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Abstract

We assess the ability of bank resolution frameworks to deal with systemic banking fragility. Using a novel and detailed database on bank resolution regimes in 22 member countries of the Financial Stability Board, we show that systemic risk, as measured by △CoVaR, increases more for banks in countries with more comprehensive bank resolution frameworks after negative system-wide shocks, such as Lehman Brothers' default, while it decreases more after positive system-wide shocks, such as Mario Draghi's "whatever it takes" speech. These results suggest that more comprehensive bank resolution may exacerbate the effect of system-wide shocks and should not be solely relied on in cases of systemic distress.

JEL Classification: G01, G21, G28

Keywords: Bank resolution regimes, bail-in, systemic risk

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Bank Resolution Regimes and Systemic Risk*

Thorsten Beck† Deyan Radev‡ Isabel Schnabel§

May 5, 2020

Abstract

We assess the ability of bank resolution frameworks to deal with systemic banking fragility. Using a novel and detailed database on bank resolution regimes in 22 member countries of the Financial Stability Board, we show that systemic risk, as measured by ΔCoVaR, increases more for banks in countries with more comprehensive bank resolution frameworks after negative system-wide shocks, such as Lehman Brothers' default, while it decreases more after positive system-wide shocks, such as Mario Draghi's "whatever it takes" speech. These results suggest that more comprehensive bank resolution may exacerbate the effect of system-wide shocks and should not be solely relied on in cases of systemic distress.

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1 Introduction

Lehman Brothers' collapse and the subsequent widespread bailout of financial institutions on both sides of the Atlantic laid bare the inadequacy of bank resolution regimes worldwide. In the absence of effective tools to manage bank failures, governments preferred to bail out failing banks to avoid the contagion effects of a disorderly bank default on the financial system rather than risking "another Lehman". These bailouts put a strain on public finances, contributing to the sovereign debt crisis in the euro area and resulting in a political backlash against bailouts.

General corporate insolvency regimes are too slow to resolve failing banks and fail to take into account systemic repercussions that propagate fragility shocks through the overall financial system. The experience of the Global Financial Crisis has therefore led to a major overhaul of bank resolution frameworks across the globe, and especially in the member countries of the Financial Stability Board (FSB), based on a number of global best practices aimed at providing authorities with sufficient powers and control over the resolution of banks (FSB, 2011). While such frameworks have been used successfully for idiosyncratic bank failures (Beck et al., forthcoming; World Bank, 2016), it is unclear whether more comprehensive resolution regimes are able to reduce risk in a systemic crisis. We therefore exploit variation in resolution regimes across 22 advanced and emerging countries over the period 2000 to 2015 to analyze how bank resolution regimes affect systemic risk after system-wide fragility shocks. Our results suggest that more comprehensive bank resolution frameworks might exacerbate system-wide fragility shocks rather than reduce them, shedding doubt on their effectiveness during systemic crises.

Theory is ambiguous on the effect of a more comprehensive bank resolution framework on stability during instances of systemic distress. On the one hand, reducing the likelihood of bailouts and thus taxpayer support, allowing early intervention, and providing ample tools for resolution of failing banks reduces moral hazard risk (Repullo, 2005; Farhi and Tirole, 2012). Specifically, bail-in and clarity on how losses will be distributed in case of bank failure can increase market discipline by equity and debtholders of banks. They can also reduce incentives for too high leverage on banks' balance sheets (Geanakoplos, 2010; Adrian and Shin, 2014). On the other hand, a rule-based system that ties regulators' hands can result in bank runs and contagion if regulators have private information about bank performance (Walther and White, forthcoming). Rule-based bail-ins might make banks more vulnerable to adverse events and thus destabilize the financial system in the middle of a crisis, through direct interlinkages of banks holding each others' claims, as well as information effects and a sudden reassessment of bank risk (Acharya and Yorulmazer, 2008; Eisert and Eufinger, 2018). According to this view, bailouts of failing banks (which were supposed to end with the recent reforms of bank resolution frameworks) can protect other banks from contagion and thus provide incentives to reduce risk-taking (Cordella and Yeyati, 2003; Dell'Ariccia and Ratnovski, 2019). There might also be economic costs of too rigid an application of rules (Keister, 2015; Leonello, 2018). Pandolfi (2018) shows that bailouts can lead to overinvestment in bad projects, while bail-ins may cause an underinvestment in good projects, which suggests that full bail-ins cannot solve the "to-big-to-fail" problem and should be used in conjunction with bailouts to reduce the undesirable side effects of both tools. Similarly, Lambrecht and Tse (2019) show that while bank bail-ins reduce managerial risk-taking and improve loan quality and banks' capital ratios relative to bail-outs, they also lead to lower levels of credit provision and value created net of recapitalization costs. The different and ambiguous theoretical predictions call for an empirical analysis of the role of bank resolution frameworks during systemic banking distress.

This paper compiles a novel database on bank resolution regimes across 22 advanced and emerging markets, including the tools and powers of resolution authorities, for the period 2000 till 2015 and assesses their relationship with systemic bank risk. An analysis of the relationship between the occurrence of systemic crises and resolution regimes may, however, suffer from endogeneity bias because bank resolution legislation might have a higher chance of being adopted in countries that are more likely to suffer from financial distress. We therefore gauge the change in systemic risk contributions of 760 banks, as measured by the change in the conditional value at risk (ΔCoVaR, Adrian and Brunnermeier, 2016), after seven different shocks to the financial system, considered to be exogenous for individual banks and unexpected, depending on the comprehensiveness of bank resolution frameworks. The analyzed events include negative system-wide shocks (such as Lehman Brothers' collapse in 2008) and positive system-wide shocks (such as Mario Draghi's "whatever it takes" speech in 2012). We employ a difference-in-difference estimation framework in the spirit of an event study, thus focusing on the differential effect of largely exogenous shocks on banks' contributions to systemic risk across countries with different resolution frameworks, while controlling for other differences across banks and countries. In our analysis, we use both a resolution index – the sum of 22 individual features of resolution frameworks – and the first five principal components of the 22 variables. The latter allows us to control for correlation and collinearity among the 22 features and better capture their interdependence.

Our results suggest that in countries with more comprehensive bank resolution frameworks systemic risk increases more after negative system-wide shocks and decreases more after positive system-wide shocks. The results are robust to different variable specifications, weighing by the number of banks in a country, dropping global systemically important banks, and controlling for the initial level of systemic risk contribution of banks. We also find no evidence that the relationship reverses at very high levels of the bank resolution index. While shocks are exogenous to bank resolutions reforms, endogeneity concerns still exist in that countries that expect their banks to contribute more to systemic risk during system-wide shocks also adopt more comprehensive bank resolution frameworks. We therefore instrument bank resolution with fiscal costs related to bailouts and the number of past crises in a country and again confirm our results.

We also gauge the effectiveness of different components of bank resolution frameworks. Principal component analysis identifies five different dimensions of resolution frameworks, including the bail-in framework, the ability to replace bank management, focus on the administrative process (rather than court-based), a designated resolution authority and the ability to manage losses with out-of-court liquidation or an asset management company. We find that the amplification effects are mainly driven by the overall bail-in framework and the tools and powers the resolution authority has at its disposal, while the existence of a designated resolution authority is related to system-wide shocks and banks' systemic risk contribution either insignificantly or in a dampening way. Given that bail-in frameworks were not in place during most of our system-wide shocks, we interpret these findings as indicating that the absence of bail-in frameworks (and thus having bailouts as default) in system-wide distress situations does not contribute to systemic risk. Finally, we do not find such an exacerbating effect of bank resolution frameworks on systemic bank risk for instances of bank-specific rather then system-wide fragility shocks, such as the Deutsche Bank announcement of losses in January 2016 or the resolution of Portugal's Banco Espírito Santo in August 2014.

Together, these results lend support to theories that focus on the destabilising effect of stringent resolution rules, including bail-in tools, during systemic stress periods. While our findings confirm previous findings that resolution frameworks can be useful in resolving idiosyncratic bank failures, these results point to the limitations of bank resolution frameworks in dealing with system-wide shocks.

Our paper relates to several strands of literature. First, there is a small but growing literature on bank resolution, which has gained momentum after the Global Financial Crisis. One important strand of this literature contains regulatory reform proposals that attempt to address the externalities caused by implicit government bailout guarantees (e. g., Čihák and Nier, 2009; BIS, 2011; Acharya, 2009; FSB, 2011, 2013; Beck, 2011). In their core, these reform proposals have similar features: reducing the complexity of systemically important banks, developing a framework for efficient burden sharing in case of bank default, and making the resolution regimes across different countries compatible, such that they provide common rules for the resolution of cross-border banks (Avgouleas et al., 2013). Most of the early literature assumes that bail-in is the optimal resolution mechanism and that it is strictly dominating bailouts (e. g., Landier and Ueda, 2009; Rutledge et al., 2012; Huertas, 2013; Klimek et al., 2015; Chari and Kehoe, 2016). More recent papers have rather pointed to the important trade-off of bail-in versus bailout, especially in times of systemic distress (Dewatripont, 2014; Dell'Ariccia et al., 2018). There is also a strand of the recent literature that contains simulations of bail-in events with different magnitudes of severity (e. g., Hüser et al., 2018), empirical studies based on specific bail-in events (e. g., Schäfer et al., 2017; Beck et al., forthcoming), and bank resolution case studies (e. g., World Bank, 2016). Our paper is the first study to gather cross-country data on the changes in bank resolution legislation and to relate these to systemic risk in the banking sector, based on a large sample of banks. While many of the studies mentioned so far focus on idiosyncratic bank failures, ours is one of the first studies to focus explicitly on the role of bank resolution regimes in times of systemic distress.

Second, our paper relates to the literature on systemic risk and its drivers. After the failure of Lehman Brothers in 2008, which most observers see as the trigger for the Global Financial Crisis, it became clear that there was no single definition of systemic risk, and neither a single way to measure it. A number of systemic risk measures have gained traction and are now widely used by researchers, such as the Conditional Value at Risk (ΔCoVaR, Adrian and Brunnermeier, 2016), the Marginal and Systemic Expected Shortfalls (MES and SES, Acharya et al., 2012), and the Capital Shortfall (SRISK, Brownlees and Engle, 2012). While many papers have used systemic risk indicators as explanatory variables to proxy for systemic risk (see, e. g., Barth and Schnabel, 2013, and Beck and De Jonghe, 2013), there is also a growing literature on the determinants of systemic risk. Brownlees and Engle (2012) find that, in addition to market-to-book ratio, SRISK depends on maturity mismatch and return to equity. Huang et al. (2012) find strong evidence that the MES of 19 big US banks depends on the bank's probability of default as well as its correlation with the other banks in the sample. Brunnermeier et al. (2012) find that systemic risk (proxied by CoVaR and SES) depends on the bank's market-to-book ratio, leverage, total size and the size of non-core business. Brunnermeier et al. (2019) analyze the relationship between asset price bubbles and systemic risk at bank level (CoVaR and SES), stressing the role of bank balance sheet characteristics in the build-up of systemic risk. Our contribution to this literature is to use the resolution legislation and its interaction with system-wide events as identification devices to systematically analyze the relationship between bank resolution regimes and systemic bank risk.

Before proceeding, we would like to point to some limitations of our analysis. This paper assesses the effectiveness of bank resolution frameworks in containing or propagating fragility shocks across banks in systemic distress periods. It does not study the ex-ante incentive effects of resolution regimes on banks' risk-taking and their impact on the probability of financial crises. Hence, it cannot provide a full evaluation of bank resolution regimes. Rather, our paper *warns against too high expectations* of the power of resolution regimes of containing system-wide crises. If spillovers to the financial system in crisis times cannot be avoided, this may, however, also put in question the positive ex-ante effects because bail-in might no longer be a credible strategy during systemic distress episodes. A second important contribution of our paper is that it presents a *broad database* on the characteristics of bank resolution regimes in FSB member countries over an extended time period, compiled on the basis of national legal texts and accompanying documents, and complemented by a broad-based survey among central banks and supervisory authorities. This database is interesting in itself because it provides a comprehensive view of the evolution of bank resolution regimes across countries since 2000. As in comparable data collections (e.g., Doing Business), our database captures the rules on the book rather than actual practice or market expectations about actual practice.

The remainder of the paper is organized as follows. Section 2 discusses the institutional details regarding bank resolution and defines our bank resolution index. Section 3 outlines the empirical strategy and briefly describes the data, while Section 4 presents our results. Section 5 concludes.

2 Bank Resolution Regimes

This section discusses the need for special bank resolution frameworks outside the general corporate insolvency regime and presents the bank resolution index, our empirical gauge of the comprehensiveness of resolution frameworks.

2.1 Corporate Insolvency versus Bank Resolution

Bank resolution can be defined as the orderly wind-up or restructuring of a bank in contrast to a (potentially disorderly) liquidation or a bailout using taxpayer resources for recapitalization. Overall, there are two types of regimes to deal with bank failure: regimes based on corporate insolvency law where proceedings are court-based, and regimes based on a special bank resolution regime where proceedings are handled by a resolution authority. Čihák and Nier (2009) argue that special bank resolution frameworks lead to gains in efficiency in terms of the trade-off between fiscal costs and financial stability impact.

General corporate insolvency (GCI) focuses exclusively on the failed institution and aims at satisfying creditors, thus not taking into account the impact of a bank failure on the stability of the financial system (e. g., through negative externalities for other financial institutions). It ignores the fact that the banking system is based on confidence and that its loss can trigger bank runs and contagion via the interbank market and cross-exposures. Neither does GCI take into account a bank's importance in its functions of providing funds to firms and consumers, deposit-taking, settlement of payments, or transmission of monetary policy. And most critically, GCI generally applies too late, namely when the bank is already no longer viable. Timelier action may, however, be legally problematic as it interferes with creditor and shareholder rights. The procedures under GCI are lengthy also because the authorities lack specific tools to wind up banks.

In contrast, a special bank resolution regime takes spill-over and macroprudential concerns into account by taking a systemic perspective. It may override shareholder and creditor rights based on an ex-ante legal foundation (bail-in), and it allows reacting in a timely manner. Moreover, it provides special resolution tools to deal with complex banking institutions. Thereby it can minimize fiscal costs (through bail-in) and help preserve critical functions of financial institutions.

Before the global financial crisis, bank resolution legislation across the globe varied in terms of intensity and scope, depending on national experiences with banking crises. Figure 1 depicts the resolution index by country group and shows that the United States had an already comprehensive bank resolution framework in the early 2000s, mostly due to the reforms implemented after the savings and loan crisis of the late 1980s and early 1990s.[1] At the onset of the Global Financial Crisis, the Federal Deposit Insurance Corporation (FDIC) had at its disposal a receivership regime for failed commercial banks where it could sell their good assets and wind down their bad assets. Following the crisis, the framework has been extended further, with distinct resolution regimes for systemically important financial companies (Title II of Dodd-Frank Act, DFA) and for

[1] A higher index number refers to a more advanced resolution regime, as explained in more detail below.

insured depository institutions (FDI Act, FDIA). European countries, on the other hand, were lagging behind, as can be seen in Figure 1. For instance, the main legislative documents that established a separate bank resolution framework in the United Kingdom (the Banking Act) and Germany (the Bank Restructuring Act) were only implemented in July 2009 and December 2010, respectively, and were amended several times thereafter.

Until that point, bank resolution legislation had been implemented exclusively at national level. The Financial Stability Board (FSB) attempted to harmonize global efforts and, in 2009, was commissioned by the Basel Committee and the G20 to prepare guidelines for good resolution regimes. In 2011, the Financial Stability Board issued a set of 12 Key Attributes (KAs), regarding, for example, the scope of resolution, the powers of the resolution authorities, and recovery and resolution planning (FSB, 2011). Since then, the FSB follows the implementation of the KAs in its 24 member jurisdictions and regularly issues peer reviews that record the progress of each country. Appendix Table A1 lists the FSB's key attributes and their definitions. The Bank Resolution Index, the core of our analysis and described in detail in the next subsection, builds on these key attributes.

