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MEASURING SWEDISH BANK RESOLUTION COST

Marianna Blix Grimaldi and Johan Linder

Preface

The Swedish National Debt Office plays a key role in the Swedish economy. Among its key responsibilities are serving as the Government´s internal bank, providing efficient management of public debt and issuing government guaranties and credits to support the smooth functioning of financial markets.

Since 2016, the Debt Office has an added mandate to support financial stability through the so-called bank resolution authority. Its duties encompass handling banks in crisis, as well as ensuring that effective deposit guarantees and investment protections are in place. As part of its responsibility for preserving financial stability, the Debt Office collaborates with other central actors, including the Ministry of Finance, the Riksbank and Swedish Financial Supervisory Authority.

The Debt Office also publishes Focus Reports and reviews of various issues within its purview. The aim is to shed light on central questions and provide in-depth information about them, both the Debt Office's regular target groups as well as to other policy institutions and the public. The series of reports also enables Debt Office employees to publish analyses externally and thereby receive valuable feedback. One particular ambition is to increase the overall awareness and knowledge about key issues relevant for the Debt Office's and thereby contribute to increased dialogue and better transparency.

Discussion of the Debt Office's questions is important not only for us as an authority, but for the broader social and economic debate.

Hans Lindblad
Director-General, Swedish National Debt Office

Focus report[1]

Economic Analysis Department

Measuring bank resolution costs – a market-based approach

Prepared by Marianna Blix Grimaldi and Johan Linder[2]
May 2018

Abstract

Our understanding of bank resolution costs is still at an early stage. In this paper, we contribute to the literature by advancing the conceptual understanding and measurement of bank resolution costs. More specifically, we identify the costs that bank creditors are liable for in times of financial distress. To this end, we construct a measure of resolution costs that draws on the contingent claim literature. We apply our model to the largest Swedish banks and compare the results to those obtained for the European systemically important banks identified by the European Banking Authority. We show that, after peaking during the financial crisis, Swedish bank resolution costs have declined significantly more than those of their European peers. As expected, we find that bank capital and economic outlook are important contributors of bank resolution costs. We also find that policy action such as the announcement of the Bank Recovery and Resolution Directive is a key driver of resolution costs across European countries.

Keywords: European bank resolution costs, banking risk, contingent claim analysis
JEL Classification Numbers: G01; G13; G21; G28

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[1] *The Swedish National Debt Office's Focus Reports describe preliminary findings and are published to economists and other interested readers solely to stimulate discussion and elicit comments. The views expressed in the Focus Reports are those of the authors and do not necessarily reflect the views of the Swedish National Debt Office. Any errors or omissions are the responsibility of the authors.*

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Introduction

The 2007–10 global financial crisis was followed by the sovereign debt and banking crisis in Europe. Despite differences across countries, a common viewpoint espoused among regulators was that some banks were simply too-big-to-fail. As a consequence, the only option available to stabilize the financial sector was to bail-out banks about to fail. The alternative of letting the bank actually go into bankruptcy was deemed too dangerous to adopt in the middle of the crisis (Geithner, 2014).

The costs of adopting a too-big-to-fail policy were high. According to Philippon and Salord (2017), in the aftermath of the financial crisis the European taxpayers covered more than two-thirds of the cost of absorbing losses and recapitalizing financial institutions in the region. Between October 2008 and 31 December 2012, the European Commission approved €3.6 trillion of state aid measures to financial institutions, of which €1.6 trillion was actually used. Member states thereby provided capital support to the financial sector equivalent to almost 5 percent of EU GDP in 2012.

After the crisis and several bank bail-outs, a new framework was put in place to solve, or at least mitigate the consequences of, the too-big-to-fail problem and deal with bank distress in a more orderly manner.[3] In short, one of the regulators' top priorities was to make sure that, in the event of a new crisis, there would be a credible *bail-in* instead of a *bail-out*. In May 2014 the Council of the European Union and the European Parliament adopted the Bank Recovery and Resolution Directive (BRRD). It included a set of harmonized rules for managing crises in financial institutions in Europe.[4] The main objective of the BRRD is to provide a framework whereby distressed financial institutions can be managed (resolved) without tax-payer's money. The framework enables the resolution authority to write down and/or convert into equity the claims of a broad range of creditors, according to a predefined creditor hierarchy. It thus in effect rejects bailouts and emphasizes the responsibility of bank stakeholders in encouraging better risk management and making financial strength a more important internal objective. By improving market discipline over banks' activities and limiting the risks banks take, costs for managing future bank failures could thus be reduced.

The legalistic intricacies of the resolution regime and their effects on the capital structure of banks have been extensively analyzed in the literature. By contrast, there has been comparatively little analysis on how to identify and measure expected costs of resolving a distressed bank under the new framework, i.e. the bank resolution costs.

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[3] *Distress events usually include default; however, distress is broader than default and comprises, for example, debt restructuring, government interventions, recapitalizations.*

[4] *The Swedish transposition of BRRD came into force on 1 February 2016 in Sweden. In February 2017, the Swedish National Debt Office and Resolution Authority published a decision memorandum on the application of the new minimum requirement for own funds and eligible liabilities (MREL), see Swedish National Debt Office (2017)*

In this paper, based on the literature on contingent claims, we identify and estimate bank resolution costs for a sample of European banks. We then propose a system-wide measure of resolution costs at the country level that can be used by regulators to monitor the evolution of resolution costs over time. We focus on the direct costs that bank creditors must cover in the event of financial distress.[5]

Our method has the advantage of estimating resolution costs based on market values, which are readily available and easily updateable. In addition, the analysis of resolution costs can easily be conducted at different levels of aggregation:

- Individual banks,
- Group of banks in any specific country and across countries,
- System-wide resolution costs.

We apply the measure to Sweden and compare it to eleven other European countries: Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Switzerland and the UK.

The empirical results suggest that our measure can alert regulators of increases in resolution costs that signal rising risks to financial stability and may require policy responses. It can also be used to aid the overall analysis for the setting of the regulatory minimum requirement for own funds and eligible liabilities (MREL requirement).

We analyze estimated resolution costs against a set of determinants to pin down what the key driving factors are. We find that economic outlook and bank capital are important contributors to bank resolution costs. We also find that policy action such as the announcement of the Bank Recovery and Resolution Directive is a key driver of resolution costs across European countries.

[5] *We do not consider the seniority order for distributing the resolution costs among the debtholders, as this is largely a legal question.*

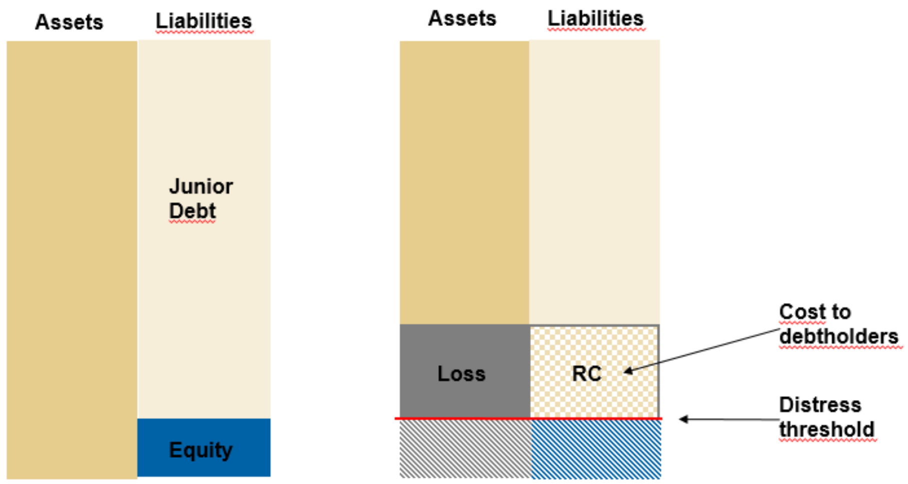
Identifying bank resolution costs

In **Figure 1** we give a graphical illustration of the definition of bank resolution costs that we adopt in this paper. We start from the balance sheet equivalence and recognize that at any time *t* the balance sheet assets are equal to the sum of the liabilities and the shareholders' value. For illustrative purposes, we assume that the liabilities are junior debt. Assuming that at time *t+1* the bank makes a loss that is larger than some threshold, the bank assets shrink to a lower level at which the bank is deemed to be in distress – or likely soon to be. The loss of the bank assets is then absorbed by the bank stakeholders, i.e. the shareholders, the debtholders and/or, in case of a bail-out, the tax-payers.

