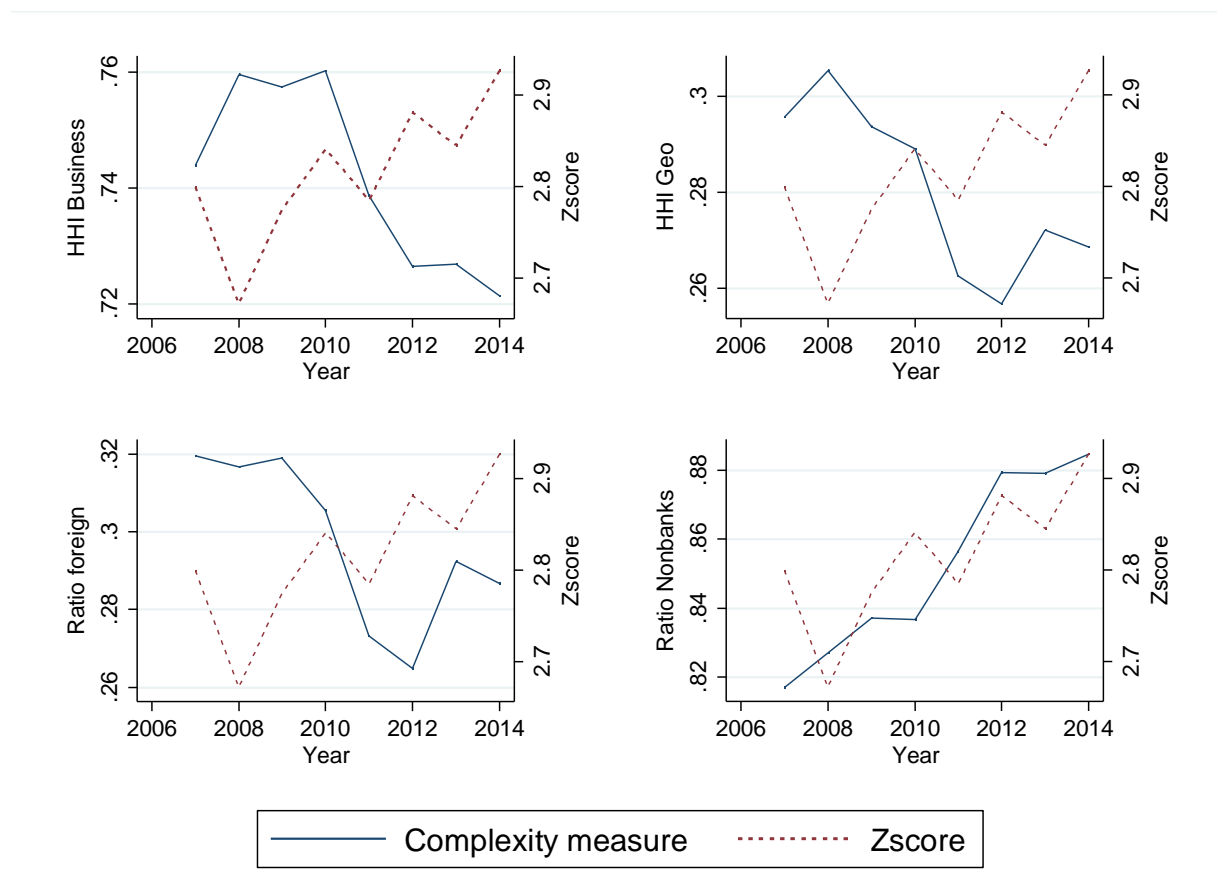
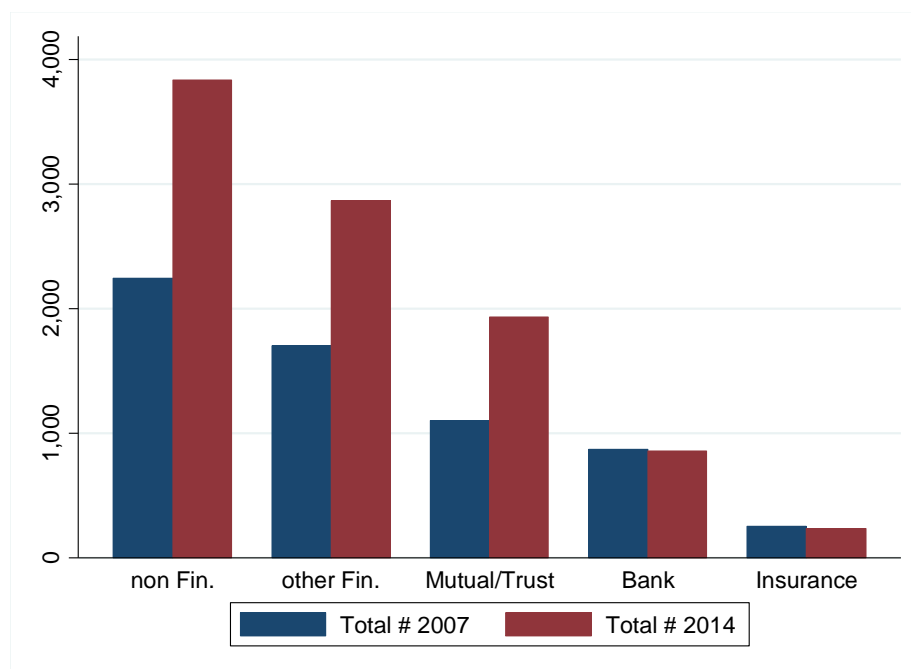