The 12 KAs served as a blueprint for the Bank Recovery and Resolution Directive (BRRD) of the European Union (EU). The BRRD harmonises the tools used in the recovery and resolution of credit institutions in the EU. Should a bank fail, its shareholders and creditors, following the credit hierarchy, should normally be first in line to absorb any risks and losses. For the Eurozone, the overall resolution framework includes the Single Resolution Mechanism (Regulation (EU) No 806/2014) based on the tools from the BRRD, as well as a Single Resolution Fund (SRF) to be built up over 8 years from 2016 onwards. Bank resolution responsibilities are divided between the Single Resolution Board (SRB) and the respective national resolution authority.

2.2 Bank Resolution Index

Data on resolution regimes. The main variable in our analysis is the Bank Resolution Index, which summarizes the comprehensiveness of bank resolution regimes and is based on detailed data on the implementation of reforms to bank resolution regimes in a broad set of countries. Our data collection starts from FSB (2013), which gives information on whether the laws in the 24 FSB member countries include certain resolution powers, tools or provisions at the time of the FSB report. Subsequently, we use the FSB's country Peer Reviews as well as IMF country reports to identify the dates when the respective powers or tools have been introduced into national law. We complement the IMF's series "Safety Net, Bank Resolution, and Crisis Management Framework – Technical Notes" with other IMF country reports or documents in the scope of the Financial Sector Assessment Program (IMF, 2018; FSAP). We further analyze annual reports by central banks, supervisors or resolution authorities as well as secondary literature and industry reports. Often, we consider the original legal texts, identifying the relevant paragraphs and attempting to find out when a particular feature comes into force. Finally and in order to verify the list of reforms that we collected, we undertook a broad-based survey among the official national authorities responsible for the resolution of banks in our sample of countries between September 2015 and June 2016.[2] The representatives at the resolution authorities were asked to verify the information from our independent data-gathering work (i. e., whether the particular features are present in the country and since when) and complement it when we could not find the data.[3] Our country sample is similar to that in the FSB report. However, due to a lack of data for Argentina and Saudi Arabia, we drop these two countries, yielding a sample of 22 countries.[4]

Resolution index. We categorize information on banks resolution frameworks into four groups with a total of 22 dummy variables, which capture the different dimensions of an effective bank resolution framework according to the FSB, as follows:

1. **General framework for bank resolution:** This group includes seven questions, with variables taking on value one if (i) there is a specific bank resolution framework, (ii) there is a specifically designated resolution authority, (iii) there is another authority that has the powers to restructure or resolve banks, (iv) the resolution authority can liquidate

[2]The list of responsible institutions is available in FSB (2013).

[3]After two reminders, we managed to achieve a 60% response rate, which helped us to improve data quality.

[4]The included countries are Australia, Brazil, Canada, China, France, Hong Kong, Germany, India, Indonesia, Italy, Japan, Mexico, Netherlands, Republic of Korea, the Russian Federation, Singapore, South Africa, Spain, Switzerland, Turkey, the United Kingdom, and the United States of America.

the bank without court decision, (v) no court decision is needed to apply resolution powers/tools to resolve a bank, (vi) there is a resolution fund (publicly or privately funded) and (vii) Basel III has been implemented. A larger number of positive responses thus suggests a more complete general framework.

2. **Powers available to the resolution authority:** This group contains seven questions, with variables taking on value one if the resolution authority has the power to (i) remove and replace bank management, (ii) appoint an administrator, (iii) operate and resolve the bank, (iv) ensure continuity of essential services and functions of the bank, (v) override shareholder rights when applying resolution powers, (vi) temporarily stay the exercise of early termination rights, and (vii) impose a moratorium on payments to unsecured creditors and customers. More positive responses thus indicate more wide-ranging powers of the resolution authorities.

3. **Tools available to the resolution authority:** This group includes four questions, with variables taking on value one if the following resolution techniques and tools are available: (i) a transfer or sale of assets and liabilities, legal rights and obligations, (ii) the establishment of a bridge institution, (iii) the establishment of an asset management vehicle, and (iv) if there is a mandatory development of resolution and recovery plans. More positive responses indicate a wider variety of options to resolve a failing bank.

4. **Framework to conduct a bail-in:** This group consists of four questions, with variables taking on value one if the following provisions are available in the bank resolution legislation: (i) a bail-in tool, (ii) a minimum requirement of eligible liabilities that can be bailed in, (iii) respect for the hierarchy of claims while providing flexibility to depart from the general principle of equal (pari passu) treatment of creditors of the same class, and (iv) public resources may only be used if private ones are not available and a bail-in was conducted. More positive responses suggest a more complete bail-in framework in the country.

We construct the first main variable in our analysis, the Bank Resolution Index, by counting all available resolution features across the four categories for each country and year, yielding an index ranging from 0 to 22:

$$Resolution\ Index_{c,t} = \sum_{m=0}^{22} I_{m,c,t}, \tag{1}$$

where $I_{m,c,t}$ takes the value of one if a particular resolution measure m exists in country c at time t, and zero otherwise. Table 1 lists the full set of resolution features considered in our analysis.

Bank Resolution Reforms Across the World. Figure 1 presents the dynamics of resolution frameworks for the U.S. and averaged across three groups of countries: Europe, Asia and the remaining countries. As discussed above, the data show a much more comprehensive bank resolution framework in the US at the beginning of our period period of examination. Also, while the main improvements after the financial crisis in the US are accomplished with major and comprehensive legislative measures, like the Dodd-Frank Act mentioned above, changes in most other countries are implemented in much smaller increments, never reaching the US level within our sample period. This trend is particularly evident in Panels 2 and 4 of Figure 1 that compares the seven European countries in our sample (Panel 2) with the US (Panel 4).

The incremental changes are also evident in the average bank resolution index, depicted in Figure 2. On average, the index rises steadily from below 7 in the beginning of the period to above 15 at the end of 2015. The increase in specific bank resolution features in national regulation and legislation is accelerated by two major events: the global financial crisis in 2008/2009 and the aftermath of the euro area sovereign debt crisis in 2012 and beyond. Overall, this picture suggests substantial cross-country variation in the implementation of resolution features across countries, often driven by the specifics of the legal and political system of the countries involved.

2.3 Disentangling the Different Dimensions of Bank Resolution

So far we have treated each of the 22 variables as independent and equally important for the overall effectiveness of bank resolution frameworks. However, some powers or tools of authorities might be more important than others, some institutional or regulatory arrangements more influential than others. Some of the provisions might also have to be adopted together in order to be effective. In statistical terms, the 22 variables are thus not independent from each other but show a high correlation: while the average empirical correlation among the variables is only 0.24, the Kaiser-Meyer-Olkin measure of sampling adequacy of 0.68 suggests a high proportion of variance caused by common factors (Cerny and Kaiser, 1977). This also implies that the simple addition of the 22 variables imposes a linear and cardinal structure not reflecting the interaction and interdependence of these variables. We therefore use Principal Component Analysis (PCA) to transform the set of 22 variables into a set of uncorrelated variables. Specifically, we use the first five principal components that explain the largest variation in the original 22 variables, so that every additional component explains the highest variance, conditional on being orthogonal to the preceding components. Identifying these five components also allows us to gauge the relative importance of different features of bank resolution frameworks, independent of being categorised in one of the groups above. The five components are (in order of importance in explaining variation):

1. **Bail-in framework**: the three most important variables in the first component are: (i) the existence of a bail-in tool, (ii) a minimum requirement of eligible liabilities that can be bailed in, and (iii) the provision that public resources may only be used after a bail-in was conducted.

2. **Management replacement**: the two most important variables in the second component are if the resolution authority has the authority to (i) remove and replace bank management, and (ii) appoint an administrator.

3. **Administrative process**: the three most important variables in the third component are if there is no court process needed for resolution and whether the resolution authority has the power to (i) operate and resolve the firm and (ii) ensure the continuity of essential services and functions.

4. **Resolution authority**: the most important variables in the fourth component are whether there is either a designated bank resolution authority or another authority has the power to intervene and resolve banks.

5. **Managing losses**: the most important variables in the fifth component are whether a bank can be liquidated without a court procedure, whether there is a res-

olution fund and whether the resolution authority can establish an asset management company.

In addition to the overall bank resolution index, we thus use the factor loadings to derive the fit of these five principal components in our empirical analysis. Figure 3 shows the development of the five components over time within our sample of 22 countries. We see an increasing trend in all five components, though the **Bail-in framwork** and **Managing losses** only increase substantially across our sample of countries after the Global Financial Crisis. Specifically, the three main variables of the **Bail-in framework** were zero before 2010 across all 22 countries, which will be important in the interpretation of our results. The main elements in **Management replacement**, on the other hand, are in place in half of the countries since 2000, and in almost all countries by 2016. The variables in **Administrative process** and in **Managing losses** similarly show variation in their implementation over time and across the different variables (with few countries having a resolution fund during our sample period). Finally, about half of the countries had a designated **Resolution authority** in 2000, while almost all had one in 2016.

3 Empirical Strategy and Data

Assessing the relationship between reforms of the bank resolution framework and systemic risk may be subject to an endogeneity bias. Countries that are more likely to experience a financial crisis might be more likely to adopt such reforms. There might also be confounding factors that drive both the reform of bank resolution frameworks and systemic risks, such as macroeconomic developments as well as other regulatory policies and reforms. We therefore focus on shocks that can be considered largely exogenous from a bank's (and country's) perspective and analyze the changes in the contribution of individual financial institutions to systemic risk in response to such shocks, depending on a country's bank resolution framework.

Specifically, we employ a panel difference-in-differences methodology and estimate a model where the bank-level systemic risk measure is regressed on an event dummy (the "treatment"), interacted with either the bank resolution index or the first five principal components, as well as bank-level and macroeconomic control variables. This approach allows for a heterogenous treatment effect across banks and countries, depending on the comprehensiveness of countries' bank resolution framework as well as other bank and country characteristics. This differs from conventional difference-in-differences analyses of reforms, which consider the reforms themselves as the treatment. In contrast, we are looking at banks' differential reaction to different shocks that are not directly related to a particular country's resolution regime and the timing of reform implementation, controlling for bank and country characteristics. The treatment effect depends on whether a particular aspect of the bank resolution legislation is applicable in a particular country in a given time period or not. This section will present the methodology, introduce the systemic risk measure and discuss the considered events.

3.1 Empirical Model

Our estimation model can be described as a panel difference-in-differences model at a daily frequency. Similar to event studies, we focus on a period of 80 days before the event (normal times) and 7 days after the event. We drop *(t-1)* to remove anticipatory effects. The event dummy takes the value of one for the period between t and t+6, and zero for the period t-81 to t-2. Then, we regress $\Delta CoVaR$ on the event dummy and its interactions with the resolution index as well as bank and macroeconomic variables. The empirical model is as follows:

$$\begin{aligned} \Delta CoVaR_{i,c,t} = \gamma_i + \beta_1 \cdot Event_t \\ + \beta_2 \cdot Resolution\ Index_{c,pre-estimation\ period} * Event_t \\ + \beta_3 \cdot Bank\ Controls_{i,c,year-1} * Event_t \\ + \beta_4 \cdot Macro\ Controls_{i,c,year-1} * Event_t + \epsilon_{i,c,t}, \end{aligned} \tag{2}$$

where $\Delta CoVaR_{i,c,t}$ is the contribution to systemic risk of bank i in country c on day t. As we include bank fixed effects γ_i and fix the resolution index and the control variables at their values in the previous year or the pre-estimation period, we can only estimate the interaction terms of the *Event* dummy with the country and bank-level variables; the level effects are captured by the fixed effects. The vector of bank controls includes total assets as a measure of size (the natural logarithm of total dollar-denominated bank assets) and leverage (the ratio of total bank assets and total bank common equity) for the year before the event. The macroeconomic variables comprise GDP growth, domestic credit to GDP and inflation for the year before the event to control for country heterogeneity. We apply two-way clustering of standard errors at the bank and day levels. This captures potential autocorrelation and takes account of the clustering of events at certain points in time. All variables are demeaned; therefore, the regression coefficient of the *Event* dummy represents the increase in systemic risk contributions for the average bank.

We expect β_1 to be positive (negative) if systemic risk increases (decreases) after an event. The main coefficient of interest, β_2, gauges the sensitivity of banks' contributions to systemic risk in response to system-wide events to the comprehensiveness of their bank resolution framework. It is positive (negative) if systemic risk increases more (less) in the presence of a more advanced resolution regime.

We run regression (2) separately for each of the events described below and in a panel version where we stack the different negative or positive events. The latter allows us to capture the third dimension (in addition to event window and bank dimensions) of variation in bank resolution frameworks within countries over time. By combining the different events into one regression, we can thus test whether changes in bank resolution frameworks make the systemic risk contribution of banks more or less responsive to shocks.

3.2 ΔCoVaR as Measure of Systemic Risk Contributions

As discussed above, there is no single measure of systemic risk contribution in the literature, but considering its prominence and wide application, we choose the $\Delta CoVaR$ (Adrian and Brunnermeier, 2016) to gauge the relationship between system-wide and idiosyncratic fragility shocks and banks' contribution to systemic risk. $\Delta CoVaR$ is the difference between the value at risk (VaR) of the financial system conditional on a particular institution experiencing extreme losses and the value at risk of the financial system conditional on the same institution's asset returns being at their median level. One advantage of this measure is that it captures not only risk spillovers within the financial system due to "individually systemic" financial intermediaries but also of institutions that are "systemic as a part of a herd" (Adrian and Brunnermeier, 2016).

VaR_q^i is defined as the q%-quantile of X^i where X^i is the growth rate of the market value of a bank's assets, i. e.,

$$Pr\left(X^i \leq VaR_q^i\right) = q\%.$$

$CoVaR_q^{j|i}$ is the VaR of institution j, conditional on $X^i = VaR_q^i$ of institution i:

$$Pr\left(X^j \leq CoVaR_q^{j|i} | X^i = VaR_q^i\right) = q\%$$

Institution i's contribution to the risk of the *system* is defined as

$$\Delta CoVaR_q^{system|i} = CoVaR_q^{system|X^i = VaR_q^i} - CoVaR_q^{system|X^i = median^i}.$$

Intuitively, $\Delta CoVaR$ represents the marginal contribution of a specific bank to the total risk of the financial system. We apply a stress level of $q = 99\%$ in our regressions.

The main estimation tool in the CoVaR approach is quantile regression, developed by Koenker and Bassett (1978). Deriving a time-variant CoVaR involves quantile regressions that include lagged state variables M_{t-1} (e. g., VIX, repo rates, T-bill rates, slope of yield curve):

$$CoVaR_{q,t}^{system|i} = \hat{\alpha}_q^{system|i} + \hat{\gamma}_q^{system|i} M_{t-1} + \hat{\beta}_q^{system|i} VaR_{q,t}^i.$$

Then, our systemic risk contributions measure, the time-varying $\Delta CoVaR$, is derived as:

$$\Delta CoVaR_{q,t}^{system|i} = CoVaR_{q,t}^{system|X^i = VaR_{q,t}^i} - CoVaR_{q,t}^{system|X^i = median^i}$$

The frequency of $\Delta CoVaR$ is daily, and it is estimated at the country level. The descriptive statistics in Table 2 show that $\Delta CoVaR$ varies substantially across banks and over time, from -3.79 (the Korean Busan Bank on September 18, 2008) up to 23.41 (the Turkish Finansbank A.S. on September 18, 2008). The mean of $\Delta CoVaR$ equals

2.35, which means that, on average, a distress at one institution is associated with an increase in the conditional value at risk of the respective country's banking system by 2.35 daily percentage points. Figures 4 and 5 show the evolution of $\Delta CoVaR$ over time, overall and for different regions. The spikes in $\Delta CoVaR$ tend to coincide with the events that we identify in the next section.

3.3 System-Wide Shocks

In the first stage of the empirical analysis, we analyze system-wide shocks that affected the global banking system (though their effects might vary across banks and countries). In order to test the hypotheses discussed above, we identify both "negative" and "positive" shocks to the banking systems, i. e., surprising events that either signal increasing fragility for the banking system or a reduction in fragility.

We empirically classify the shocks into a positive group and a negative group by estimating Equation 2 without including the interaction term of the shock with bank resolution. Since a higher $\Delta CoVaR$ represents higher systemic risk, for positive (negative) shocks, we expect β_1 in Equation 2 to be negative (positive). The results are presented in Section 4.1.