In **Figure 1** and in the following analysis, we have set the threshold equal to the value of the total liabilities.[6] We therefore make a fairly standard assumption that the bank will be in distress when the value of its assets is *less* than the value of its debt commitments. This also implies that the loss – in **Figure 1** denoted as RC – will be borne by creditors.[7]

Under a credible bail-in regime, RC will be completely absorbed by debtholders. We focus on this part and for simplicity we hereafter denote it as "bank resolution costs".[8]

Figure 1. An illustration of bank resolution costs



Source: Authors'.

[6] *While this assumption is not necessary it is a rather common one. With some light modifications of the model, the threshold could be chosen to be equal to, for example, regulatory capital; see for example (Noss and Sowerbutts, 2012).*

[7] *It should be noted that this notion of resolution costs differs from the ex-post, accounting notion of total resolution costs. In the latter case the total resolution costs is equal to the book value of equity adjusted for the gains and losses on the liquidation of assets and liabilities and receivership expenses (Bennet and Unal, 2015).*

[8] *Under a credible resolution regime, there should be a sufficient amount of available bail in-able debt to absorb the asset value loss and to rebuild sufficient equity capital. Therefore, RC in **Figure 1** represents the minimum amount of bail-inable debt that should be in place.*

Measuring bank resolution costs

In order to measure bank resolution costs, we base our analysis on the literature on bank distress and systemic risk.

This literature is large and has grown significantly after the 2007–10 financial crisis. Most of the bank distress models can be classified into three broad categories. The most traditional approach for assessing bank distress is from an individual institution's perspective that draws on balance sheet information and in which the probability of distress is estimated from key accounting ratios. Among the models that fall into this group are the Altman's Z-score (Altman, (1968); Altman and Katz, (1976)) and Ohlson's (1980) O-score model. They have become well known and widely adopted. Their popularity, however, is not a reflection of a stable consensus about how well they perform in terms of accuracy or prediction. A major criticism leveled against this type of models is that they lack a theoretical ground and that they extract information from historical sources such as financial statements. They could well miss a rapid deterioration and financial distress from sources exogenous to past financial data, such as shift in sentiment from a major political event or other shocks.

The second approach measures distress by using measures determined directly in the market, such as credit default swaps and aggregate realized volatility. This literature has traditionally focused on individual institutions but has also been extended to a systemic perspective that focuses on market-based probabilities of a tail event occurring over a given horizon. Segoviano and Goodhart (2009) extract the probabilities of distress for individual banks using various financial data. They then combine these individual measures into the probability of distress of a portfolio of banks containing all the banks in a given banking system. Alla et al. (2018) quantify systemic risk losses for macroprudential stress testing purposes by using a reduced-form model to value financial entity assets, based on a cross-entropy approach. Adrian and Brunnermeier (2016) use a CoVaR – a measure developed from a Value at Risk approach, and calculate the contribution of different banks to the riskiness of the entire system.

As with the first approach, models in this category typically lack a theoretical foundation but they are very operative in that market information is continuously incorporated, which helps their relative performance and predictive ability, especially at the short run.

In between these two approaches lies the contingent claim analysis approach (CCA) pioneered by Black and Scholes (1973) and Merton (1974). The Merton model is a structural model that provides a theoretical underpinning for bank default. It is based on a combination of forward looking (market-based) and balance sheet information. The basic model uses the standard Black-Scholes option pricing theory to value bank equity as a call option on the underlying asset value given the limited liability of shareholders. Bank liabilities are taken as the distress threshold.

Many variations of structural models have been applied, sometimes with mixed results. The International Monetary Fund has used the structural model approach for their policy work including their assessment programs of the financial sector (FSAP). The structural approach was used also in the FSAP for Sweden in 2012 and then again in 2016. The Office of Financial Research (Bisias et al., (2012)) lists the CCA among the tools for monitoring and analyzing systemic risks in the financial sector. Based on a version of Vasicek (1984) and Crosbie and Bohn (2003), the structural model approach is applied professionally in Moody's KMV to predict distress and its costs. Several papers have analyzed different aspects of bank distress based on structural models. For example, Lehar (2005) uses structural models to derive measures of financial fragility which can be implemented at both the individual and the aggregate levels. Gray and Jobst (2013) use a CCA approach to quantify government implicit guarantees. Gropp, et al. (2006), Harada, Takatoshi and Takahashi (2010), Jessen and Lando (2015) have examined the usefulness of distance-to-default as a tool for predicting bank and corporate default. Singh et al. (2015) use distance to default to analyze bank risk behavior and connectedness in the EMU countries. Gray, Merton and Bodie (2007)use the CCA to explore sovereign credit risk. Gray et al. (2013) incorporate the CCA in a larger model for analyzing the interactions between banking sector risk, sovereign risk, corporate sector risk, real economic activity, and credit growth.

Compared to the models in the first two categories, a clear advantage of the structural approach is that the combination of theoretical foundations and up-to-date market information helps obtain a set of risk measures that capture the probability of default and related costs. Additionally, and similarly to the pure marked-base measures, the measures derived from the structural model are forward-looking (using equity prices and option implied volatilities). It is also important to note that such measures are not *realised* measures of bank distress. Rather, they quantify the perceptions of market participants around bank distress in ways that it may be said capture what is sometimes labelled as the "*wisdom of markets*".

Methodology and data

Our proposed measure of resolution costs is based on the structural approach method. It quantifies the probability of bank distress and the costs associated with it. Also, in contrast to some of the market-based approaches it measures risk at each point in time and does not overly rely on tail events. With our approach policy makers get a form of *risk metric* for bank resolution costs that takes into account the *entire* distribution of possible outcomes. One advantage of our approach compared to drawing on tail events alone is that estimates are more stable and less likely to overstate the costs.

The model

Following the established literature of structural models, we assume an explicit relationship between distress risk and capital structure. The capital structure is thus given by the basic balance relationship in (1) - at time t the bank has asset A_t financed by equity E_t and zero-coupon debt D_t of face amount F maturing at time $T > t$:

$$A_t = E_t + D_t \qquad (1)$$

When $A_T > F$, the bank's debtholders can be paid the full amount F and shareholders' equity still has value $A_T - F$. On the other hand, the bank goes into distress at T if $A_T < F$, in which case debtholders have the first claim on residual asset A_T and shareholders are left with nothing.[9] Asset volatility, σ_A, is assumed to be constant per unit of time in the simplest version of the model.[10]

The application of the standard Black – Scholes option pricing formula (Black and Scholes (1973)) yields the well-known closed-form expression for the equity as:

$$E_t = A_t N(d_1) - Fe^{-r(T-t)}N(d_2) \tag{2}$$

where *r* is the risk-free rate under risk neutrality and $N(^*)$ denotes the normal cumulative distribution function, with the quantities d_1 and d_2 given by the expressions:

$$d_1 = \frac{\ln\left(\frac{A_t}{F}\right)+(r+\frac{{\sigma_A}^2}{2})(T-t)}{\sigma_A\sqrt{(T-t)}} \tag{3}$$

$$d_2 = d_1 - \sigma_A\sqrt{(T-t)} \tag{4}$$

Debtholders are exposed to default risk, but they can hedge their position by purchasing a European put option written on the underlying asset A_t with strike price F. The put option will be worth $F - A_T$ if $A_T < F$, and worthless if $A_T > F$. Thus, the risky debt can be expressed as the risk-free bond F minus the payoff of an European put option written on underlying asset A_t with strike price F maturing at T:

$$D_T = \mathrm{F} - \max(F - A_T, 0) \tag{5}$$

where $\max(F - A_T, 0)$ is the payoff of the put option.