Figure 3: Complexity measures decomposed 2007 versus 2014

This graph shows the number of subsidiaries by a) type and b) region for the years 2007 and 2014.

a) Number of subsidiaries by type



b) Number of subsidiaries by region

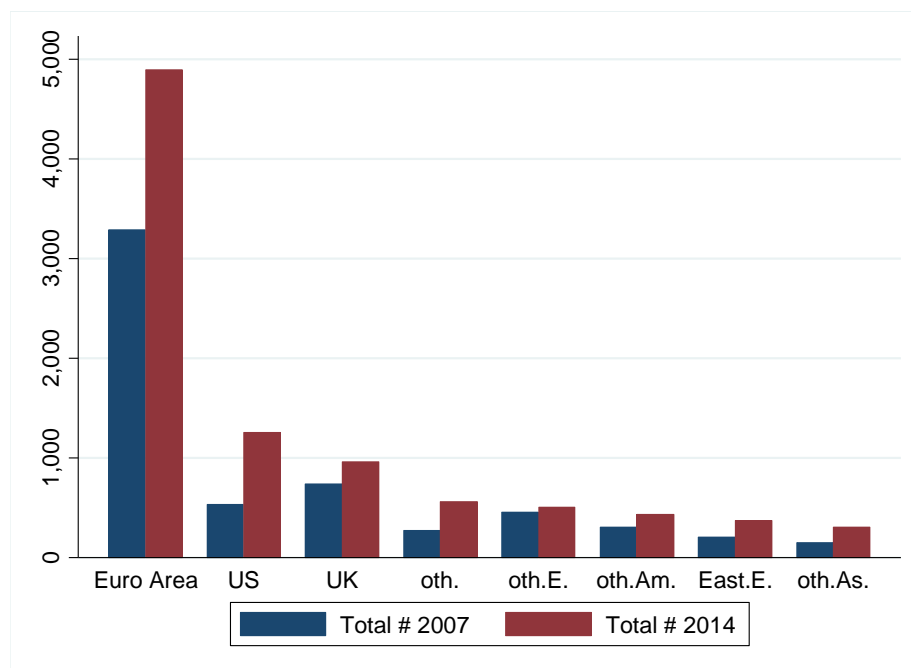
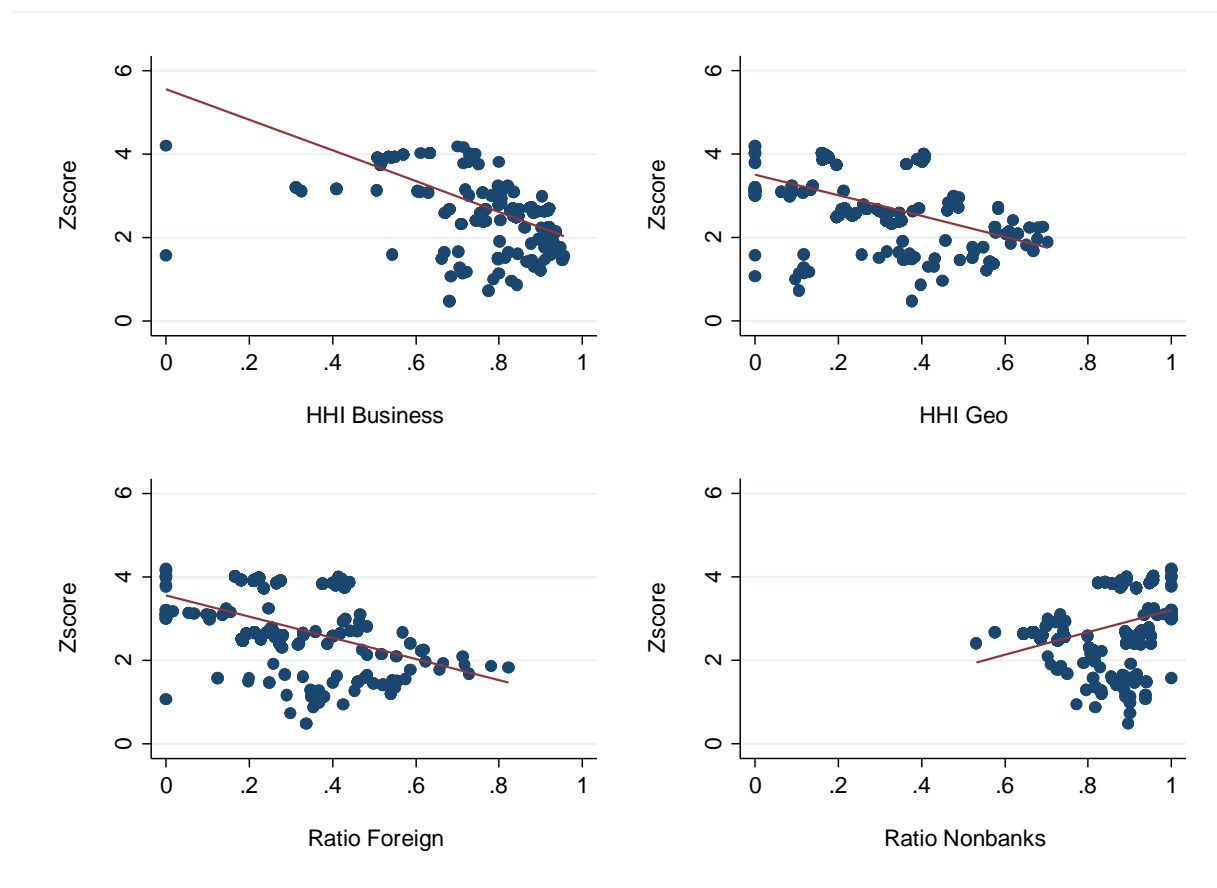


Figure 4: Scatterplot complexity measures and Zscore

This figure scatters the *Zscore* (y-axis) against one of the complexity measures (x-axis). The sample covers stock listed banks in the Euro area over the period 2007-2014. The complexity measures include the HHI Business, HHI Geo, Ratio Foreign, and Ratio Nonbanks as defined in Section 2.1.



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