The shocks that we include in our analysis are the following:

The outbreak of the subprime crisis: August 9, 2007. The first event is the date when the French investment bank BNP Paribas suspended three investment funds that had invested in subprime mortgage debt, citing a lack of liquidity in the market. The bank's announcement was the first of many credit-loss and write-down announcements by banks, mortgage lenders and other institutional investors. This event is often considered as the outbreak of the subprime crisis. The announcement led to the intervention of the European Central Bank, which injected 95 billion euros into the European banking market.

Lehman Brothers' collapse: September 15, 2008. Our second significant event is the filing for bankruptcy by Lehman Brothers, which deepened the Global Financial

Crisis. Beginning with the bankruptcy announcement on September 15, 2008, the financial crisis entered an acute phase marked by failures of prominent American and European banks and efforts by the governments around the world to rescue distressed financial institutions.

Greece's bailout: May 5, 2010. In late 2009, the newly elected Greek government announced that a recalculation of the national statistics revealed a higher than previously expected fiscal deficit. Despite this new information, the auctions for Greek government debt in January and March 2010 were overbooked – although requesting higher yields, investors did not expect a euro area country to default. In late April 2010, the Greek government requested an international bailout, which was announced by the Troika (the European Commission, the European Central Bank and the International Monetary Fund) on May 2. The bailout entailed an extensive list of austerity measures that Greece had to fulfill and led to anti-austerity riots in Greece starting on March 5. We choose the latter date as the onset of our third event, as it marked the start of a period of political and economic uncertainty within and beyond the euro area.

The US Government Rating Downgrade by Standard & Poor's : August 5, 2011. Following a negative ourlook warning in April 2011, in early 2011, Standard & Poor's downgraded the rating of the US Federal Government from AAA (outstanding) to AA+ (excellent). The motivation of the downgrade was in the US political process and the US government-debt-ceiling crisis that almost lead to the default of the US federal government on its debt during the same week. The downgrade was met with negative reactions from both Republican and Democratic representatives and led to the resignation of S&P's CEO Deven Sharma. All three major US stock indices and the global stock markets declined by 5 to 7% within a day. A credit rating downgrade reflects an increase in the default risk on the particular type of debt and since institutions across the global financial system have substantial holdings of US government bonds, we consider the downgrade to be a systemic shock.

Greece's sovereign debt swap (PSI): March 9, 2012. In late February 2012, the Troika agreed on a restructuring of Greek sovereign debt, where private investors were offered to swap their bonds for newly issued bonds with a significant haircut. This swap was called Private Sector Involvement (PSI) and entailed a haircut of 53.5%, leading to a 100 billion euro debt reduction for Greece. On 9 March 2012, the International Swaps and Derivatives Association (ISDA) issued a communiqué calling the debt restructuring deal a "Restructuring Credit Event" that triggers payment of credit default swaps. In case not enough bondholders would agree to a voluntary bond swap, the Greek government threatened to and did introduce a retroactive collective action clause to enforce participation. The restructuring avoided disorderly default of Greece and was therefore met with positive reactions by market participants.

Mario Draghi's "whatever it takes" announcement: July 26, 2012. At the height of the euro area crisis, at a speech in London on July 26, 2012, ECB president Mario Draghi gave an assessment of the state of the eurozone economy and made the famous remark: "Within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough." A week after his speech, the ECB announced a program that would allow the ECB to buy the bonds of distressed euro area countries under certain strict conditions, known as Outright Monetary Transactions (OMT). Although the ECB has never actually used this program, the promise was enough to calm investors and bring down bond yields across the euro area.

Cyprus' bail-in: March 18, 2013. The Greek PSI in early 2012 lead to a banking crisis in Cyprus due to the large holdings of Greek debt of its two biggest banks: Bank of Cyprus and Laiki Bank. Initially, the banks were bailed out in mid-2012, but the crisis was not resolved and by mid-March 2013 the Eurogroup, European Commission (EC), European Central Bank (ECB) and International Monetary Fund (IMF) offered a bailout to the Cypriot government in exchange of a bail-in levy on 48% of the uninsured deposits in the Bank of Cyprus and the closure of Laiki Bank. Since that was arguably the first major application of bail-in of banks before the introduction of the

BRRD in the euro area, we consider it a systemic event with implications for all members countries of the FSB. Although viewed as an ad-hoc measure at the time, it led to solving the financial crisis in the country and to a decrease in market volatility in Europe.

3.4 Descriptive Statistics

Appendix Table A2 provides a description of the variables used in our regression analysis, while Table 2 presents the descriptive statistics. The bank-specific balance sheet data covers 760 banks (with some variation for the different events) in 22 FSB member countries.[5] The balance sheet data are collected from Bankscope, while the macroeconomic data are from the World Bank's World Development Indicators database. The frequency is annual for the balance sheet and macroeconomic data.

Banks vary significantly in terms of assets (from 1.57 million dollars to 3.8 trillion dollars) and leverage (from 1, or virtually no leverage, to 62.1). The average annual GDP growth and inflation are positive in our sample, they range from -8% to 15% and from -4% to 13%, respectively. Although comprising mainly OECD members, our sample of countries also varies substantially in terms of financial development, as measured by domestic credit to GDP, ranging from 18.2 to 177, with the mean and median at 104 and 119, respectively.

4 Results

We first present regressions that show whether shocks were negative or positive before presenting our main results of the sensitivity of the reaction of banks' systemic risk contribution to country-differences in bank resolution regimes. We present a number of robustness tests before gauging the importance of different components of resolution frameworks and of a set of shocks during our sample period that were bank-specific rather than system-wide.

[5] The original dataset contained 1350 banks, from which about 750 were from the United States and 150 from Japan. To avoid skewing the results towards representing a particular country, we cap the number of banks to the top 100 per country.

4.1 Classification of Shocks

This section presents the results from our strategy for the classification of system-wide events. Our analysis singles out four negative and three positive system-wide shocks, presented in Panels A and B of Table 3, respectively.

Panel A shows that in a 7 days window after the shock, the US downgrade leads to the largest increase in average systemic risk contributions at 1.2 percentage points, followed by the subprime crisis outbreak at 0.84, Lehman Brothers' collapse at 0.75 and the Greek bailout at 0.63.[6] This confirms that these events increased systemic risk. In Panel B, the Greek sovereign debt restructuring leads to the largest average decrease in systemic risk at 0.4 percentage points, followed by the Cypriot bail-in at 0.13. Within the standard 7-day window that we employ, the effect of Draghi's speech is negative, but insignificant at 0.06 percentage points. It rises to 0.2 percentage points 30 days after the event and is significant at the 1% level. The latter result reflects the general impression that in the first days after the announcement, the markets were not sure what the effect on financial stability would be and that the message was transmitted and understood with a certain delay. Therefore, in our baseline specification in the next section, we decided to present the results for both the 7-day and the 30-day windows for that particular event.[7]

4.2 Bank Resolution and Systemic Risk after System-Wide Shocks

We first give a visual impression of our results. Figure 6 depicts the dynamics of systemic risk after a negative system-wide event, the default of Lehman Brothers. The figure suggests that banks in countries with more advanced resolution regimes experienced a larger increase in systemic risk in response to a negative system-wide event. In Panel A, the banks are split into banks in countries with an above-median (red) and below-median (blue) value of the Bank Resolution Index. Banks in countries with above-median regimes have, on average, higher $\Delta CoVaR$, even though Panel A clearly shows a parallel trend before Lehman Brothers' collapse.[8] After the event, we observe a clear divergence between

[6] The effect for Lehman's bankruptcy more than triples within 30 days after September 15, 2008.

[7] In unreported robustness tests, we confirm that all the findings reported in the next subsection are confirmed when using a 30-day rather than 7-day window.

[8] The bank fixed effects in our estimation model will pick up this difference in levels, so cross-sectional variations in systemic risk levels due to unobserved factors are not an endogeneity concern here.

the two bank groups, which is even more evident in Panel B, where we depict the difference between the two groups. This difference becomes even larger beyond the 7-day event window used in our regression analysis.

The results in Panel A of Table 4 confirm that systemic risk increases more strongly after negative system-wide shocks for banks in countries with more comprehensive bank resolution frameworks. In this table, we present the baseline results for the four negative system-wide shocks in our study: the outbreak of the subprime crisis, Lehman Brothers' bankruptcy, and the turmoils after the Greek bailout and the US downgrade, as well the results of the regression where we stack the four events. The coefficient of the interaction of the event dummy with the resolution index is positive and strongly significant in all five cases. Therefore, on average, the more comprehensive the bank resolution framework, the higher the increase in systemic risk in response to a negative system-wide shock. Bigger banks show higher systemic risk contributions after the event, while, somewhat surprisingly, higher leverage is associated with a smaller increase in systemic risk.

The results are not only statistically but also economically significant. Take the example of the Greek bailout in 2010 (Panel A, column 3 of Table 4). Banks in the country at the 75th percentile of the Bank Resolution Index (Korea, index value of 12) experience an increase in $\Delta CoVaR$ that is on average by 0.216 larger than that of banks in the country at the 25th percentile of the Index (Spain, index value of 8), which equals one third of the base effect and 15.32% of one standard deviation of $\Delta CoVaR$ in the event period.

The results in Panel B of Table 4 show that the opposite happens in positive system-wide events: Systemic risk decreases more strongly after positive system-wide shocks for banks in countries with more comprehensive bank resolution frameworks. Here we focus on three "positive" system-wide shocks during our sample period: the Greek restructuring, Mario Draghi's "whatever it takes" speech, and the Cypriot bail-in. We find negative and strongly significant coefficients for the event dummy for the Greek PSI and the bail-in in Cyprus, while, just like in the previous section, the effect for the 7 days following Mario Draghi's speech is insignificant. The coefficients of the interaction are strongly significant for all three events as well as for the panel where we stack the three positive events. For Mario Draghi's speech both the shock coefficient and the coefficient of the interaction increase in absolute size and gain in statistical significance when a longer event window of 30 days is used (column 4). A higher level of the bank resolution index is thus associated with a stronger decrease in systemic risk after the positive shock, so the relationship appears to be symmetric for positive and negative events. This is plausible if the previous increase was also more pronounced in countries with more advanced bank resolution regimes. The effects of bank size and leverage are also symmetric to the results for negative events, with reversed signs.

To sum up, after a *negative system-wide shock*, systemic risk *increases*, and it increases *more* in the presence of a more comprehensive resolution regime (after controlling for bank and country characteristics). After a *positive system-wide shock*, systemic risk *decreases*, and it decreases *more* in the presence of a more comprehensive resolution regime. Overall, these results suggest that bank resolution regimes have *amplifiying* effects for system-wide events: they increase rather than dampen the swings in systemic risk in response to financial shocks. These results are thus consistent with theories focusing on the destabilising effects of bank resolution framework during system-wide distress situations.

4.3 Robustness

We perform a number of sensitivity checks to confirm the robustness of our findings, especially to measurement, data sample, and endogeneity biases, presented in Table 5, with Panel A presenting panel regressions of the negative and Panel B presenting the panel regressions of the positive shocks. First, we apply weights to our regressions to reduce the influence of countries that are overrepresented in our sample. In particular, since the variable of interest is at the country level, we weigh every observation by the inverse of the number of banks in a given country. In this way, every country gets the same weight in our estimations. The results in columns (1) confirm our previous findings, with results for individual event regressions presented in Appendix Table A3. These results do not diverge substantially from our baseline tables in coefficient sign or size. As an alternative, in unreported regressions, we drop US and Japanese banks from the baseline regressions and our results remain qualitatively the same.

Second, to test whether systemically important and possibly too-big-to-fail banks drive our results, we exclude the Global Systemically Important Banks (G-SIBs) as defined by the FSB. This also mitigates the concern that some of the larger banks in our sample have significant presence in several countries and therefore more than one resolution framework would apply.[9] Our main coefficient of interest remains qualitatively unaffected across all regressions, suggesting that our main findings are robust to excluding the largest and systemically most important financial institutions (see columns 2 and Table A4 for individual event regressions).

Third, we test for non-linearities in the relationship between the bank resolution index and reactions in banks' systemic risk contribution to shocks. It might be that bank resolution frameworks can only help address systemic risk if all the key attributes identified by the FSB are in place. For example, even though the US had already many elements of an efficient resolution framework in place in 2008, it did not extend to investment banks, such as Lehman Brothers, or bank holding companies. In columns (3) (see Panels A and B of Table A5 for the individual event regressions), we therefore add an interaction of the shock with the square of the resolution index. In the regressions of the negative system-wide events, the interaction of the shock variable with the squared resolution enters positively and significantly, suggesting that resolution regimes increase systemic risk even further at higher levels of the resolution index. In the case of positive shocks, the interaction of the shock with the squared resolution index enters negatively throughout, but significantly only in the first shock – the Greek restructuring. In summary, there is no evidence that our main findings would not hold at very high levels of the resolution index, if anything the results become stronger at very high levels of the resolution index.

Fourth, while we control for bank fixed effects that also take into account the difference in the levels of systemic risk at the country level, there may still be a selection bias – more comprehensive regimes may have been implemented in countries with higher levels of systemic risk. Therefore, we add an interaction of the shock with *initial* $\Delta CoVaR$ and

[9] In the case of cross-border banks, there are different modes of resolution, including the Single Point Entry, where losses are first upstreamed to the parent-bank level, and the Multiple Points of Entry where losses are treated separately across different subsidiaries, typically across different countries (see Bolton and Oehmke, 2019). Being subject to different resolution regimes, however, should bias our coefficient estimates towards zero.

report the results in columns (4) (see Panels A and B of Table A6 for individual event regressions). This interaction term enters positively in the regressions of negative shocks and negatively in the regressions of the positive shocks and mostly though not always significantly, suggesting that the impact of shocks on banks' systemic risk contribution is stronger if banks start out with a higher systemic risk contribution. However, controlling for this interaction term does not change the main coefficient of interest substantially, compared to our baseline regressions in Table 4, neither in significance nor coefficient size.

Fifth, in unreported regressions, we also use alternative definitions of leverage: the Tier 1 capital ratio and Tier 1 capital to total assets. Neither variation reverses the sign of the coefficient of leverage for any of our events. Since countries can adjust their bank resolution regimes during the estimation and event windows, we also use the value of the Resolution index without fixing it to the pre-event period. Since such changes occur very rarely, this alternative specification does not change our results beyond minor adjustments several digits after the decimal point.[10]

Finally, we address the possible endogeneity of bank resolution regimes by using only the variation that is explained by financial crises, as reforms of the bank resolution framework are often introduced after crises, as discussed in Section 2. While the systemic shocks are certainly orthogonal to countries' resolution frameworks, countries might have more comprehensive resolution regimes if they expect their banks to experience more systemic distress in the case of system-wide shocks. We therefore use as instruments two variables derived from the banking crises database developed by Laeven and Valencia (2018).[11] The first variable is the ratio between bailout-related fiscal costs and the overall output loss in the latest crisis in a country. We expect that if bailouts have occurred in the past, the politicians are more likely to commit to implementing more comprehensive resolution regimes, to avoid unpopular and costly bailouts in the future. The second instrument is a simple count of the banking crises in the past 40 years, recorded in Laeven and Valencia (2018) to account for cumulative effect of crises in the past decades. We again expect a positive correlation between past crises and current resolution regimes.

[10]The results from all unreported estimations are available upon request.

[11]The variables are defined in Appendix Table A2.

The results from the two-stage least squares estimation for the negative and the positive events are presented in Panels A and B of Table 6, respectively. The coefficients of the interactions, albeit quantitatively different, are qualitatively consistent with our baseline results. Apart from the case of the Greek bailout, we cannot reject the null hypothesis that the overidentifying instrument is valid, while for the Greek bailout, the null is marginally rejected at the 10% significance level. While these specification tests are weak and we can certainly not rely exclusively on these instrumental variable regressions, these regression results point in the same direction as other results in this section, mitigating the concern that our main findings are driven by endogeneity.