As is well known, the put option price at time *t* can be determined by applying the Black-Scholes formula for European put option:

$$P_t = Fe^{-r(T-t)}\mathrm{N}(-d_2) - A_t\mathrm{N}(-d_1) \tag{6}$$

The structural model uses an additional equation linking the asset volatility σ_A to the volatility of bank's equity by applying Ito's lemma:

$$\sigma_E = \frac{A_t}{E_t}\frac{\partial E_t}{\partial A_t}\sigma_A(T-t) \tag{7}$$

where σ_E is the equity volatility.

[9] *The model imposes a no-arbitrage condition and, in addition, assumes a frictionless market.*

[10] *This is a direct consequence of the assumption that assets are distributed as a generalized Brownian motion. This constant volatility assumption is not typically satisfied by options trading in the market and consequently many different models have been proposed. In the calibration of the model we will approximate the volatility by using the implied volatility of out-of-the-money options. In addition, as a robustness check, in the model we will introduce higher moments than the variance.*

Using Eqs. 2 and 7, we obtain the implied asset value A and volatility σ_A. Once numerical solutions for A and σ_A are found, for each individual bank it is possible to calculate the so-called *distance-to-distress* as:

$$DD_t = \frac{\ln\left(\frac{A_t}{F}\right) + (\mu + \frac{{\sigma_A}^2}{2})(T-t)}{\sigma_A\sqrt{(T-t)}} \quad (8)$$

where μ is the asset drift. Distance-to-distress can be interpreted as the number of standard deviations the value of the bank's asset is away from its distress barrier, i.e. from the value of its debt commitments. Therefore, it can be used as a measure of the probability that the market value of the assets will be less than the liabilities over the time horizon (see Appendix 1 for details).

Once DD_t is obtained, the probability of distress, the ex-ante and ex-post resolution costs can be calculated as:

$$Probability\ of\ distress_{\ t} = N(-DD_t) \quad (9)$$

$$Ex-post\ resolution\ cost_t = \left(1 - \frac{N(-DD_t)}{N(-DD_t + \sigma_A\sqrt{(T-t)})}\right)\left(\frac{A_t}{Fe^{-r(T-t)}}\right)(Fe^{-r(T-t)}) \quad (10)$$

$$Ex-ante\ resolution\ cost_t = Fe^{-r\tau}\mathrm{N}\left(-DD_t + \sigma_A\sqrt{(T-t)}\right) - A(t)\mathrm{N}(-DD_t) \quad (11).[11]$$

[11] *From any bank's perspective, (9) and (10) correspond to the loss given default and expected losses.*

The interpretation of the bank risk metrics

Probability of distress

An important component of bank risk is not only the loss (capital shortfall) in a case of distress, but also the probability that such distress occurs. Under the model assumptions, distress occurs when the value of bank assets becomes lower than the value of the liabilities. Thus, the probability of distress is the probability that the value of the bank will be less than the face value of its debt at maturity.[12]

Ex-post resolution cost

From a bank stakeholder's perspective, the loss that a bank incurs, given that the bank is in distress, is the *ex-post* bank resolution cost and therefore it is a measure of the cost of resolving a bank that is in distress. More precisely, it is the cost required to return an insolvent bank to the point where it is solvent again, that is, at a point where the market value of its asset is *at least* equal to that of its liabilities.[13]

For the most part, the *ex-post* resolution cost is the same regardless of whether a bank is resolved through bail-in or bail-out. If a failed bank is resolved through a bail-in, the *ex-post* resolution costs correspond to the part of debt that could be written down or converted into the equity that is received in exchange for the bailed-in debt. Therefore, it corresponds to the debt that it is written down.

It is important to note that the *ex-post resolution costs,* when taken together with the losses covered by the banks equity, cannot fully correspond to the loss absorption amount (LLA) set by the resolution authority as part of the minimum requirement for own funds and eligible liabilities (MREL).[14] The latter amount is based on the capital requirements set by supervisory authorities complemented by qualitative analysis and expert judgment and adheres to the principles and rules set by the BRRD and the related secondary legislation. Rather, the *ex-post* resolution costs, provides a quantitative yardstick that contain relevant information for monitoring resolution costs. It is consistently estimated over time and easy to replicate and thus fully transparent. This is a clear advantage for policy makers when weighing various policy alternatives. *Ex-post* resolution costs can therefore aid the overall analysis for the setting of the MREL requirement.

If a bank is resolved through a bail-out instead, the resolution costs correspond to the cost of the amount of equity injected or guaranteed by the competent authorities minus the fair value of that equity.

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[12] Merton model implied probability based on the risk free rate differs from the real-world (or physical) probability. Real-world probabilities are usually less than the model-implied -also known as risk-neutral- default probabilities. The difference is due to the fact that the risk-neutral probability takes into account the non-diversifiable component of risk over and above bank-specific risks. Such a component has been found to be significant (Hull et al., 2005).

[13] Here resolution costs refer only to the direct financial costs of a bank going into distress. Therefore, indirect financial costs associated with bank failures such as potential GDP loss and unemployment or any other costs related to macroeconomic outcomes are not considered.

[14] See Swedish National Debt Office (2017) for a definition of institutional LLA and a description of MREL.

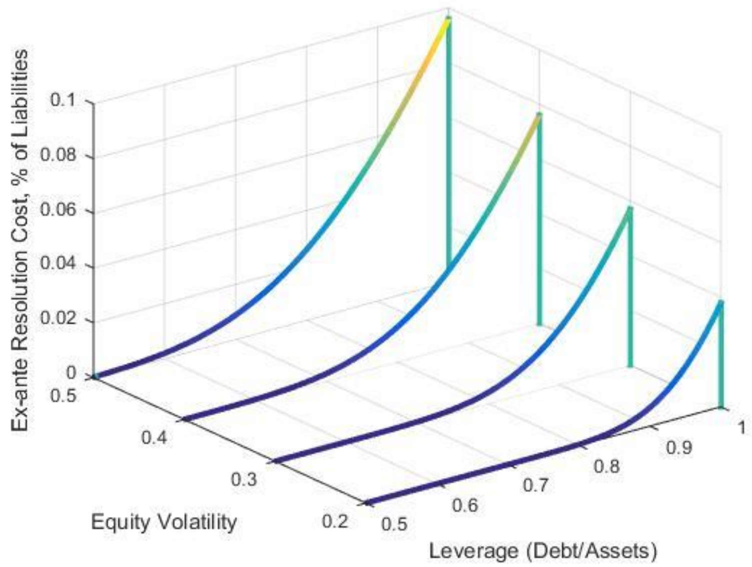
Ex-ante resolution cost

The *ex-ante* resolution cost is the cost of resolving a bank that is in distress weighted by the probability of that distress occurring. Thus, *ex-ante* resolution costs are derived by multiplying the probability of distress and the ex-post resolution cost.

As bank risk indicator, the *ex-ante* cost is a better measure than the *ex-post* cost because it also captures the probability-weighted risk outside periods of rare but regular crises. It is for this reason that the following analysis will focus on *ex-ante resolution costs*.

The three key inputs for calculating the *ex-ante* resolution cost are market capitalization, debt levels and equity volatility (appearing in the *DD* in equation (11)). This means that *ex- ante* resolution costs are affected by changes in each one of these variables, or a combination of them. In general, a higher value of *ex-ante* resolution costs is associated with either a high level of financial leverage, i.e. the ratio between its debt and assets, - or a high level of equity volatility or both.

Figure 2. Ex-ante resolution costs, bank leverage and equity volatility



Source: Authors' calculations.

Figure 2 shows that for low levels of leverage, the ex-ante resolution costs are relatively stable, for any given level of volatility. When equity volatility is low, moreover, the ex-ante resolution costs are relatively small. Ex-ante resolution costs increase more dramatically when equity volatility is high. However, while equity volatility tends to dominate the effect of financial leverage, in reality as well as in the model it is the interaction between volatility and leverage that drives bank resolution costs.

Data

This paper covers the four largest Swedish banks which are categorized as Other Systemically Important Institutions (O-SII), according to the list of O-SII which is updated every year by the European Banking Authority (2016). The Financial Stability Board – an international body with a broad mandate for monitoring and making recommendations to promote financial stability globally - defines systemically important institutions as "… *financial institutions whose distress or disorderly* *failure, because of their size, complexity and systemic interconnectedness, would cause significant disruption to the wider financial system and economic activity*", (FSB, (2011)).