4.4 Different Components of Bank Resolution and Systemic Risk

While the results based on the resolution index yield significant and consistent results pointing to an exacerbating role of bank resolution in systemic shock periods, the index uses equal weights for all 22 variables and ignores correlations between them, thereby raising methodological and interpretational concerns. We therefore replace the interaction of the event dummy with the resolution index with interactions of the first five principal components of the bank resolution variables, as discussed in Section 2.2. Table 7 presents the results from the PCA analysis for the negative and positive system-wide shocks, respectively. Here we only report the coefficient estimates for the interaction of *Event* with each of the five first principal components.

The results in Panel A of Table 7 suggest that the amplifying effect of bank resolution frameworks in negative systemic shock periods is mainly driven by three of first five principal components, namely the **bail-in framework**, **managing losses** and **administrative process**. The principal components relating to these three dimensions enter positively and significantly in the panel regressions. In terms of individual shocks, the **bail-in** principal component enters positively and significantly in three of the four events, while the **managing losses** principal components enters positively and significantly in all four events, at least at the 10% level. Given that no country had a bail-in framework in place during the first three events and few during the last event, we interpret the results as suggesting that the absence of a bail-in framework does not exacerbate negative system-wide shocks, while the resolution authorities' ability to manage losses outside the court process and with the establishment of an asset management company, the administrative nature of the resolution process and the ability for the resolution authority to operate a failing bank and ensure essential services seem to exacerbate the impact of system-wide shocks on banks' systemic risk contributions. Having a designated resolution authority, on the other hand, seems to be a mitigating factor, as this principal component enters negatively and significantly in the panel regression and negatively and significantly at least at the 10% level in three of the four events.

The results in Panel B suggest that the amplifying effects of bank resolution frameworks in periods of positive shocks comes from four of the five principal components. While the resolution authority component does not enter significantly in the panel regression, all other principal components enter negatively and significantly in the panel regression. In terms of specific shocks, both the second and the fifth principal components enter negatively and significantly in two of the three positive events. Similarly, the third principal component enters negatively and significantly at least at the 10% level in two of the three events, suggesting that not having to involve courts and the ability for the resolution authority to operate a failing banks and ensure essential services dampens the effect of positive shocks on banks' systemic risk contributions. Given that most positive system-wide shocks happened before the bail-in framework was introduced, we interpret the negative signs on the first principal components as suggesting that the absence of bail-in provisions does not exacerbate the impact of shocks on systemic risk.

In unreported robustness tests, we gauge the sensitivity of these results to (i) weighing the observations by the inverse of the number of banks per country, (ii) dropping G-SIBs, and (iii) adding an interaction of the shock with *initial* $\Delta CoVaR$. While some of the coefficient estimates turn insignificant in the weighted regressions, they continue to enter with the same signs as in the main regressions. Regressions including the squared terms of the five principal components almost always enter with the same sign as the components themselves, suggesting that the relationship becomes stronger rather than weaker at higher levels of the respective component. Finally, controlling for the *initial* $\Delta CoVaR$

does not change our findings.

In summary, the designation of a resolution authority is a beneficial contribution to resolution frameworks even during system-wide shocks. In contrast, the bail-in framework and specific powers for the resolution authority seem to drive the amplifying effect of resolution framework in times of system-wide shocks.

4.5 Bank Resolution and Systemic Risk after Bank-Specific Shocks

Do our findings imply that bank resolution frameworks as established and reformed over the past two decades are not fit for purpose? In the following, we extend our set of events to bank-specific shocks to explore whether our findings also apply to non-system-wide fragility shocks or are specific to systemic distress episodes. We define bank-specific shocks as shocks that primarily affect one bank but might cause spill-over effects across banks and countries. The particular events that we analyze are:

Société Générale's admission to 4.9 billion euro rogue trading losses: January 21, 2008. On January 19, 2008, Société Générale uncovered fraudulent transactions created by the bank's trader Jérôme Kerviel. The bank started closing the positions on January 21. Due to unfavorable market conditions at the time, the closure of the positions resulted in a loss of almost 5 billion euro on trades totaling 50 billion euro. On January 21, 2008 alone, European stock markets declined by 6 percent, partially exacerbated by the closing of the positions. The loss was a considerable and unexpected solvency shock for the bank as it wiped put a large portion of its equity.

Bear Stearns' collapse: March 14-17, 2008. March 17 was the first working day after the sale of Bear Stearns to JPMorgan Chase, after the former's stock price collapsed due to losses stemming from subprime market exposures. On March 16, Bear Stearns was acquired for 2 dollars per share by JPMorgan Chase in a fire sale avoiding bankruptcy. The deal was backed by the Federal Reserve, which provided up to 30 billion dollars to cover possible Bear Stearn losses.

The resolution of Portugal's Banco Espírito Santo: August 4, 2014. In the first six months of 2014, Banco Espírito Santo lost the equivalent of 4.8 billion dollars due to bad loans to companies held by the family-controlled Espírito Santo Financial Group, raising concerns about the health of the bank. On Sunday, August 3, 2014, the Portuguese government announced state aid of 4.4 billion euro for the transfer of certain BES assets to a bridge bank – Novo Banco –, which was to be created on the following day. To support the recapitalization of the bridge bank, BES shareholders and subordinated debt holders contributed almost 7 billion euro, limiting the amount of state capital needed by the bridge bank. The toxic assets remained in the existing bank, which was subsequently liquidated.

Deutsche Bank's announcement of €6.8 billion losses: January 21, 2016. In a surprise earnings announcement in the evening of January 20, 2016, Deutsche Bank declared a net loss of 6.8 billion euro due to rising restructuring and litigation costs. The next day saw a decline of 7% in Deutsche Bank's stock price. This was the first annual loss for the bank since 2008.

The results for idiosyncratic shocks contrast markedly with the findings for system-wide shocks, as illustrated by Figure 7, which depicts the dynamics of systemic risk after a negative bank-specific event (Deutsche Bank's loss announcement). The figure suggests that banks in countries with more comprehensive resolution regimes tend to experience a smaller increase in systemic risk after a *negative idiosyncratic* shock. In Panel A, banks are again split into those in countries with a Bank Resolution Index above the median (red) and those with an index value below the median (blue). Once again, banks in countries with above-median regimes have, on average, higher $\Delta CoVaR$, and again we observe a parallel trend in Panel A before the event. After the event, $\Delta CoVaR$ continues the pre-shock trends for both groups, but the gap narrows as time passes. The overall negative trend is clearly visible in Panel B, where the difference between the two groups is shown. Therefore, the graphical analysis suggests that banks in countries with more comprehensive resolution regimes tend to experience a *smaller* increase in systemic risk after a negative idiosyncratic shock and this effect again persists after the 7-day event window of our regression analysis.

Table 8 confirms this conclusion with regression analysis. Here, we present the regression results for the overall index for the four bank-specific events, Société Générale's trading loss in early 2008, Bear Stearns' resolution in March 2008, Banco Espírito Santo's restructuring in 2014 and Deutsche Bank's loss announcement in 2016. For the first and the latter two events, we restrict our sample to European banks, while for Bear Stearns, we report the results for the global sample.[12] For all events, systemic risk contributions of banks increase in response to the shock.[13] In the case of the fire sale of Bear Stearns and the restructuring of Banco Espírito Santo, the increase in systemic risk is not significantly related to the bank resolution regime. In contrast, there is a significantly risk-decreasing effect of resolution regimes in the cases of Société Générale and Deutsche Bank. Turning to the economic effect, we find that the effect of the bank resolution regime on systemic risk is smaller than the economic effect in the case of system-wide shocks. If we consider Deutsche Bank's shock, banks in the country at the 75th percentile of the Bank Resolution Index (Spain, index value of 19) experience a *decrease* in $\Delta CoVaR$ that is on average by 0.10 larger than that of banks in the country at the 25th percentile of the Index (Italy, index value of 14), which equals one fourth of the base effect and 9% of one standard deviation of $\Delta CoVaR$ in the event period.

In summary, unlike in the negative *system-wide* events studied in the previous section, we find that a more comprehensive bank resolution regime has either no effect or it even reduces systemic risk for negative *idiosyncratic* events, controlling for bank and country characteristics. Hence, we find evidence for the existence of a *stabilizing* effect of bank resolution regimes after idiosyncratic events.

[12]Idiosyncratic events are unlikely to spread globally and therefore we concentrate on European banks for the European events. We consider the global sample for Bear Stearns, because reducing the sample only to the US would lead to dropping of the interaction with the resolution index. We performed a robustness check by adding Canadian and Mexican banks to the US sample and arrived at qualitatively similar results to the outcomes with the global sample.

[13]This is confirmed when we exclude the interaction between the shock and the resolution index.

5 Conclusion

A credible and comprehensive bank resolution regime is an important pillar in dealing with bank defaults and in breaking the link between sovereigns and banks caused by large-scale bailouts. In this paper, we analyze how the presence of bank resolution regimes affects the evolution of systemic risk at times when the financial system is hit by system-wide shocks. Theory has provided different hypotheses, suggesting either a risk-increasing or risk-decreasing effect of bank resolution regimes during system-wide shocks.

We find that a more comprehensive bank resolution regime may indeed further *increase* systemic risk in a crisis. While resolution procedures appear to have a stabilizing effect in *idiosyncratic crises*, they may reinforce systemic risk in *system-wide crises*, where we find strong amplifying effects. This casts doubt on whether bank resolution regimes will be able to solve the time inconsistency problem inherent in bank rescues. Equally important as the aggregate results is the analysis of specific components of the bank resolution framework. While a designated resolution authority can help to dampen the impact of negative system-wide shocks, the absence of bail-in provisions as introduced in recent years, did not exacerbate system-wide shocks, shedding doubt on the adequacy of these provisions for system-wide distress periods. Similarly, the ability to manage losses through liquidation and asset management companies and the administrative nature of the process exacerbate the impact of system-wide shocks on systemic risk.

It has to be acknowledged that the time period that we are considering featured resolution regimes, which were less sophisticated than they are today. But we have seen in recent years that bail-in is politically difficult even in non-crisis times. Our paper suggests that it will be even harder in crisis times because resolution measures like bail-in may reinforce uncertainty in the middle of a crisis and may give rise to contagion effects. Therefore, it seems that more efforts are needed to improve the macroprudential scope of bank resolution regimes, to be able to contain systemic risk in a crisis. Otherwise, resolution regimes cannot be credible. One possibility, as suggested by IMF (2018) in its assessment of the Eurozone's financial safety net, is to introduce a strictly defined financial stability exemption for bail-in rules during systemic distress periods and allow for government recapitalisation without bail-in. Clear governance structures are necessary for such an exemption, though. Another policy conclusion from our findings is that systemic crisis preparation and crisis management have to take a more prominent role within financial safety nets.

Overall, our results should be seen as a warning against too high expectations regarding the power of resolution regimes in system-wide crises. Instead, they have to be complemented by additional regulatory measures. In the end, the analysis gives rise to an uncomfortable question for both policymakers and academics: Will we ever be able to do without bailouts in a system-wide crisis?

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Figures and Tables

Figures

Figure 1: Resolution Index: Average per country group. This figure depicts the average dynamics of the Resolution Index for Europe (France, Germany, Italy, Netherlands, Spain, Switzerland and the United Kingdom), Asia (China, Hong Kong, India, Indonesia, Japan, Republic of Korea, Singapore), the United States of America and the rest of the sample (Australia, Brazil, Mexico, the Russian Federation, South Africa and Turkey) between 2000 and 2016.

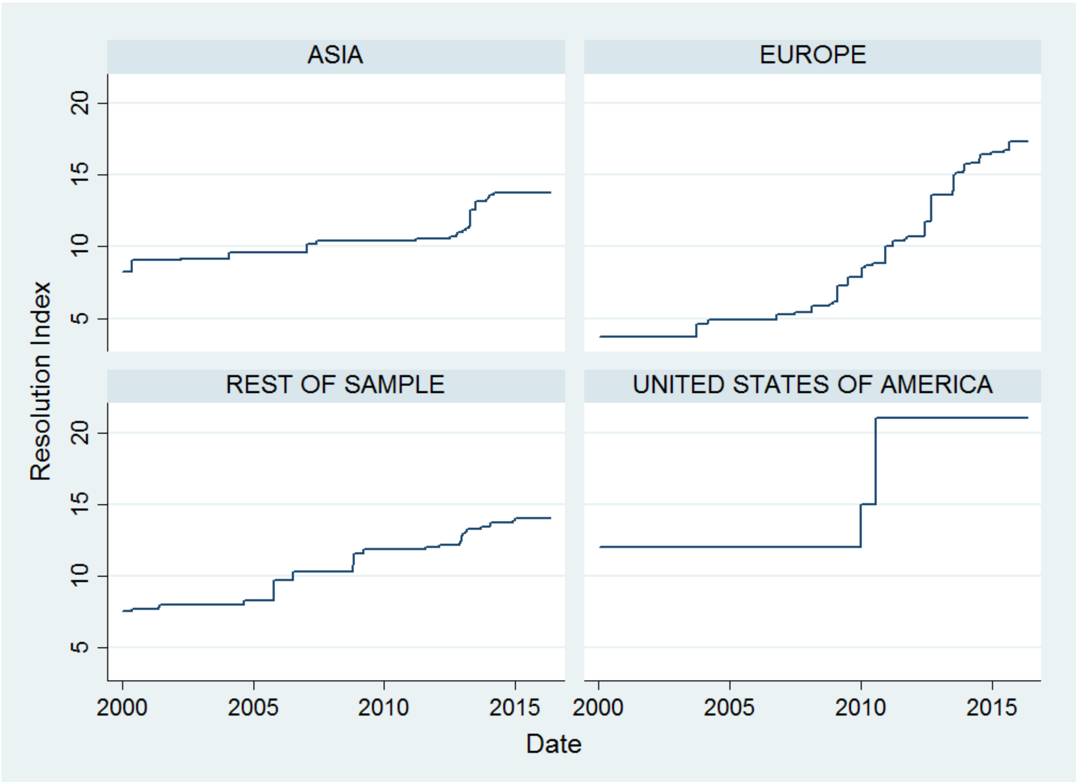


Figure 2: Resolution Index: Average for 22 countries. This figure depicts the dynamics of the unweighted average of the Resolution Indices of 22 FSB countries between 2000 and 2016. Refer to Figure 1 for the individual countries in the sample.

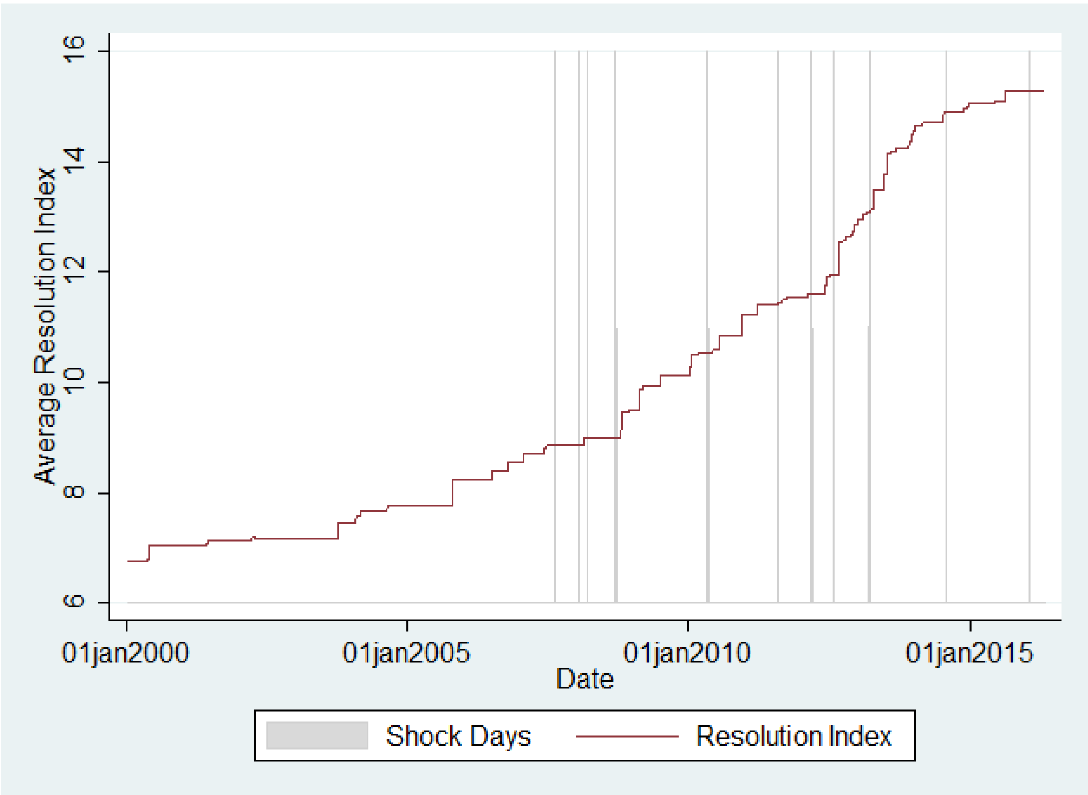


Figure 3: Principle Components: Average for 22 countries. This figure depicts the dynamics of the unweighted average of the first five principal components of 22 resolution features across FSB countries between 2000 and 2016. Refer to Figure 1 for the individual countries in the sample.

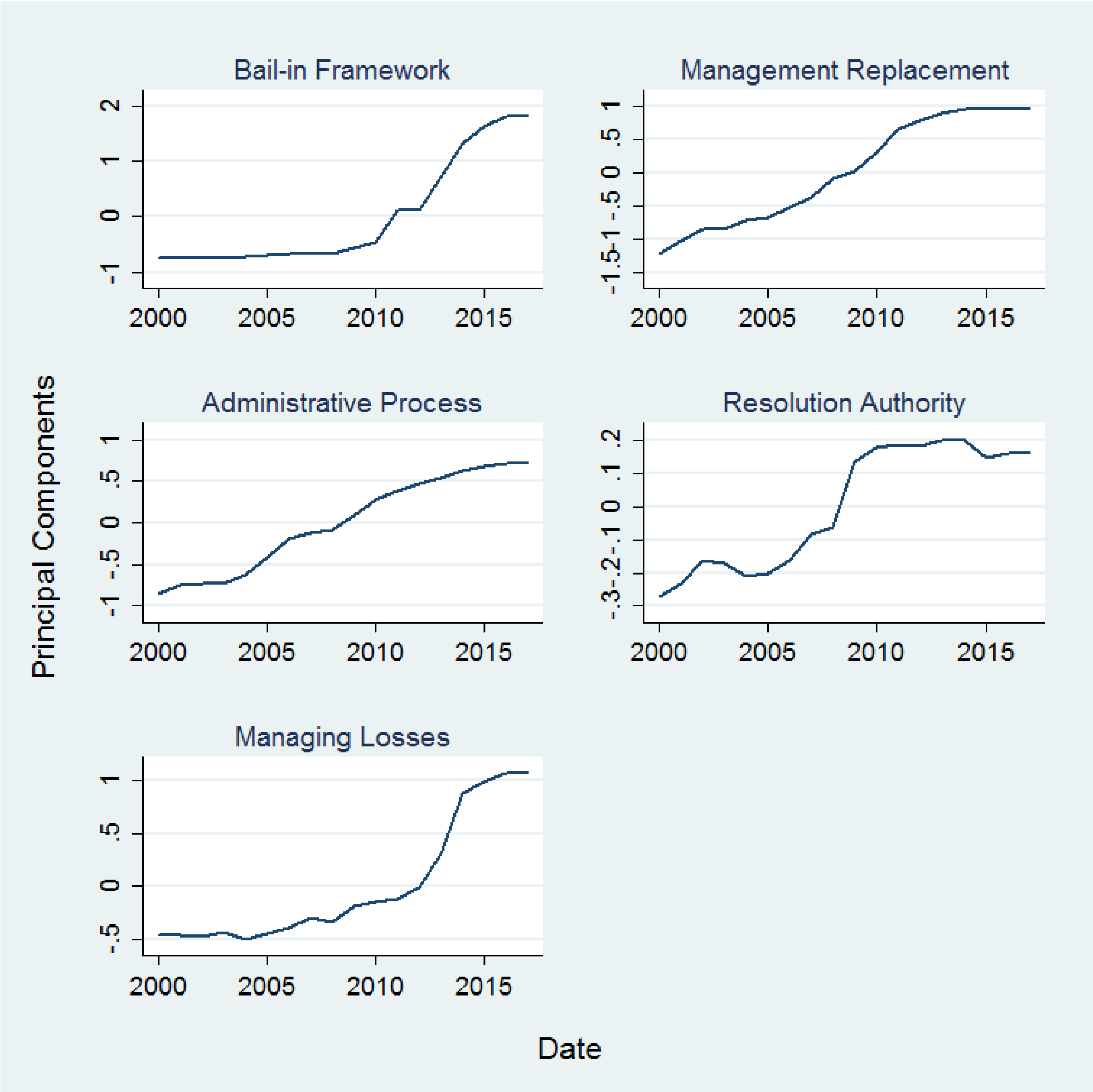


Figure 4: ΔCoVaR: Unweighted average. This figure depicts the dynamics of the unweighted average of $\Delta CoVaR$ for 760 banks in 22 FSB countries between 2000 and 2016. Refer to Figure 1 for the individual countries in the sample.

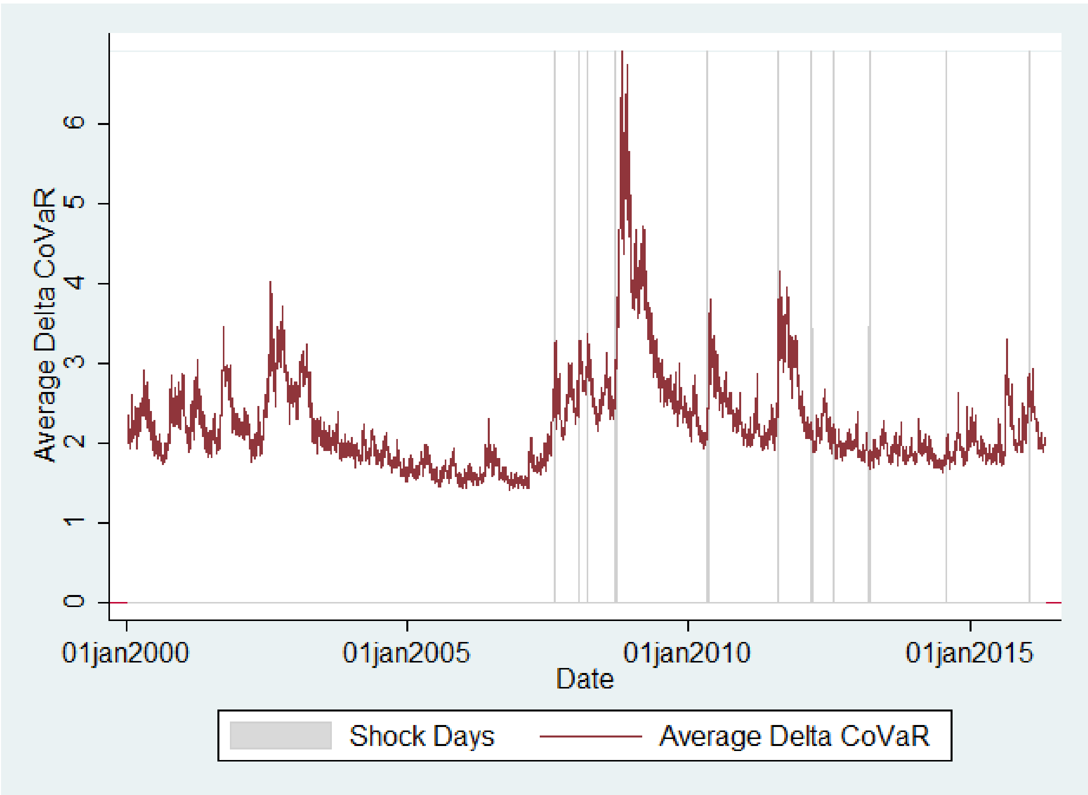


Figure 5: ΔCoVaR: Average per country group. This figure depicts the unweighted average dynamics of $\Delta CoVaR$ for 760 banks in 22 FSB countries between 2000 and 2016. Refer to Figure 1 for the individual countries in each group.

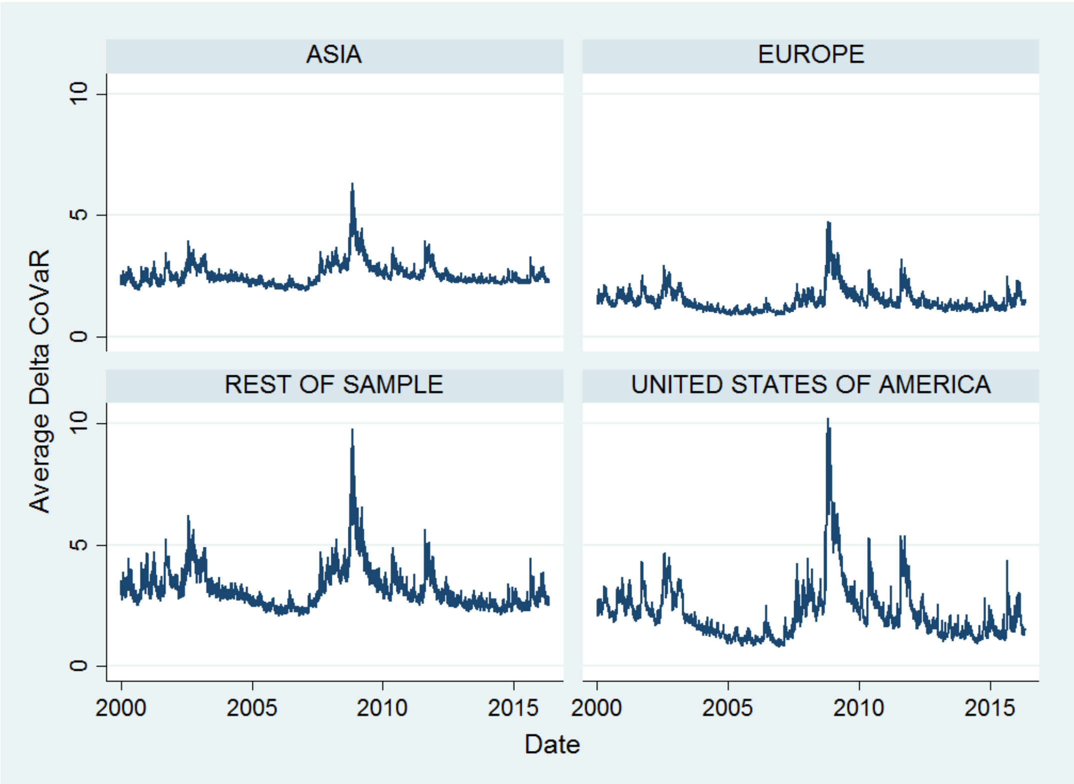


Figure 6: ΔCoVaR, Lehman. Panel A represents the average ΔCoVaR of banks in countries with Sub-median (blue) and with Above-median Resolution Regime (red). Panel B represents the difference between average ΔCoVaR of banks in countries with Sub-median (blue) and with Above-median Resolution Regime (red) from Panel A.

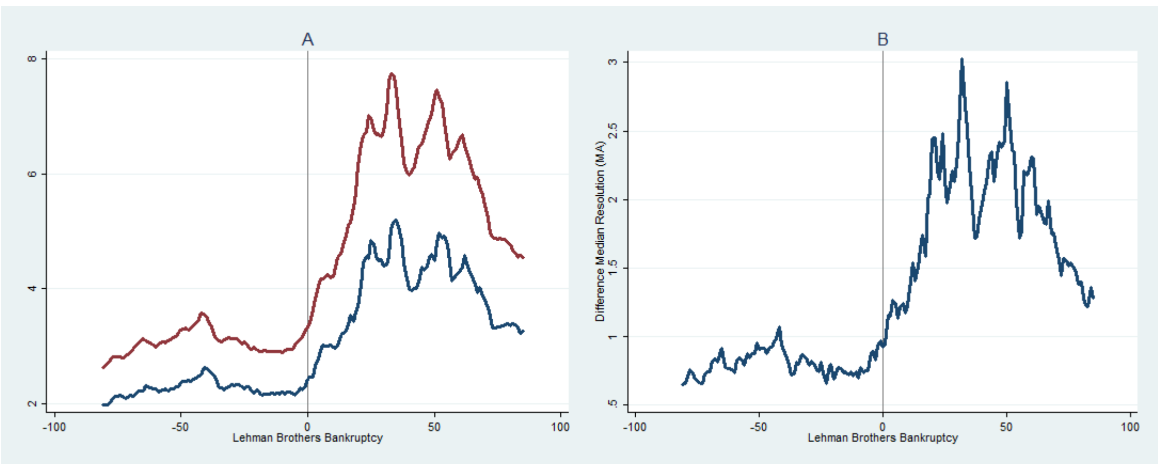
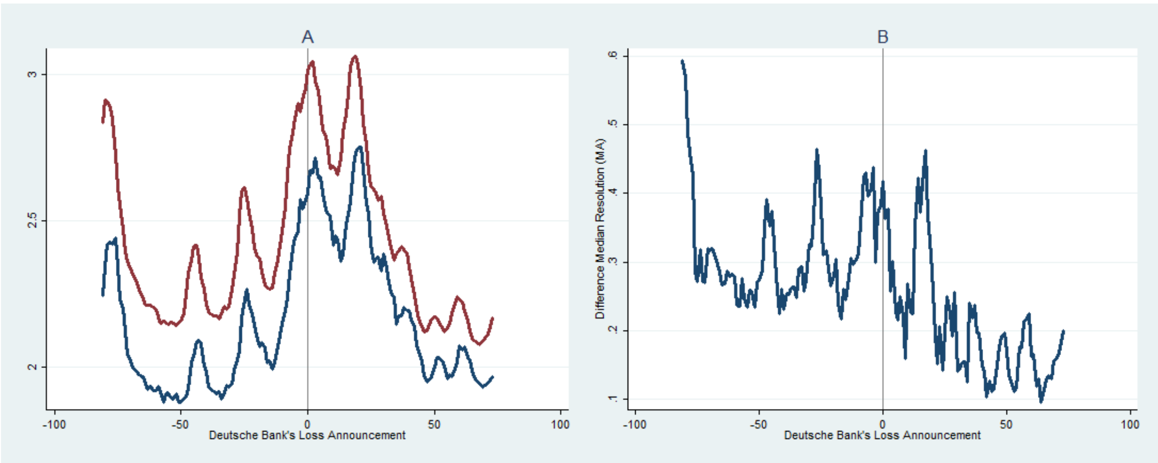


Figure 7: ∆CoVaR, Deutsche Bank's Loss Announcement. Panel A represents the average ∆CoVaR of banks in countries with Sub-median (blue) and with Above-median Resolution Regime (red). Panel B represents the difference between average ∆CoVaR of banks in countries with Sub-median (blue) and with Above-median Resolution Regime (red) from Panel A.