The four largest bank account for about 80 per cent of the Swedish banking sector's total assets. For comparison, we also select a sample of European banks which, similar to the Swedish banks in our sample, are O-SIIs. We use only European banks whose shares have been publicly listed and that are headquartered in the selected EU countries. In order to avoid measurement problems from changing composition of the sample, we select only banks that have been continuously traded and have not gone through major structural changes such as nationalization or restructuring. This means that banks as, for example, Fortis and Northern Rock are excluded which makes our metric a *conservative* measure. Additionally, to include as many as banks as possible in the sample, we use data for the period 2005-17Q3. With these restrictions, we obtain a total of 28 banks, 13 of them are recognized as global systemically important institutions (G-SII).[15] **Table 1** lists the financial institutions in our sample. When analyzing the Swedish bank sector alone we extend the sample period and use data 1999–17Q3.

[15] *See Basel Committee on Banking Supervision (2016).*

Table 1. List of O-SIIs included in the sample

Country	Name of institution identified as O-SII
Austria	• Erste Group Bank
Belgium	• KBC Group
Denmark	• Danske Bank
France	• BNP Paribas* • Societe Generale* • Groupe Credit-Agricole*
Germany	• Deutsche Bank AG* • Commerzbank AG
Italy	• Unicredit Group S.p.a.* • Gruppo Intesa-Sanpaolo • Gruppo Monte dei Paschi di Siena
Netherlands	• ING Bank
Norway	• DNB
Spain	• Santander* • BBVA • Banco Popular Espanol • Banco Sabadell
Sweden	• Nordea Bank AB* • Svenska Handelsbanken AB • Swedbank AB • Skandinaviska Enskilda Banken AB
Switzerland	• UBS* • Credit Suisse
UK	• HSBC Holding Plc* • Barclays Plc* • Royal Bank of Scotland Group Plc* • Standard Chartered Plc* • Lloyd

*Note: the banks included in the sample are O-SIIs publicly listed and traded. They have been recognized as O-SII. according to the European Banking Authority (2016). * denotes those banks that are recognized as globally systemically important institutions (G-SII).*
Source: European Banking Authority

The market-based data include daily observations of risk-free interest rates, daily stock prices and outstanding shares. The bank liabilities are recovered instead from quarterly balance sheet data. GDP data are from national accounts. We use a forward-looking measure of volatility from daily equity option data. Equity option implied volatility incorporates not only historical information on prices but also market participants' expectations about future events. The implied volatility is not constant across strike prices for the same contract maturity. It is usually higher for in- and out-of-the money than for the at-the-money options. Therefore, the at-the-money volatility can be interpreted as a lower-bound for the implied volatilities and it is likely to underestimate the true market expected variability of the underlying asset. For this reason, we use the implied volatility of out-of-the money options to approximate the volatility (see Appendix 2 for details).

We compute bank resolution costs at a monthly frequency. This means we use market-based data from the last day of each month and we interpolate the information from quarterly balance sheet data. **Table 2** lists the data we use in the model.

Table 2. Description of the model's input variables

Market-based variables		
• Equity prices		*Daily frequency*
• Interest rates	*1-year government bond yield*	*Daily frequency*
• Equity option volatility		*Daily frequency*
Balance sheet variables		
• Short term liabilities	*Short term borrowing*	*Quarterly frequency*
• Long term liabilities	*Long term borrowing*	*Quarterly frequency*
• Outstanding shares	*Total outstanding share in public*	*As reported in balance sheet reports*
• *Return on assets*		*Quarterly frequency*
National accounts		
• GDP		*Quarterly frequency*

Source: Bloomberg and Thomson Reuters

Model results

System-wide and bank-specific resolution costs

We aggregate the bank-specific resolution costs to obtain a system-wide indicator of bank resolution costs. In practical terms, the aggregation of bank-specific resolution cost measures can be done by using different methodologies, each with its own advantages and disadvantages. Here we follow the most straightforward approach and simply sum up the bank-specific resolution costs in order to obtain a system-wide measure. One advantage is that we do not need to model explicitly the dependence structure between banks but instead it is captured through its impact on forward-looking equity prices and equity option volatilities.

Figure 3 depicts the evolution of *ex-ante* resolution costs for the Swedish bank sector. Our sample starts in 1999Q4 and ends in 2017Q3. The system-wide resolution costs show several spikes. The first spikes occurred in early 2000s. As in many other advanced economies, these years were characterized by an economic downturn and increase in unemployment. The economic downturn did not occur only in Sweden and was common among many advanced economies, including the US and Germany. Moreover, several negative shocks occurred: the tech-bubble, 9/11, the stock market crash in March 2002 and several large international and domestic corporate failures. As **Figure 3** shows, those shocks were short-lived but occurred rather frequently during a relatively short period of time.

The largest spike in system-wide resolution costs occurred in 2009, at the apex of the global financial crisis. The economic downturn that ensued was significant. In Sweden, GDP dropped by about 5 percent in 2009. To mitigate the broad negative economic consequences of the crisis, the government and central bank swiftly implemented a number of measures to support the Swedish banking system. The credit supply to the Swedish banks was substantially expanded by the Riksbank. At the same time, extended guarantees and various support programs were extended to the financial sector, including capital injection programs that were designed by the government and implemented by the Swedish National Debt Authority.[16]

The combined policy response brought relief to the financial system. At the same time, the Swedish economy proved to be much more resilient than during the crisis in the 1990s. Already in 2010 the economy rapidly began to recover. As the Swedish financial system and economic outlook improved, the probability of distress for banks correspondingly declined and so did their resolution costs.

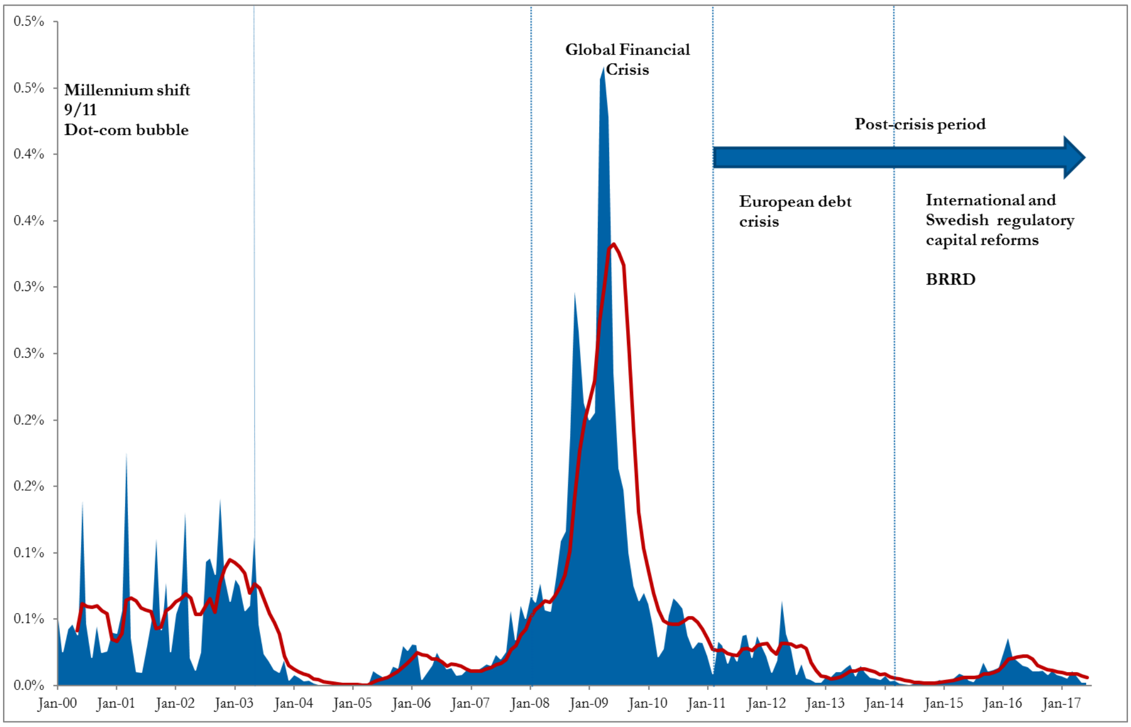
During the post-crisis period and especially after the European debt crisis, with the economy returning to healthy growth and a very expansionary monetary policy, the system-wide resolution costs decline markedly. In this period the Swedish banks' return-on-equity – a measure of bank

[16] *Policy action was taken on an international scale. In Europe, for example, the European Central Bank (ECB) extended its short-term liquidity support by offering unlimited funds and started to buy securities issued by banks, such as covered bonds. Later on, the European Commission adopted the European Recovery Plan and allowed governments to implement measures to bail out banks. Among the countries that explicitly bailed out banks are Austria, Belgium, Germany Ireland and UK.*

profitability – was on average about 12 percent, a much higher level than that one of European banks.