Tables

Table 1: Bank Resolution Index and Subindices

Bank Resolution Index
Subindex 1. General framework
1.1. Specific bank resolution framework 1.2. Specifically designated bank resolution authority 1.3. Another authority has powers to restructure/resolve banks 1.4. Liquidate the bank without the need of court decision 1.5. Resolution powers/tools can be used fast and flexibly. Proxy: court decision needed or not? (1 = No court decision needed) 1.6. Resolution fund (publicly and privately financed) 1.7. Implementation of Basel III
Subindex 2. The resolution authority has the power to...
2.1. Remove and replace management 2.2. Appoint an administrator 2.3. Operate and resolve the firm 2.4. Ensure continuity of essential services and functions 2.5. Override rights of shareholders when applying resolution powers 2.6. Temporarily stay the exercise of early termination rights 2.7. Impose a moratorium with a suspension of payments to unsecured, creditors and customers plus creditor stay
Subindex 3. Resolution tools available to the resolution authority
3.1. Transfer or sell assets and liabilities, legal rights and obligations 3.2. Establishment of a bridge institution 3.3. Establishment of an asset management vehicle 3.4. Mandatory development of resolution and recovery plans
Subindex 4. The bail-in framework includes...
4.1. Bail-in tool 4.2. A minimum requirement of eligible liabilities (i. e., bail-inable debt) 4.3. Provisions to respect the hierarchy of claims while providing flexibility to depart from the general principle of equal (pari passu) treatment of creditors of the same class 4.4. Provisions constituting that public resources may only be used if private ones are not available and a bail-in was conducted

Table 2: Descriptive statistics

Variable	Mean	St. Dev.	Minimum	Median	Maximum	N
$\Delta CoVaR$	2.211973	1.63724	-3.787341	1.817119	23.40833	513656
Size	1.27E+11	3.79E+11	1578034	1.31E+10	3.81E+12	513656
Ln(Size)	23.03597	2.559935	14.27169	23.29775	28.9681	513656
Leverage Ratio	13.22938	11.27804	1	11.1579	62.10367	513656
Ann. GDP Growth	2.307122	3.458762	-7.820885	2.192186	15.24038	513656
Inflation	2.232332	2.84059	-3.932095	1.683726	13.10942	513656
Dom. Credit to GDP	103.9895	52.2634	18.17927	118.8352	176.9135	513656

Table 3: Classification of Shocks. This table reports the results from the estimation of Equation 2 at the bank level for a number of negative system-wide events, *without* the interaction of the event variable with the Resolution Index. The sample comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The independent variables are bank size and leverage, country annual GDP growth, inflation and financial development, and their interactions with the event variable. All regressions include bank fixed effects. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A

	7 days after the shock			
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)
Shock	0.8377*** (0.000)	0.7453*** (0.000)	0.6285*** (0.000)	1.1993*** (0.000)
Shock * Size	0.1833*** (0.000)	0.1762*** (0.000)	0.1477*** (0.000)	0.2820*** (0.000)
Shock * Leverage	-0.0180*** (0.000)	-0.0145*** (0.000)	-0.0175*** (0.000)	-0.0331*** (0.000)
Shock * GDP Growth	-0.0697*** (0.001)	-0.0868*** (0.004)	-0.0153* (0.100)	-0.1376*** (0.000)
Shock * Inflation	0.0357** (0.011)	0.1136*** (0.002)	-0.0053 (0.652)	0.0241* (0.079)
Shock * Fin. Dev.	-0.0027 (0.103)	-0.0004 (0.904)	0.0003 (0.575)	-0.0020** (0.025)
Observations	63008	64944	64504	66968
R-squared	0.9046	0.9253	0.9253	0.9065
Within R-squared	0.2658	0.1516	0.1721	0.3869
Number of Banks	716	738	733	761

Panel B

	7 days after the shock			30 days after
	Greek Restructuring (1)	Draghi (2)	Cypriot Bail-in (3)	Draghi (30 days) (4)
Shock	-0.3964*** (0.000)	-0.0593 (0.131)	-0.1324*** (0.000)	-0.1998*** (0.000)
Shock * Size	-0.0947*** (0.000)	-0.0126 (0.134)	-0.0280*** (0.000)	-0.0430*** (0.000)
Shock * Leverage	0.0113*** (0.000)	0.0017* (0.063)	0.0044*** (0.000)	0.0059*** (0.000)
Shock * GDP Growth	0.0469*** (0.000)	0.0159*** (0.007)	0.0037 (0.514)	0.0346*** (0.000)
Shock * Inflation	-0.0093* (0.075)	-0.0135*** (0.003)	-0.0043 (0.387)	-0.0301*** (0.000)
Shock * Fin. Dev.	0.0011*** (0.005)	0.0002 (0.107)	-0.0001 (0.310)	0.0003 (0.120)
Observations	65912	66880	67320	84360
R-squared	0.8986	0.9488	0.9590	0.9471
Within R-squared	0.0587	0.0039	0.0263	0.0919
Number of Banks	749	760	765	760

Table 4: Resolution Index: Baseline Results. This table reports the results from the estimation of Equation 2 at the bank level for a number of system-wide events. Panel A (B) reports the outcomes after negative (positive) shocks. The sample comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The independent variables are the Resolution Index, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks					
	7 days after the shock				
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)	Panel (5)
Shock	0.8378***	0.7453***	0.6286***	1.1990***	0.8559***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Resolution	0.0227**	0.0340***	0.0540***	0.1258***	0.0665***
	(0.011)	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Size	0.1774***	0.1655***	0.1304***	0.2473***	0.1793***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Leverage	-0.0177***	-0.0131***	-0.0136***	-0.0249***	-0.0180***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Shock * GDP Growth	-0.0709***	-0.0915***	-0.0138	-0.0593***	-0.0515***
	(0.000)	(0.002)	(0.143)	(0.008)	(0.000)
Shock * Inflation	0.0425***	0.1258***	-0.0078	0.0109	0.0261**
	(0.003)	(0.001)	(0.506)	(0.426)	(0.046)
Shock * Fin. Dev.	-0.0010	0.0016	0.0013**	0.0022**	0.0015
	(0.579)	(0.611)	(0.026)	(0.013)	(0.124)
Observations	63008	64944	64504	66968	259424
R-squared	0.9048	0.9254	0.9263	0.9113	0.8406
Within R-squared	0.2671	0.1531	0.1830	0.4187	0.1500
Number of Banks	716	738	733	761	864

Panel B					
	7 days after the shock			30 days after	7 days after
	Greek Restructuring (1)	Draghi (2)	Cypriot Bail-in (3)	Draghi (30 days) (4)	Panel (5)
Shock	-0.3963***	-0.0593	-0.1324***	-0.1999***	-0.1989***
	(0.000)	(0.131)	(0.000)	(0.000)	(0.000)
Shock * Resolution	-0.0448***	-0.0088**	-0.0081***	-0.0220***	-0.0208***
	(0.000)	(0.026)	(0.003)	(0.000)	(0.000)
Shock * Size	-0.0808***	-0.0099	-0.0256***	-0.0364***	-0.0384***
	(0.000)	(0.234)	(0.000)	(0.000)	(0.000)
Shock * Leverage	0.0084***	0.0008	0.0037***	0.0037***	0.0047***
	(0.000)	(0.347)	(0.000)	(0.000)	(0.000)
Shock * GDP Growth	0.0203**	0.0102*	-0.0002	0.0204**	0.0120**
	(0.017)	(0.082)	(0.969)	(0.030)	(0.014)
Shock * Inflation	-0.0054	-0.0103**	-0.0022	-0.0221***	-0.0041
	(0.287)	(0.032)	(0.659)	(0.001)	(0.428)
Shock * Fin. Dev.	-0.0004	-0.0000	-0.0002*	-0.0002	-0.0001
	(0.338)	(0.995)	(0.094)	(0.321)	(0.391)
Observations	65912	66880	67320	84360	190991
R-squared	0.8993	0.9488	0.9591	0.9477	0.8831
Within R-squared	0.0647	0.0047	0.0281	0.1011	0.0298
Number of Banks	749	760	765	760	790

Table 5: Resolution Index: Panel Regressions. This table reports the results from the estimation of Equation 2 at the bank level. Panel A (B) provides results for the merged sample of negative (positive) events. The sample comprises listed banks in 22 countries. Columns (1) in both panels present weighted regressions. Columns (2) exclude G-SIBs. The dependent variable is the level of $\Delta CoVaR$. The independent variables are the Resolution Index, its squared term, Initial $\Delta CoVaR$, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks				
	7 days after the shock			
	(1)	(2)	(3)	(4)
Shock	0.8130***	0.8244***	0.7052***	0.8573***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Resolution	0.0340***	0.0683***	0.0831***	0.0538***
	(0.001)	(0.000)	(0.000)	(0.000)
Shock * $Resolution^2$			0.0107***	
			(0.000)	
Shock * Initial dCoVaR				0.2441***
				(0.000)
Shock * Size	0.1655***	0.1514***	0.1779***	0.1308***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Leverage	-0.0118***	-0.0178***	-0.0158***	-0.0143***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * GDP Growth	-0.0496***	-0.0366***	-0.0378***	-0.0771***
	(0.000)	(0.002)	(0.003)	(0.000)
Shock * Inflation	0.0185	0.0132	0.0350***	-0.0138
	(0.200)	(0.305)	(0.003)	(0.240)
Shock * Fin. Dev.	0.0007	0.0012	0.0021**	0.0018*
	(0.467)	(0.198)	(0.050)	(0.089)
Observations	259424	247896	259424	259424
R-squared	0.8591	0.8487	0.8417	0.8429
Within R-squared	0.1107	0.1365	0.1554	0.1618
Number of Banks	864	830	864	864

Panel B: Positive Shocks				
	7 days after the shock			
	(1)	(2)	(3)	(4)
Shock	-0.2204***	-0.1920***	-0.1834***	-0.1994***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Resolution	-0.0109***	-0.0209***	-0.0171***	-0.0200***
	(0.001)	(0.000)	(0.000)	(0.000)
Shock * $Resolution^2$			-0.0011**	
			(0.019)	
Shock * Initial dCoVaR				-0.0559***
				(0.000)
Shock * Size	-0.0399***	-0.0327***	-0.0371***	-0.0229***
	(0.000)	(0.000)	(0.000)	(0.009)
Shock * Leverage	0.0040***	0.0046***	0.0044***	0.0035***
	(0.001)	(0.000)	(0.000)	(0.002)
Shock * GDP Growth	0.0155**	0.0048	0.0110**	0.0173***
	(0.012)	(0.277)	(0.019)	(0.002)
Shock * Inflation	-0.0039	0.0002	-0.0061	0.0047
	(0.577)	(0.971)	(0.245)	(0.436)
Shock * Fin. Dev.	0.0002	-0.0001	-0.0002	-0.0003*
	(0.375)	(0.572)	(0.252)	(0.090)
Observations	190991	182423	190991	190991
R-squared	0.9006	0.8970	0.8831	0.8832
Within R-squared	0.0376	0.0326	0.0299	0.0314
Number of Banks	790	756	790	790

Table 6: IV Estimation. This table reports the results from instrumental variable estimation of Equation 2 at the bank level for a number of system-wide events. Panel A (B) reports the outcomes after negative (positive) shocks. The sample comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The variable to be instrumented for is the Resolution Index. The instruments are fiscal costs to output loss ratio of the latest crisis and the number of past crises. The independent variables are bank size and leverage, country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks					
	7 days after the shock				
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)	Panel (5)
Shock	0.8430*** (0.000)	0.7453*** (0.000)	0.6287*** (0.000)	1.1990*** (0.000)	0.8559*** (0.000)
Shock * Resolution	1.5248* (0.096)	1.0578* (0.060)	0.1346*** (0.000)	0.1212*** (0.000)	0.2603*** (0.000)
Shock * Size	-0.2154 (0.411)	-0.1045 (0.510)	0.1044*** (0.000)	0.2486*** (0.000)	0.1217*** (0.000)
Shock * Leverage	0.0071 (0.762)	0.0230 (0.321)	-0.0079*** (0.003)	-0.0252*** (0.000)	-0.0082*** (0.009)
Shock * GDP Growth	-0.1497** (0.037)	-0.2118*** (0.007)	-0.0114 (0.153)	-0.0622*** (0.004)	-0.0208 (0.104)
Shock * Inflation	0.4954* (0.084)	0.4351** (0.023)	-0.0117 (0.205)	0.0114 (0.393)	0.0318*** (0.001)
Shock * Fin. Dev.	0.1116 (0.109)	0.0509* (0.069)	0.0028*** (0.000)	0.0021* (0.052)	0.0092*** (0.000)
Observations	63008	64944	64504	66968	259424
J-stat	1.1003	1.8145	5.0037	1.7270	4.4273
P-value (J-stat)	0.5769	0.4036	0.0819	0.4217	0.1093
Number of Banks	716	738	733	761	864

Panel B: Positive Shocks				
	7 days after the shock			
	Greek Restr. (1)	Draghi (2)	Cyprus (3)	Panel (4)
Shock	-0.3963*** (0.000)	-0.0593*** (0.000)	-0.1324*** (0.000)	-0.1989*** (0.000)
Shock * Resolution	-0.0452*** (0.000)	-0.0066*** (0.006)	-0.0166*** (0.000)	-0.0243*** (0.000)
Shock * Size	-0.0834*** (0.000)	-0.0106*** (0.000)	-0.0232*** (0.000)	-0.0374*** (0.000)
Shock * Leverage	0.0088*** (0.000)	0.0011** (0.023)	0.0029*** (0.000)	0.0044*** (0.000)
Shock * GDP Growth	0.0136 (0.147)	0.0116** (0.032)	-0.0042 (0.380)	0.0102** (0.029)
Shock * Inflation	-0.0080 (0.133)	-0.0111*** (0.002)	0.0001 (0.986)	-0.0034 (0.317)
Shock * Fin. Dev.	-0.0006 (0.197)	0.0001 (0.686)	-0.0003** (0.012)	-0.0002 (0.237)
Observations	65912	66880	67320	190989
J-stat	0.2683	0.3031	1.2563	0.359
P-value (J-stat)	0.8745	0.8858	0.5336	0.8357
Number of Banks	749	760	765	789

Table 7: Principal Component Analysis. This table reports the results from the estimation of Equation 2 at the bank level for a number of system-wide events. Panel A (B) reports the outcomes after negative (positive) shocks. The sample comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The independent variables are the first five principal components, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. Each *column* in the tables presents the outcome of a separate regression. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks

	7 days after the shock				
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)	Panel (5)
Bail-in Framework	0.3623***	0.2721**	0.0123	0.1059***	0.1013***
Management Replacement	0.0245	0.0292	0.0213	0.1586***	0.0262
Administrative Process	0.0207	0.0233	0.0860***	0.1040**	0.0657***
Resolution Authority	-0.0822***	-0.0609***	-0.0324*	-0.0124	-0.0570***
Managing Losses	0.2254***	0.1382***	0.1750***	0.0516*	0.1563***

Panel B: Positive Shocks

	7 days after the shock			30 days after	7 days after
	Greek Restructuring	Draghi	Cypriot Bail-in	Draghi	Panel
	(1)	(2)	(3)	(4)	(5)
Bail-in Framework	-0.0362***	-0.0068	-0.0050	-0.0145***	-0.0118**
Management Replacement	-0.0587***	-0.0021	-0.0219***	-0.0156*	-0.0298***
Administrative Process	-0.0342*	0.0033	-0.0268***	-0.0053	-0.0226***
Resolution Authority	0.0031	0.0037	-0.0025	0.0113	-0.0008
Managing Losses	-0.0254**	-0.0091**	-0.0094	-0.0208***	-0.0150**

Table 8: Resolution Index, Idiosyncratic Events. This table reports the results from the estimation of Equation 2 at the bank level for a number of bank-specific events. The samples for columns (1), (3) and (4) comprise listed banks in 7 European countries. The sample for column (2) comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The independent variables are the Resolution Index, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

	7 days after the shock			
	European Banks	All Banks	European Banks	
	Société Générale (1)	Bear Stearns (2)	B. Esp. Santo (3)	D. Bank (4)
Shock	0.2343**	0.3991***	0.3396***	0.7118***
	(0.030)	(0.000)	(0.000)	(0.000)
Shock * Resolution	-0.0091*	0.0042	0.0130	-0.0192*
	(0.097)	(0.498)	(0.206)	(0.094)
Shock * Size	0.0709***	0.0577***	0.0483***	0.1065***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Leverage	-0.0027*	-0.0056***	-0.0035**	-0.0056
	(0.052)	(0.004)	(0.023)	(0.313)
Shock * GDP Growth	-0.0776*	-0.0017	0.0041	0.0413
	(0.096)	(0.882)	(0.727)	(0.124)
Shock * Inflation	0.0618	0.0052	0.0728***	0.0479
	(0.116)	(0.646)	(0.000)	(0.392)
Shock * Fin. Dev.	0.0028*	-0.0040***	0.0005	-0.0021
	(0.061)	(0.001)	(0.465)	(0.326)
Bank FE	Yes	Yes	Yes	Yes
Observations	22088	62920	21296	15928
Adjusted R-squared	0.8718	0.9279	0.9557	0.8673
Within R-squared	0.0995	0.0564	0.1749	0.1305
Number of Banks	251	715	242	181

A Appendix Tables

Table A1: Key Attributes of Effective Resolution Regimes for Financial Institutions (FSB (2011))

#	Attribute	Definition
KA 1	**Scope**	Resolution regimes should apply to all potentially systemically important financial institutions, i. e., banks, financial holding and insurance companies, non-regulated entities within conglomerates, branches of foreign firms and financial market infrastructures.
KA 2	**Resolution authority**	Each country should designate an entity responsible for resolution that is operationally independent. If several agencies are responsible for resolution (e. g., for different sectors), roles and cooperation mechanisms should be clearly stated.
KA 3	**Resolution powers**	RAs should have a broad set of resolution tools available, including powers to replace the management, the transfer of assets, the establishment of a bridge bank or an asset management company or bail-in powers.
KA 4	**Set-off, netting, collateralization, segregation of client assets**	Provisions shall remain in place and entry into resolution should not trigger set-off or early termination rights.
KA 5	**Safeguards**	Creditors should never be worse off than in liquidation and the RA may need to compensate creditors if it departs from the general hierarchy of claims. The pari passu principle should apply, i. e. creditors within the same class should be treated equally and without preferences, provisions of public funds only being used after a bail-in. Actions should be subject to legal review.
KA 6	**Funding of firms in resolution**	The use of public funds for resolution should be kept to a minimum and respective mechanisms must be in place.
KA 7	**Legal framework conditions for cross-border cooperation**	Cooperation should be encouraged and facilitated. Automatic initiation of resolution activities in other countries should be avoided and creditors from different jurisdictions should be treated equally. Branches should be subjected to host country law.
KA 8	**Crisis Management Groups (CMGs)**	RAs in home and host countries of G-SIFIs should ensure preparedness for crises and resolution via CMGs that comprise representatives of institutions involved in resolution such as of the respective supervisory and resolution authority, the central bank, the finance ministry and the deposit insurance scheme.
KA 9	**Institution-specific cross-border cooperation agreements**	Agreements should be made for all G-SIFIs, regarding inter alia the establishment of CMGs as well as responsibilities for the different actors involved and information sharing.
KA 10	**Resolvability assessments**	RAs should assess the feasibility of resolution strategies for G-SIFIs on a regular basis. They may require changes to business practices or structures.
KA 11	**Recovery and resolution planning**	Recovery plans, entailing recovery options to mitigate possible shocks, are to be developed by the banks, while the competent resolution authority shall develop resolution plans for banks under its radar to familiarize with legal and operating structures.
KA 12	**Access to information and information sharing**	Legal impediments to information sharing should be dismantled. Firms should be required to introduce Information Management Systems that provide information on regular basis.