In summary, the system-wide resolution costs appear to track well the ups- and downs of the bank sector developments and it promptly changes close to, or even in advance, of the most significant events, notably the global financial crisis.

Figure 3. The Swedish ex-ante resolution costs (percent GDP)

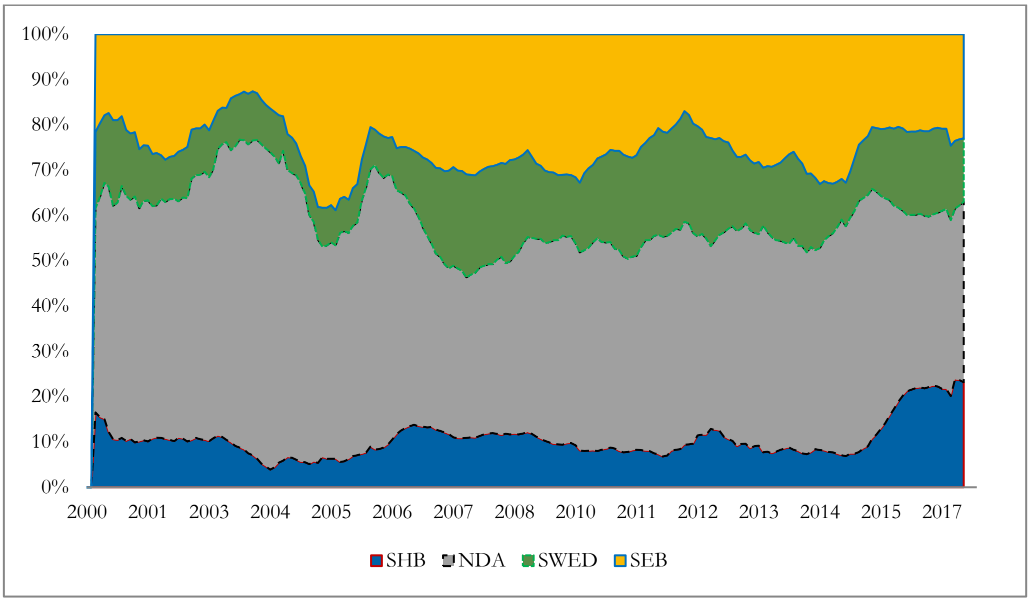


Note: the red line shows the six-month moving average of system-wide resolution costs (blue area).
Source: Authors' calculations.

Contribution of each bank to system-wide resolution costs

Given the technically straightforward way in which we aggregated the bank-specific resolution costs, it is relatively easy to measure and visualize the contribution of each individual bank to the system-wide resolution costs.

Figure 4. Bank-specific contribution to system-wide resolution costs



Note: the chart shows the twelve-month moving average of bank-specific resolution costs as percentage of system-wide resolution costs.
Source: Authors' calculations.

The bank-specific contribution to system-wide resolution costs can aid in building a measure of systemic importance that can be used to rank the banks in real time. Crucially, systemic importance is time-varying and it depends on the economic environment. Structural trends and cyclical factors influence the systemic importance of a bank. For example, under weak economic conditions there is a higher probability that losses in the bank sector will be correlated and that defaults in even unimportant elements of the bank system could trigger a far greater loss of confidence.

The dependence of systemic importance on financial and economic conditions has implications for how frequently the systemic importance of a bank should be assessed. In the wake of the global financial crisis, the Financial Stability Board and the Basel Committee developed guidelines and promoted an indicator-based approach for the assessment of systemic importance. The indicators are intended to reflect different negative externalities that a bank can have on the system and the real economy. The Basel indicators are grouped in five equally-weighted categories: cross-jurisdictional activity, size, interconnectedness, substitutability/financial institution infrastructure and complexity. The assessment of O-SII, that is other systemically important institutions other than globally systemically important ones (G-SII) follow a similar approach. Every year, the European Banking Authority publishes a list of O-SII, including G-SII, based on previous year-end data. However, when financial systems are under stress or when significant changes in the business or risk profile of the single banks have taken place a more frequent, real time-based information assessment is likely to be needed to supplement the assessment provided under the Basel Committee methodology.

In **Figure 4** we show the contribution to system-wide resolution costs for the four Swedish banks. In line with our expectations and previous evidence, Nordea is the bank that contributes most to the system-wide resolution costs. A closer inspection of our measure in **Figure 4** shows that while

Nordea is a category of its own, relatively stable and higher than every other bank – in accordance with its G-SII status – the other banks' systemic importance has informative dynamics. SEB's and Swedbank's systemic importance increased already some time before the financial crisis but have remained fairly stable thereafter, hovering around 25 percent and 15 percent respectively. Handelsbanken remains the lowest ranked for the large part of the sample period. Notwithstanding, more recently, Handelsbanken's systemic importance has increased noticeably. In 2017 it has reached 23 percent, on par with SEB and higher than Swedbank, thereby bringing all three Swedish banks very close to each other. With the latest developments, the Swedish bank sector has in this sense become significantly more homogeneous than it used to be.

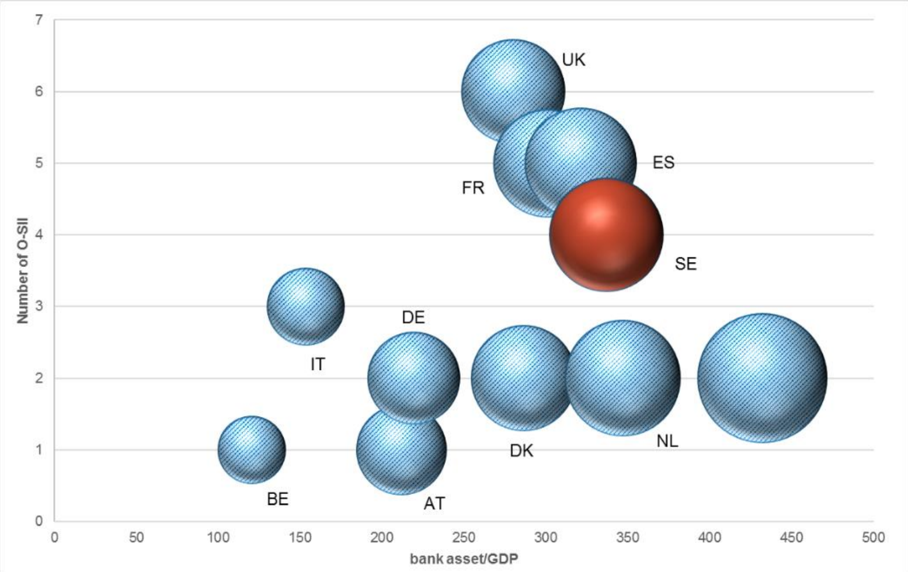
How Swedish ex-ante resolution costs relate to those of other European banks?

In the wake of the global financial crisis a new regulatory regime with higher capital buffers and strengthened bank resilience has been gradually implemented. In addition to that, a new bank recovery and resolution framework (BRRD) for managing banks in distress has been developed and has come into force in Europe in 2016. It is thus interesting to analyze the development of resolution costs across banks and countries and compare them to those of the Swedish banks.

The Swedish banks are internationally active and highly integrated with the European bank sector and economy. Additionally, and as shown in Figure 5, Sweden has among the highest number of publicly listed and headquartered O-SII banks and a relatively large bank sector compared to the size of the overall economy.[17]

[17] *At the time of writing, Nordea had just announced its decision to change headquarters to Helsinki. Without counting Nordea, the size of the Swedish bank sector compared to the overall economy is around 200 percent of GDP.*

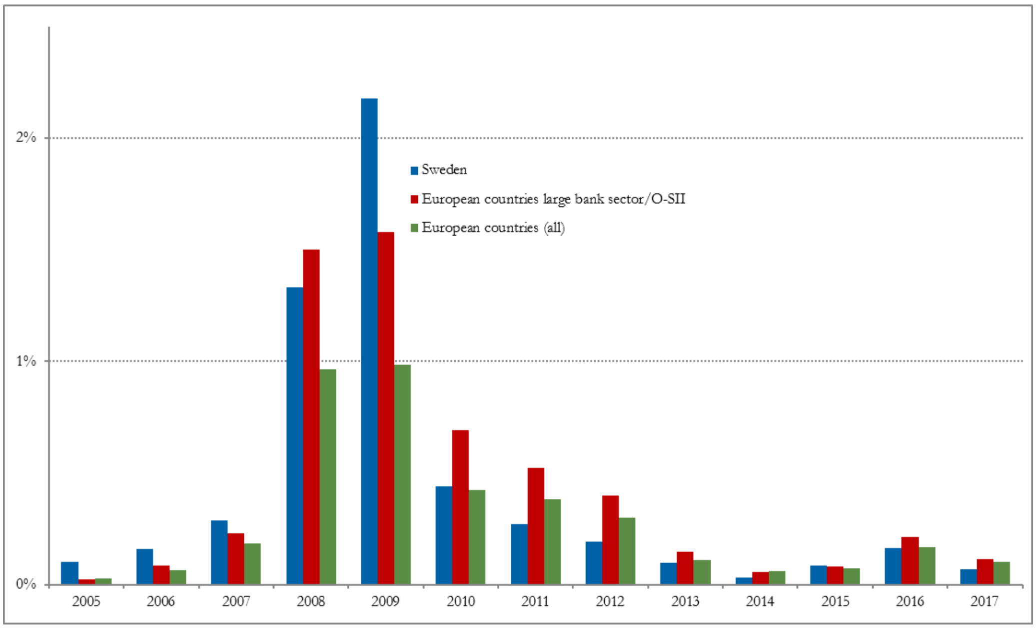
Figure 5. Number of O-SIIs and size of the bank sector, by country



Note: the ratio of bank total assets to GDP (December 2015). Total assets refer to the balance sheet value of the assets.
Source: Riksbank and authors' calculations.

For each country in the sample, we have computed the country-wide resolution costs by summing up the bank-specific resolution costs of the O-SII banks with headquarter in that country. Thereafter, we computed the European resolution costs as the average of the country-specific resolution costs. Additionally, we computed the resolution costs of the subset of countries that, similar to Sweden, have a high number of systemically important banks and/or a relatively large bank sector, as shown in Figure 5 - that is, France, Netherlands, Spain, Switzerland and UK. We compare these measures and show them in **Figure 6.**

Figure 6. Resolution costs in Sweden and in selected European countries



Note: European countries with large bank sector are France, Netherlands, Spain Switzerland and UK. Resolution costs are in percent of GDP and are shown as yearly averages.
Source: Authors' calculations

During the 2008–09, resolution costs for all European banks in our sample increased significantly. Swedish resolution costs were particularly high, most likely reflecting their higher perceived vulnerability to the Baltic states, which were especially vulnerable during the crisis. After the financial crisis, resolution costs have declined for all banks, showing an overall similar pattern of ups-and-downs. Such evidence further supports the notion of the Swedish banks' significant interrelation with the European bank sector. However, Swedish resolution costs appear to have declined the most, both compared to the European average and to the average of countries that, similarly to Sweden, have a relatively high number of OSIIs and/or a large bank sector.

Determinants of resolution costs

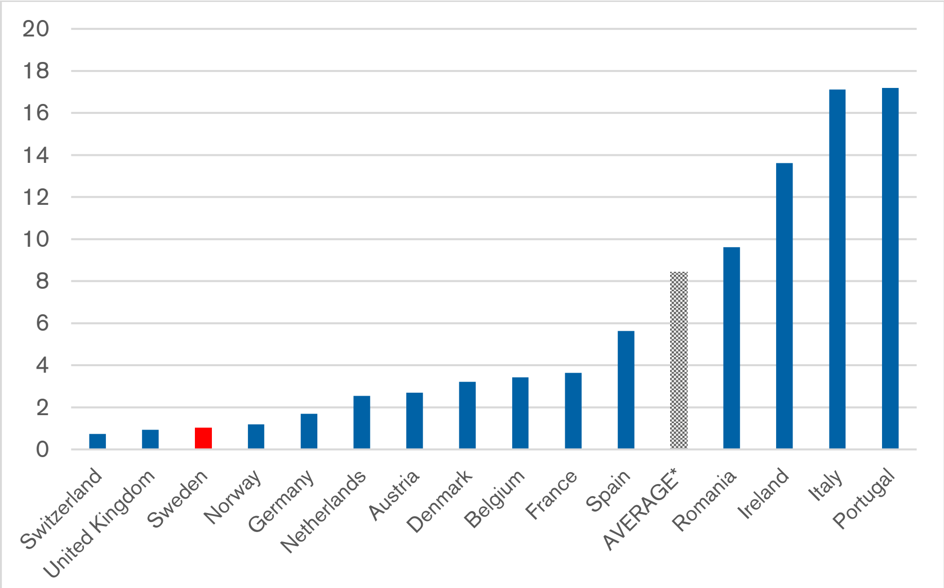
There can be several reasons behind the difference between the Swedish and European resolution costs. Before going into the details of the determinants of resolution costs, we present some stylized facts.

Stylized facts

For a large part of the period covered in this paper, Swedish economic growth has been significantly higher than in Europe. In Sweden, the GDP growth plunged during the 2008-09, but quickly recovered and in the following years it stayed at a level higher than the European average. At the end of 2016, the Swedish yearly GDP growth was estimated at around 3 percent and projected to remain relatively strong whereas the European average was about 1.9 percent and stable.

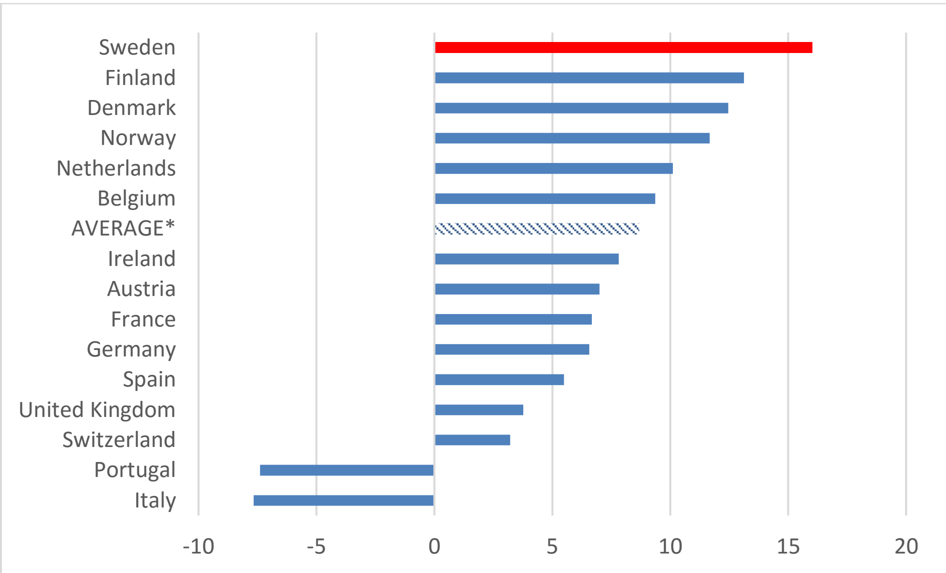
After the global financial crisis was followed by the European debt crisis the vulnerabilities of many European banks came into harsh light. The European bank profitability deteriorated significantly, due to both a decline in revenues and high cost-inefficiencies. More importantly, over and above cyclical factors the deterioration in profitability was driven by structural factors such as a high level of sector fragmentation, highly correlated sources of income and a low level of digitalization which made it difficult for the banks to take advantage of opportunities to reduce their costs and improve their efficiency, resulting in a significant increase of their cost-to-income ratio during 2010–16 (ECB, 2017). In addition, saddled by large proportions of non-performing loans on their balance sheets, many European banks suffered a further decrease in their profitability which, in some instances even became negative. During that period, the Swedish banks had instead among the lowest share of non- performing loans and enjoyed a relatively high profitability (see Figure 7 and Figure 8).