Table A2: Regression Variables Description.

Variable	Description	Source
Size	Total individual bank assets, denominated in dollars.	Bankscope
Ln(Size)	Natural logarithm of total individual bank assets, denominated in dollars.	Bankscope
Leverage Ratio	Ratio of total individual bank assets and total individual bank equity	Bankscope
Ann. GDP Growth	Annual country GDP growth	World Bank's WDI
Inflation	Annual country inflation	World Bank's WDI
Dom. Credit to GDP	Domestic bank credit to GDP	World Bank's WDI
Fiscal Costs to Output Loss	Fiscal Costs to GDP to Output loss to GDP of past crises in a country. Fiscal costs are defined as the component of gross fiscal outlays related to the restructuring of the financial sector. They include fiscal costs associated with bank recapitalizations but exclude asset purchases and direct liquidity assistance from the treasury. Output losses are computed as the cumulative sum of the differences between actual and trend real GDP over the period [T, T+3], expressed as a percentage of trend real GDP, with T the starting year of the crisis.	Laeven and Valencia (2018), Own calculations
Number of Crises	Number of past banking crises in a country	Laeven and Valencia (2018), Own calculations

Table A3: Resolution Index: Weighted Regressions. This table reports the results from the estimation of Equation 2 at the bank level for a number of system-wide events. Panel A (B) reports the outcomes after negative (positive) shocks. The regressions are weighted by the number of banks per country. The sample comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The independent variables are the Resolution Index, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks				
	7 days after the shock			
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)
Shock	0.7862***	0.7147***	0.5831***	1.3399***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Resolution	0.0305***	0.0294***	0.0350***	0.0861***
	(0.007)	(0.000)	(0.000)	(0.000)
Shock * Size	0.1435***	0.1534***	0.1238***	0.2830***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Leverage	-0.0087*	-0.0089**	-0.0085***	-0.0255***
	(0.055)	(0.030)	(0.004)	(0.000)
Shock * GDP Growth	-0.0876***	-0.0647***	-0.0272***	-0.0472**
	(0.002)	(0.008)	(0.005)	(0.031)
Shock * Inflation	0.0372**	0.0767**	0.0093	0.0489
	(0.027)	(0.010)	(0.393)	(0.119)
Shock * Fin. Dev.	0.0000	0.0007	0.0017***	0.0015
	(0.983)	(0.735)	(0.010)	(0.160)
Observations	63008	64944	64504	66968
R-squared	0.9333	0.9380	0.9418	0.9062
Within R-squared	0.2170	0.1297	0.1584	0.3429
Number of Banks	716	738	733	761

Panel B: Positive Shocks				
	7 days after the shock			30 days after
	Greek Restr. (1)	Draghi (2)	Cyprus (3)	Draghi (30 days) (4)
Shock	-0.4107***	-0.0587	-0.1324***	-0.2029***
	(0.000)	(0.162)	(0.000)	(0.000)
Shock * Resolution	-0.0302***	-0.0056**	-0.0052**	-0.0140***
	(0.000)	(0.035)	(0.012)	(0.000)
Shock * Size	-0.0760***	-0.0095	-0.0227***	-0.0347***
	(0.000)	(0.306)	(0.000)	(0.000)
Shock * Leverage	0.0064***	0.0010	0.0024***	0.0031***
	(0.002)	(0.185)	(0.006)	(0.003)
Shock * GDP Growth	0.0137*	0.0122*	0.0053	0.0264**
	(0.074)	(0.087)	(0.320)	(0.018)
Shock * Inflation	-0.0050	-0.0087	-0.0091	-0.0246***
	(0.522)	(0.223)	(0.135)	(0.006)
Shock * Fin. Dev.	-0.0003	0.0001	0.0000	0.0000
	(0.466)	(0.532)	(0.937)	(0.913)
Observations	65912	66880	67320	84360
R-squared	0.9221	0.9583	0.9654	0.9563
Within R-squared	0.0530	0.0031	0.0224	0.0756
Number of Banks	749	760	765	760

Table A4: Resolution Index: No G-SIBs. This table reports the results from the estimation of Equation 2 at the bank level for a number of system-wide events. Panel A (B) reports the outcomes after negative (positive) shocks. The sample comprises listed banks in 22 countries, excluding Global Systemically Important Banks (G-SIBs). The dependent variable is the level of $\Delta CoVaR$. The independent variables are the Resolution Index, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks

	7 days after the shock			
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)
Shock	0.8132***	0.7244***	0.6019***	1.1568***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Resolution	0.0281***	0.0387***	0.0583***	0.1296***
	(0.002)	(0.000)	(0.000)	(0.000)
Shock * Size	0.1544***	0.1484***	0.1059***	0.2090***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Leverage	-0.0172***	-0.0137***	-0.0137***	-0.0252***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * GDP Growth	-0.0591***	-0.0822**	-0.0058	-0.0267
	(0.002)	(0.010)	(0.490)	(0.160)
Shock * Inflation	0.0325**	0.1178***	-0.0171	-0.0087
	(0.016)	(0.001)	(0.141)	(0.482)
Shock * Fin. Dev.	-0.0009	0.0016	0.0009*	0.0020**
	(0.584)	(0.581)	(0.068)	(0.024)
Observations	60280	62040	61600	63976
R-squared	0.9118	0.9297	0.9341	0.9176
Within R-squared	0.2531	0.1411	0.1735	0.3923
Number of Banks	685	705	700	761

Panel B: Positive Shocks

	7 days after the shock			30 days after
	Greek Restructuring (1)	Draghi (2)	Cypriot Bail-in (3)	Draghi (30 days) (4)
Shock	-0.3822***	-0.0580	-0.1281***	-0.1948***
	(0.000)	(0.125)	(0.000)	(0.000)
Shock * Resolution	-0.0454***	-0.0083**	-0.0082***	-0.0219***
	(0.000)	(0.028)	(0.002)	(0.000)
Shock * Size	-0.0681***	-0.0091	-0.0222***	-0.0326***
	(0.000)	(0.203)	(0.000)	(0.000)
Shock * Leverage	0.0084***	0.0007	0.0037***	0.0036***
	(0.000)	(0.431)	(0.000)	(0.000)
Shock * GDP Growth	0.0084	0.0075	-0.0039	0.0130
	(0.254)	(0.210)	(0.465)	(0.156)
Shock * Inflation	0.0015	-0.0091*	0.0009	-0.0176***
	(0.753)	(0.058)	(0.856)	(0.007)
Shock * Fin. Dev.	-0.0003	-0.0000	-0.0001	-0.0002
	(0.416)	(0.843)	(0.253)	(0.343)
Observations	62920	63888	64328	80586
R-squared	0.9114	0.9543	0.9623	0.9530
Within R-squared	0.0619	0.0045	0.0258	0.0966
Number of Banks	715	726	731	726

Table A5: Resolution Index: Squared Resolution Index. This table reports the results from the estimation of Equation 2 at the bank level for a number of system-wide events. Panel A (B) reports the outcomes after negative (positive) shocks. The sample comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The independent variables are the Resolution Index, its squared term, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks				
	7 days after the shock			
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)
Shock	0.6224*** (0.000)	0.6489*** (0.000)	0.4513*** (0.001)	1.0759*** (0.000)
Shock * Resolution	0.0677*** (0.000)	0.0577*** (0.000)	0.1101*** (0.000)	0.0897*** (0.000)
Shock * $Resolution^2$	0.0128*** (0.000)	0.0074** (0.027)	0.0141*** (0.000)	0.0089*** (0.002)
Shock * Size	0.1794*** (0.000)	0.1668*** (0.000)	0.1258*** (0.000)	0.2381*** (0.000)
Shock * Leverage	-0.0154*** (0.000)	-0.0125*** (0.000)	-0.0096*** (0.001)	-0.0234*** (0.000)
Shock * GDP Growth	-0.0429** (0.046)	-0.0827** (0.014)	-0.0074 (0.425)	-0.0594*** (0.005)
Shock * Inflation	0.0263* (0.064)	0.1216*** (0.001)	0.0103 (0.346)	0.0301** (0.029)
Shock * Fin. Dev.	-0.0006 (0.708)	0.0020 (0.545)	0.0025*** (0.001)	0.0026*** (0.004)
Observations	63008	64944	64504	66968
R-squared	0.9056	0.9255	0.9275	0.9119
Within R-squared	0.2737	0.1541	0.1958	0.4227
Number of Banks	716	738	733	761

Panel B: Positive Shocks				
	7 days after the shock			30 days after
	Greek Restructuring (1)	Draghi (2)	Cypriot Bail-in (3)	Draghi (30 days) (4)
Shock	-0.3494*** (0.000)	-0.0505 (0.238)	-0.1281*** (0.000)	-0.1794*** (0.000)
Shock * Resolution	-0.0335*** (0.000)	-0.0063** (0.012)	-0.0073*** (0.001)	-0.0162*** (0.000)
Shock * $Resolution^2$	-0.0033*** (0.000)	-0.0006 (0.182)	-0.0003 (0.505)	-0.0015*** (0.002)
Shock * Size	-0.0779*** (0.000)	-0.0091 (0.295)	-0.0253*** (0.000)	-0.0344*** (0.000)
Shock * Leverage	0.0077*** (0.000)	0.0007 (0.487)	0.0036*** (0.000)	0.0033*** (0.001)
Shock * GDP Growth	0.0182** (0.020)	0.0094 (0.120)	-0.0005 (0.921)	0.0186** (0.046)
Shock * Inflation	-0.0118** (0.021)	-0.0109** (0.017)	-0.0029 (0.592)	-0.0236*** (0.000)
Shock * Fin. Dev.	-0.0006 (0.127)	-0.0000 (0.980)	-0.0002* (0.066)	-0.0002 (0.298)
Observations	65912	66880	67320	84360
R-squared	0.8993	0.9488	0.9591	0.9477
Within R-squared	0.0647	0.0048	0.0283	0.1023
Number of Banks	749	760	765	760

Table A6: Resolution Index: Initial $\Delta CoVaR$. This table reports the results from the estimation of Equation 2 at the bank level for a number of system-wide events. Panel A (B) reports the outcomes after negative (positive) shocks. The sample comprises listed banks in 22 countries. The dependent variable is the level of $\Delta CoVaR$. The independent variables are the Resolution Index, Initial $\Delta CoVaR$, bank size and leverage, and country annual GDP growth, inflation and financial development, and their interactions with the event variable. The numbers in parentheses are p-values. We apply a two-way clustering of standard errors at the *bank* and *time* levels. Statistical significance at the 1%, 5% and 10% levels is denoted by ***, **, and *, respectively.

Panel A: Negative Shocks				
	7 days after the shock			
	Subprime (1)	Lehman (2)	Greek Bailout (3)	US Downgrade (4)
Shock	0.8378***	0.7463***	0.6291***	1.2008***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Resolution	0.0224**	0.0201***	0.0482***	0.1239***
	(0.012)	(0.001)	(0.000)	(0.000)
Shock * Initial dCoVaR	0.0041	0.1369**	0.1165***	0.2857***
	(0.895)	(0.014)	(0.004)	(0.000)
Shock * Size	0.1769***	0.1316***	0.1022***	0.1813***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * Leverage	-0.0176***	-0.0107***	-0.0112***	-0.0201***
	(0.000)	(0.000)	(0.000)	(0.000)
Shock * GDP Growth	-0.0719***	-0.1104***	-0.0170	-0.0878***
	(0.000)	(0.002)	(0.105)	(0.001)
Shock * Inflation	0.0421***	0.0747**	-0.0254**	-0.0359**
	(0.003)	(0.034)	(0.019)	(0.011)
Shock * Fin. Dev.	-0.0010	0.0014	0.0015**	0.0023***
	(0.567)	(0.669)	(0.027)	(0.009)
Observations	63008	64944	64504	66968
R-squared	0.9048	0.9260	0.9269	0.9139
Within R-squared	0.2671	0.1593	0.1890	0.4356
Number of Banks	716	738	733	761

Panel B: Positive Shocks				
	7 days after the shock			30 days after
	Greek Restructuring (1)	Draghi (2)	Cypriot Bail-in (3)	Draghi (30 days) (4)
Shock	-0.3977***	-0.0593	-0.1327***	-0.1999***
	(0.000)	(0.131)	(0.000)	(0.000)
Shock * Resolution	-0.0257***	-0.0088**	-0.0089***	-0.0220***
	(0.000)	(0.026)	(0.002)	(0.000)
Shock * Initial dCoVaR	-0.1901***	-0.0107	-0.0458***	-0.0424***
	(0.000)	(0.534)	(0.000)	(0.002)
Shock * Size	0.0025	-0.0076	-0.0166***	-0.0272***
	(0.728)	(0.202)	(0.002)	(0.000)
Shock * Leverage	0.0014	0.0007	0.0032***	0.0032***
	(0.184)	(0.341)	(0.000)	(0.001)
Shock * GDP Growth	0.0253***	0.0115	0.0098*	0.0255**
	(0.001)	(0.114)	(0.064)	(0.012)
Shock * Inflation	0.0316***	-0.0086**	0.0015	-0.0154**
	(0.000)	(0.013)	(0.732)	(0.012)
Shock * Fin. Dev.	-0.0005**	-0.0000	-0.0003**	-0.0004*
	(0.036)	(0.771)	(0.023)	(0.072)
Observations	65912	66880	67320	84360
R-squared	0.9018	0.9488	0.9592	0.9478
Within R-squared	0.0884	0.0048	0.0308	0.1040
Number of Banks	749	760	765	760

B Appendix Principal Component Analysis

The Principal Component Analysis (PCA) is a statistical procedure to transform the observations of a set of possibly correlated variables into a set of uncorrelated variables (principal components). The transformation is conducted in such a way that the first component explains the largest possible variation in the data, and every additional component explains the highest variance, conditional on being orthogonal to the preceding components. PCA is usually used to provide a lower-dimensional picture of high-dimensional data by using the first several principal components that explain the largest variation in the original variables.