Figure 7. Non-performing loans, as percentage of total gross loans



*Note: * indicates EU 28 plus Switzerland, average.*
Source: IMF, Financial Soundness Indicators. Data as per 2016.

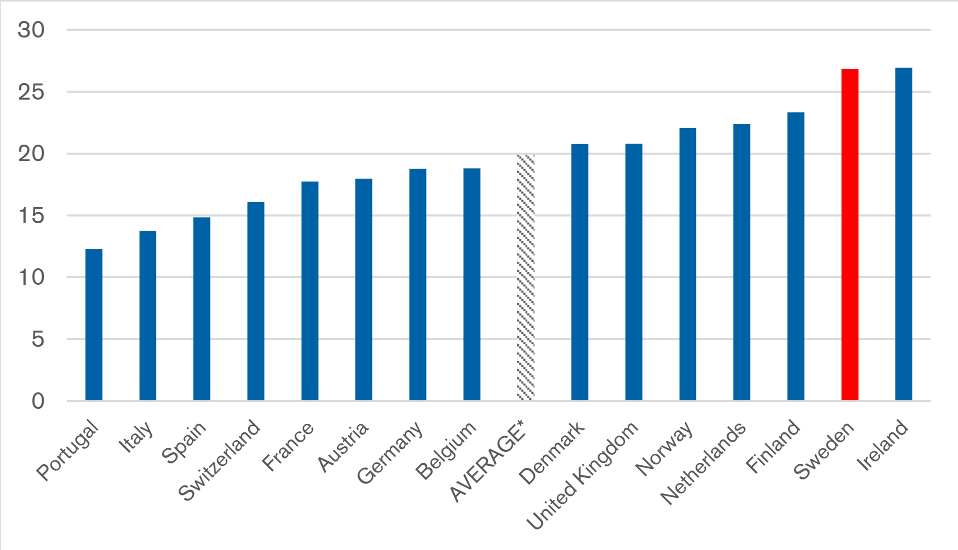
Figure 8. Bank profitability, as measured by ROE



Note: indicates EU 28 plus Switzerland, average.*
Source: IMF, Financial Soundness Indicators. Data as per 2016.

Generally, Swedish banks have had stricter capital requirements and higher capital in terms of the risk-weighted assets than their European peers.[18] But it was especially in the aftermath of the financial crisis that Swedish banks substantially increased their capital levels leading to a visible wedge with their European peer banks (**Figure 9**).[19] Capital buffers improve the banking sector's ability to absorb shocks and - whatever the source of stress, they reduce the risk of spillover from the financial sector to the real economy.

Figure 9. Regulatory capital to risk weighted assets, percent



*Note: * indicates EU 28 plus Switzerland, average.*
Source: IMF, Financial Soundness Indicators. Data as per 2016.

Therefore, by increasing the resilience of a bank and reducing contagion risk, capital buffers can affect both the probability of a bank going into distress and the *ex-post* resolution costs and, consequently, the *ex-ante* resolution costs.

Following the financial crisis, Sweden took an active decision to put more ambitious rules in place than in other countries. More specifically, Sweden tightened capital requirements to a level beyond that internationally agreed. In 2011, the Riksbank, the Swedish Ministry of Finance and the Financial Stability Authority agreed to mandate a further increase of the capital requirements for systemically important banks, with the effect that the four major Swedish banks were assigned an additional capital requirement of 5 percent in core capital. After 2011, continued reforms were designed and progressively implemented. In 2013, a risk-weighted floor of 15 per cent for Swedish mortgages

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[18] For an overview of Swedish capital requirements see the Swedish Financial Stability Authority (2017)

[19] When measured as leverage ratio, the Swedish capital level are not as high.

was introduced pushing the capital buffer higher. That risk-weighted floor was further increased to 25 percent in 2015, further strengthening the buffer.[20]

Measures from the Financial Stability Authority were complemented by the BRRD with the MREL requirements. In 2017, the Swedish Resolution Authority proposed for the four major Swedish banks the MREL level of about 25 per cent of the bank risk-weighted assets, a likely higher requirement than that proposed for most peers.[21]

Regression analysis

To corroborate the qualitative evidence of the stylized fact described in the previous section we investigate the determinants of the resolution costs over time. The set of considered explanatory variables covers both macro-financial variables reflecting the current state of the economy and variables potentially related to bank solvency and profitability.

The benchmark regression is a simple ordinary least square with fixed effects. The generic equation is:

$$ResCosts_{i,t} = c_i + \beta_m Macro_{i,t} + \beta_b Bank_{i,t} + \epsilon_{i,t} \tag{12}$$

where the explanatory variables $Bank_{i,t}$ and $Macro_{i,t}$ are the variable vectors that we discuss below. We choose the resolution cost per share over the total to control for the scale of the variables and for the potential noise created by the fact that the number of shares issued is generally unrelated to the variables in the $Macro_{i,t}$ and $Bank_{i,t}$ vectors. Also, resolution costs are in logarithms terms.

In our basic regression the $Macro$ vector comprises the following elements:

1. Business climate
2. Interest rate term structure
3. GDP growth
4. General credit conditions

The variables included in the $Bank$ vector are:

1. Size
2. Bank capital
3. Bank profitability
4. Leverage

In the $Macro$ vector, to approximate the shape of the *interest rate term structure* we include the difference between the 2 and 10 year interest rate of the euro area yield curve. The rationale for choosing the euro area yield curve instead of country-specific rates is the high degree of correlation among the interest rates of the single countries in our sample. Even for those countries that are outside the euro area - Denmark, Norway, Sweden and the UK – the average correlation over the

[20] See, Swedish Financial Authority (2014) and (2009).

[21] The Bank of England proposed MREL level is 24 percent of risk-weighted assets (2017).

entire period with the other country-specific interest rate is about 66 percent for Norway, 90 percent for Sweden and Switzerland and 88 percent for UK.

We also introduce the change in the 3-month government bond yield as a proxy for monetary policy.

We would expect the resolution costs to be affected by both the change in the 3-month yield and the slope of the yield curve. However, the expected sign of the impact of the interest rates on resolution costs is theoretically ambiguous. A more accommodative monetary policy can reduce resolution costs. However, it may also result in lower revenues which in turn could decrease the bank net income and increase resolution costs. Similarly, any steepening of the yield curve may be related to a better economic outlook and/or a less expansionary monetary policy.

We approximate the *business climate* by the well-known VIX index computed from the S&P 500 index options, (sometimes labelled as the *market fear index)*. An increase in the volatility index is associated with an increase in uncertainty and a deterioration of the business climate with potential negative consequences for the real economy. Therefore, an increase in the VIX is associated with rising resolution costs. However, the VIX is a measure of market activity and not so much of bank activity. It could be that banks may have a stable level of activities and earnings even when the VIX is increasing.

We also include the so-called TED spread, that is the difference between the interbank lending rate (Euribor) and the risk-free rate (yield on the short term government bonds). The TED spread is a measure of the general credit conditions in the interbank market. An increase in the spread signals heightened strains among lending and borrowing banks and increased stress in the interbank market. Therefore, a rise in the TED spread is expected to be associated with an increase in bank resolution costs.

Bank distress probabilities diminish when the economy is on a positive growth path and doing well. Thus, a higher GDP growth is associated with lower probability of distress and lower resolution costs.

In the $Bank$ vector we have included two different measures of *bank capital*, namely Tier I and the total capital ratio. The Tier I ratio compares a bank's Tier I capital – its equity capital and retained earnings – to its total risk-weighted assets (RWA). RWAs are essentially a bank's total assets recalculated to a smaller number to reflect the relatively low-risk nature of some assets. Similarly, the total capital ratio is the total bank capital measured against the risk-weighted assets, where the total capital includes the Tier I capital and all forms of subordinated debt, loan losses provisions and preferred stock that are not included in Tier I.