B.1 Optimization Problem

Let x be a zero-mean random variable. Suppose we want the direction w such that the projection of x along this direction has maximum variance:

$$\max_w \operatorname{Var}(w'x) \quad \text{st.} \quad \|w\| = 1.$$

We have

$$\begin{aligned} \operatorname{Var}(w'x) &= \mathrm{E}w'xx'w \\ &= w'\Sigma w. \end{aligned}$$

The Lagrangian is

$$L = w'\Sigma w + \lambda(w'w - 1).$$

The stationary condition is

$$\begin{aligned} \frac{\partial L}{\partial w} = 2\Sigma w - 2\lambda w &= 0, \\ \Sigma w &= \lambda w. \end{aligned}$$

Thus w is an eigenvector of Σ. Since

$$w'\Sigma w = w'(\lambda w) = \lambda,$$

the direction with maximum variance is the largest eigenvector. This procedure can be iterated to get the second largest variance projection (orthogonal to the first one), and so on. For a set of data points, we use the ML estimate of the covariance matrix.

B.2 PCA and Bank Resolution

In order to gain better intuition about the particular drivers of the relationship between bank resolution and systemic risk, we can run regressions that include interactions of the shock variable with each item in the resolution index. Since the individual bank resolution measures may be correlated, we perform a Principal Component Analysis. PCA is usually undertaken in cases when there is a sufficient correlation among the original variables to warrant the factor/component representation and a reduction in dimensionality.

To this end, we perform the following steps:

1. We tabulate the correlation matrix of our resolution measures and calculate Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy[14] to identify whether PCA is necessary.

2. We perform PCA, describe the explained variation of the individual components and choose the number of principal components that we will use in our further analysis

3. Based on the most dominant factor loadings, we provide descriptors (names) of the individual components

4. Using the loadings of the individual components, we derive the fitted values of each principal component

[14] The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (Cerny and Kaiser, 1977) takes values between 0 and 1, with small values indicating that overall the variables have little in common to warrant a principal components analysis and values above 0.5 are considered satisfactory for a principal components analysis.

Table B1: Correlation: Resolution Measures. This table reports the pairwise correlations between the resolution measures defined in Table1. The data spans the period 2000–2016 and covers 22 bank resolution measures in the 22 FSB countries in our sample, or 374 observation in total.

	Q 11	Q 12	Q 13	Q 14	Q 15	Q 16	Q 17	Q 21	Q 22	Q 23	Q 24	Q 25	Q 26	Q 27	Q 31	Q 32	Q 33	Q 34	Q 41	Q 42	Q 43	Q 44
Q 11	1																					
Q 12	0.39	1																				
Q 13	0.25	-0.50	1																			
Q 14	0.13	0.10	0.27	1																		
Q 15	0.35	0.35	-0.13	0.24	1																	
Q 16	-0.03	0.18	-0.09	0.20	0.01	1																
Q 17	0.28	0.21	0.12	0.26	0.11	0.16	1															
Q 21	0.25	0.34	0.05	0.23	0.18	0.23	0.12	1														
Q 22	0.21	0.32	0.02	0.06	0.12	0.22	0.13	0.62	1													
Q 23	0.37	0.09	0.47	0.49	0.38	0.13	0.09	0.50	0.41	1												
Q 24	0.42	0.28	0.03	0.41	0.39	0.12	0.22	0.06	0.20	0.44	1											
Q 25	0.58	0.13	0.28	0.27	0.33	0.03	0.37	0.31	0.29	0.47	0.42	1										
Q 26	0.21	0.41	-0.20	0.19	0.05	0.59	0.32	0.20	0.17	0.05	0.18	0.17	1									
Q 27	0.29	0.23	0.12	0.32	0.21	-0.12	0.22	0.17	0.25	0.13	0.24	0.29	0.22	1								
Q 31	0.36	0.21	0.29	0.50	0.15	0.27	0.29	0.63	0.55	0.52	0.32	0.35	0.21	0.29	1							
Q 32	0.42	0.15	0.16	0.37	0.07	0.25	0.22	0.40	0.35	0.40	0.25	0.49	0.33	0.32	0.61	1						
Q 33	0.21	0.35	0.01	0.41	0.20	0.40	0.40	0.30	0.44	0.33	0.29	0.14	0.33	0.10	0.54	0.41	1					
Q 34	0.25	0.32	-0.10	0.17	0.09	0.34	0.21	0.08	0.20	0.09	0.34	0.29	0.51	0.25	0.24	0.34	0.29	1				
Q 41	0.19	0.43	-0.29	0.16	0.12	0.39	0.23	0.17	0.14	0.08	0.24	0.21	0.69	0.18	0.17	0.27	0.18	0.62	1			
Q 42	0.15	0.34	-0.23	0.13	0.11	0.20	0.19	0.13	0.11	0.12	0.27	0.17	0.49	0.14	0.13	0.21	0.14	0.56	0.79	1		
Q 43	0.08	0.19	0.06	0.21	-0.24	0.54	0.26	0.18	0.18	0.11	-0.08	-0.03	0.38	-0.15	0.22	0.19	0.33	0.26	0.40	0.42	1	
Q 44	0.14	0.31	-0.21	0.11	0.11	0.46	0.19	0.12	0.10	0.02	0.16	0.15	0.59	0.13	0.12	0.19	0.22	0.39	0.72	0.40	0.35	1

Table B2: Kaiser-Meyer-Olkin Measure of Sampling Adequacy. This table reports Kaiser-Meyer-Olkin Measure of Sampling Adequacy for the resolution measures defined in Table1. The data spans the period 2000–2016 and covers 22 bank resolution measures in the 22 FSB countries in our sample, or 374 observation in total.

Variable	KMO
Q 11	0.5918
Q 12	0.6836
Q 13	0.4173
Q 14	0.5901
Q 15	0.5342
Q 16	0.6415
Q 17	0.7410
Q 21	0.7022
Q 22	0.6561
Q 23	0.6661
Q 24	0.6072
Q 25	0.8267
Q 26	0.8083
Q 27	0.5640
Q 31	0.7988
Q 32	0.7395
Q 33	0.8123
Q 34	0.8761
Q 41	0.7377
Q 42	0.6164
Q 43	0.5448
Q 44	0.7193
Overall	0.6808

Tables B1 and B2 represent, respectively,. the correlation matrix of our 22 variables and a summary of the KMO measure of sampling adequacy. The data spans the period 2000–2016 and covers the 22 measures defined in Table 1 for the 22 FSB countries in our sample, or 374 observation in total. Table B1 indicates substantial correlations among some variables, and almost all KMO measures in Table B2 are above 0.5. The overall KMO measure for the data is also close to 0.70. In summary, these indicators provide a strong support for the application of PCA to our data.

We perform PCA analysis on our dataset and report the results in Table B3. Figure B1 depicts the eigenvalues of all 22 components. The eigenvalues of six of the components are above unity, meaning that they represent the variation at least as well as the original measures. The total variation of the dataset that is explained by the six components is 0.70. The eigenvalue of the sixth component is not significantly different from 1 at the

Table B3: Principal Component Analysis: Eigenvalues. This table reports the eigenvalues from a Principal Component Analysis on the resolution measures defined in Table1. The data spans the period 2000–2016 and covers 22 bank resolution measures in the 22 FSB countries in our sample, or 374 observation in total. The components are sorted by their eigenvalues in a descending order.

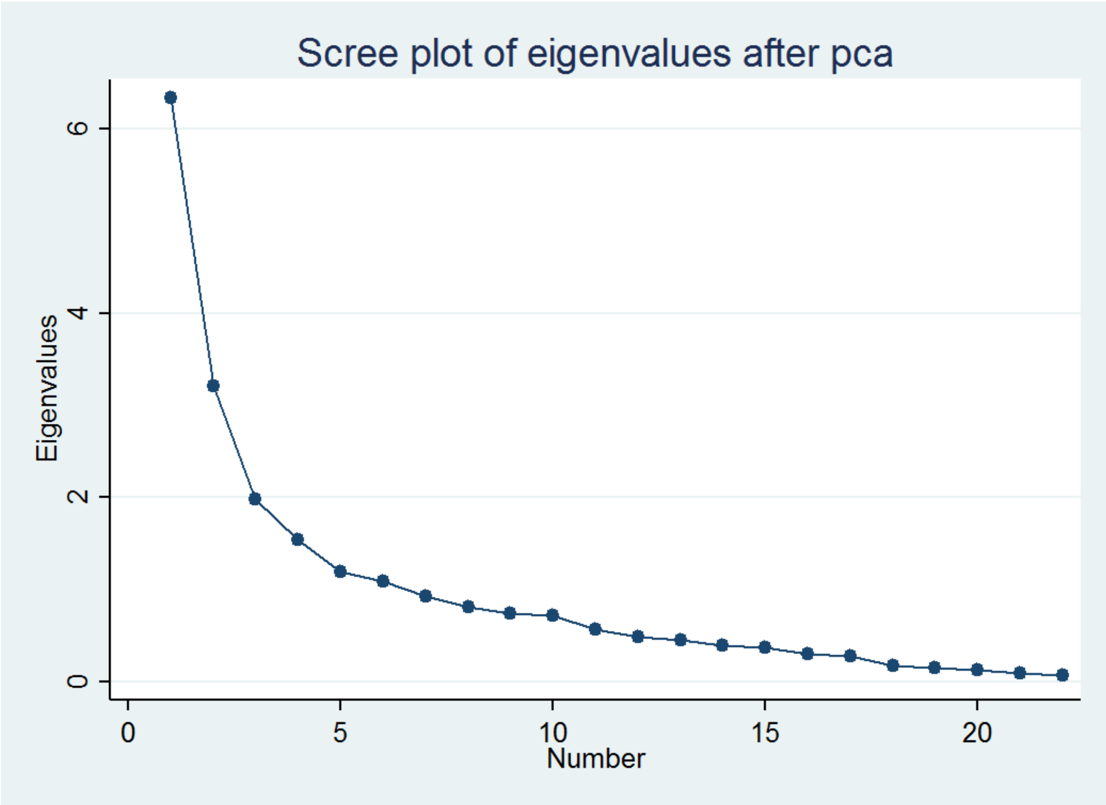
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	6.3361	3.1301	0.2880	0.2880
Comp2	3.2060	1.2246	0.1457	0.4337
Comp3	1.9814	0.4408	0.0901	0.5238
Comp4	1.5406	0.3535	0.0700	0.5938
Comp5	1.1871	0.0946	0.0540	0.6478
Comp6	1.0925	0.1618	0.0497	0.6974
Comp7	0.9306	0.1255	0.0423	0.7397
Comp8	0.8052	0.0649	0.0366	0.7763
Comp9	0.7402	0.0217	0.0336	0.8100
Comp10	0.7185	0.1553	0.0327	0.8426
Comp11	0.5633	0.0828	0.0256	0.8682
Comp12	0.4804	0.0285	0.0218	0.8901
Comp13	0.4519	0.0608	0.0205	0.9106
Comp14	0.3911	0.0225	0.0178	0.9284
Comp15	0.3686	0.0635	0.0168	0.9452
Comp16	0.3051	0.0218	0.0139	0.9590
Comp17	0.2833	0.1046	0.0129	0.9719
Comp18	0.1787	0.0305	0.0081	0.9800
Comp19	0.1482	0.0246	0.0067	0.9868
Comp20	0.1236	0.0298	0.0056	0.9924
Comp21	0.0937	0.0196	0.0043	0.9966
Comp22	0.0741	.	0.0034	1

5% significance level. All preceding components do not include 1 in their 95% confidence interval and therefore we proceed our analysis with the first five principal components. The explained variation is at the high level of 0.65.

Table B4 presents the factor loadings of the eigenvalues for each of the 22 resolution measures. The loadings represent the correlations between the components and the original variables. The unexplained variation of each individual variable using the five components is relatively low and rarely above 0.40. To gain a better intuition of which original variables are most correlated with the principal components, we exclude the values that are below 0.30 in absolute terms and present the results in Table B5.[15] We notice that the first principal component is most correlated with the bail-in subset of survey questions and therefore, we name the component "Bail-in Framework". Using the same logic, we name components 2–5 "Management Replacement", "Administrative Process",

[15]The threshold of 0.3 is a standard rule of thumb in practice.

Figure B1: Principal Component Analysis: Eigenvalues This figure reports the eigenvalues from a Principal Component Analysis on the resolution measures defined in Table1. The data spans the period 2000–2016 and covers 22 bank resolution measures in the 22 FSB countries in our sample, or 374 observation in total. The components are sorted by their eigenvalues in a descending order.



"Resolution Authority" and "Managing Losses".

In the final step, we use the factor loadings to derive the fits of the five principal components and use them in the regression analysis in Section 4.4.

Table B4: Principal Component Analysis: Loadings. This table reports the factor loadings (the correlation between the original variables and the respective principal components) of the resolution measures defined in Table1 and the first five principal components from Table B3. The data spans the period 2000–2016 and covers 22 bank resolution measures in the 22 FSB countries in our sample, or 374 observation in total.

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
Q 11	0.1622	0.1320	0.1202	0.0781	-0.3482	0.4266
Q 12	0.0996	0.2186	0.1382	-0.4741	-0.0522	0.2478
Q 13	-0.0269	-0.0106	0.0028	0.6240	-0.0483	0.1672
Q 14	0.0106	-0.0781	0.4411	0.2363	0.2334	0.3344
Q 15	-0.0861	-0.0284	0.5241	-0.2845	-0.1089	0.2851
Q 16	0.1406	0.0531	0.0602	0.0083	0.4809	0.3173
Q 17	0.1466	0.0906	0.0726	0.0882	-0.0196	0.7620
Q 21	-0.0527	0.5341	-0.0707	-0.0724	0.0117	0.2675
Q 22	-0.0379	0.5398	-0.0959	-0.1109	-0.0204	0.2719
Q 23	-0.0648	0.1679	0.3279	0.2176	0.0482	0.3205
Q 24	0.0818	-0.1271	0.4994	-0.0090	-0.0625	0.3430
Q 25	0.1739	0.1031	0.1201	0.2049	-0.3392	0.3631
Q 26	0.3741	0.0193	-0.0327	-0.0483	0.1213	0.2989
Q 27	0.1711	0.1068	0.0220	0.0534	-0.3705	0.5742
Q 31	0.0026	0.3794	0.0961	0.1667	0.0799	0.2455
Q 32	0.1752	0.2543	-0.0196	0.2270	-0.0796	0.4226
Q 33	-0.0290	0.2082	0.2653	-0.0453	0.3398	0.3706
Q 34	0.3935	-0.0466	0.0146	0.0305	-0.0623	0.3921
Q 41	0.4503	-0.0601	-0.0262	-0.0937	0.0136	0.1544
Q 42	0.3910	-0.0746	-0.0160	-0.0598	-0.0234	0.4008
Q 43	0.2052	0.0797	-0.1415	0.1473	0.3949	0.3471
Q 44	0.3401	-0.0606	0.0029	-0.0815	0.1147	0.4366

Table B5: Principal Component Analysis: Coefficients $\geq |0.3|$. This table reports the factor loadings of the resolution measures defined in Table1 and the first five principal components from Table B3 that are above the absolute value of 0.3. The data spans the period 2000–2016 and covers 22 bank resolution measures in the 22 FSB countries in our sample, or 374 observation in total.

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
Q 11					-0.3482	0.4266
Q 12				-0.4741		0.2478
Q 13				0.6240		0.1672
Q 14			0.4411			0.3344
Q 15			0.5241			0.2851
Q 16					0.4809	0.3173
Q 17						0.7620
Q 21		0.5341				0.2675
Q 22		0.5398				0.2719
Q 23			0.3279			0.3205
Q 24			0.4994			0.3430
Q 25					-0.3392	0.3631
Q 26	0.3741					0.2989
Q 27					-0.3705	0.5742
Q 31		0.3794				0.2455
Q 32						0.4226
Q 33					0.3398	0.3706
Q 34	0.3935					0.3921
Q 41	0.4503					0.1544
Q 42	0.3910					0.4008
Q 43					0.3949	0.3471
Q 44	0.3401					0.4366