The MREL capital requirement complements the bank capital requirement with other explicitly bail-in-able instruments, such as junior debt that can be converted to equity when the financial conditions of a bank deteriorate materially. Therefore, the MREL requirement provides additional loss-absorbing capacity, on top of that provided by bank capital. In our analysis we focus on bank capital as it is the most conservative approach, but as because the MREL requirement has come into place only very recently.

In general, the more capital a bank holds the higher is the loss-absorbing capacity. Thus, we would expect a higher capital ratio to be associated with lower resolution costs.

The return on equity of a bank (ROE) is often said to be the premier indicator of *bank profitability* that can be obtained from a bank's financial statement. Other things being equal, we would expect lower resolution costs with a higher ROE.

As a proxy for *bank size* we use the total market equity for each bank divided by the cross-sectional average of market equity. The impact direction of bank size on resolution costs is not clear a priori. Large size could be associated with larger resolution costs since a large bank can simply cause more havoc. However, a large size can also give advantages including those related to economy of scale contributing to an increase in profitability and lower resolution costs. B*ank leverage*, by contrast, does not have an ambiguous sign as a more leveraged bank is riskier. We measure leverage as the ratio of asset book value to market equity. In the regression analysis, we use either capital or leverage, as they are close substitutes.

Table 3 summarizes the predicted effects of the aforementioned variables whereas in **Table 4** we report the results of our econometric analysis.[22]

[22] *Because of lack of data we have decided to exclude liquidity measures. However, the econometric specification - OLS with fixed effects - partially offsets that.*

Table 3. Resolution costs' determinants

Macro-financial variables		**Expected sign**
Global climate	VIX	+
Economic development	GDP growth	-
Interest rate term structure	Slope yield curve	+/-
Interbank credit conditions	TED spread	+
Bank-specific variables		
Size	Mark cap./mark cap. cross-sect. average	+/-
Capital	Tot cap ratio	-
Profitability	ROE	-
Leverage	Assets/Liabilities	+

Source: Reuters Eikon and authors' calculations.

We find that resolution costs are strongly associated with negative GDP growth. Worsening *general credit conditions*, an increase in the TED spread, is associated with an increase in resolution costs. Bank *profitability* has the expected sign and is statistically significant. *Size* turns out to be not significant. Finally, we find that a deterioration in *business climate* – a positive change in the VIX index – appears to be positively associated with resolution costs.[23]

We add a dummy variable D_t to the benchmark model in equation (12) to capture the announcement of the new European resolution regime (BRRD) announced in May 2014[24]:

$$ResCosts_{i,t} = c_i + \beta_m Macro_{i,t} + \beta_b Bank_{i,t} + D_t + \epsilon_{i,t} \qquad (13)$$

The BRRD should mark a significant shift in market expectations about the way in which failing banks are dealt with and that were prevalent before the crisis. Under the BRRD bail-outs are replaced by bail-ins and therefore the implied government guarantees are reduced drastically.

The results of the regression analysis show that the BRRD is negatively associated with bank resolution costs, suggesting that the announcement of the new resolution framework marked a shift in market perceptions and had an overall positive impact on the bank sector. Resolution regimes that can allocate losses effectively among bank stakeholders through bail-ins are beneficial for several reasons. First, they can reduce the likelihood that banks fail through greater and improved market discipline. When bank stakeholders expect to be bailed in and therefore exposed to losses in the event of failure they are more likely to impose greater discipline on managers, thus reducing leverage and excessive risk-taking. Second, by recognizing the potential for loss and by calling for *dedicated* loss-absorbing capacity for winding down banks in distress, the new framework can reduce the risk of domino effect and potential systemic spillovers. Third, by clarifying ex- ante how losses accrue to private creditors in resolution, the new framework introduces greater transparency, which helps addressing burden-sharing issues (especially cross-border). Finally, they reduce the

[23] *It turns out that the VIX index is strongly correlated with the GDP growth. Therefore, we use the change in the VIX in the specification. Taking into account the change does not materially affect the coefficient of the other variables.*

[24] *In 2010, the US established a resolution framework for systemic financial institutions under the Dodd-Frank Act.*

direct fiscal cost of bank failures and may weaken the feedback effects between sovereign and bank vulnerabilities (the "sovereign-bank nexus") which was at the core of the European debt crisis. These positive effects of the new resolution framework call for diminished resolution costs.

In summary, the empirical results suggest that a favorable economic development and bank capital are significant drivers of resolution costs. High bank profitability and more favorable interbank credit conditions can lower resolution costs. Not least, we find that the announcement of the new resolution regime, arguably a milestone in the regulation of the bank sector towards increased financial stability and greater transparency, is associated with negative resolution costs, possibly reflecting the improved market discipline and lower risk of spillover effects of failing banks on the financial sector at large.

Table 4. Regression results

	(i)			(ii)			(iii)		
	Coeff.	t-stat.	Prob.	Coeff.	t-stat.	Prob.	Coeff.	t-stat.	Prob.
Term spread	-0.13	-0.69	0.49	0.13	0.72	0.47	0.14	0.74	0.46
GDP growth	-0.17	-3.78	**0.00**	-0.22	-4.98	**0.00**	-0.22	-4.99	**0.00**
ΔVIX	0.03	1.83	0.07	0.03	1.80	0.07	0.02	1.76	0.08
TED spread	0.02	5.72	**0.00**	0.02	5.70	**0.00**	0.02	5.66	**0.00**
Size	-0.55	-18.9	0.00	0.10	1.28	0.20	0.10	1.28	0.20
Bank capital	-0.10	-6.54	**0.00**	-0.08	-4.59	**0.00**	-0.08	-4.55	**0.00**
ROE	-0.07	-13.2	**0.00**	-0.02	-3.60	**0.00**	-0.02	-3.64	**0.00**
BRRD announc.							-1.19	-12.10	**0.00**
Constant	0.59	1.63	0.10	-0.91	-2.33	0.02	-0.91	-2.35	0.02
Adj. R-square	0.24			0.62			0.63		
Observations	4196			4196			4196		
Fixed-effect	No			Yes			Yes		
Fixed-effect redundancy test:				*Stat.*	*p-value*		*Stat.*	*p-value*	
○ *Cross section F*				157.2	0.000		157.6	0.000	
○ *Cross-section Chi-square*				2950.5	0.000		2956.7	0.000	

Source: Authors' calculations.

Robustness checks

Alternative determinants

We repeat the estimations in equation (12) with different variables and find that most of the results remain qualitatively the same. We approximate leverage by using the book value of asset; we use the index SKEW instead of VIX to capture business climate and the GDP growth of the 28 countries in the European Union instead of the growth rate of the euro area countries to approximate for economic developments. We use interest rates at different maturities for the term structure and the term spread. Additionally, we use swap rates instead of government bond yield. We also use the three-month TED spread instead of the one-month spread. Finally, we introduce year-dummies to control for time-fixed effects and find that we cannot reject, at conventional significance levels, the null hypothesis that the year-dummies are jointly irrelevant.

In summary, results are generally unaffected by choosing those alternative determinants and we judge them as sufficiently robust.

Alternative econometric specifications
We use two alternative techniques. First, we use a pooled OLS specification, in which all observations are bundled together, thus forfeiting information about country heterogeneity. Second, we replace the OLS specification with generalized least squares (GLS). GLS estimates should be more efficient than OLS in the presence of heteroscedasticity and correlation in the residuals. By and large these alternative estimates confirm the results of the benchmark OLS regression.

Alternative estimates of equity volatility and default threshold
We check the benchmark model results against different estimates of equity volatility and different values of the default threshold. We find that the estimates are not materially different from the benchmark results (Appendix 2).

Expanding the model with volatility adjustment
To analyze the robustness of our results, we expand our benchmark model with a volatility adjustment to incorporate skewness and kurtosis of asset returns. Similar to Gray and Jobst (2013), we do this by using a Gram-Charlier expansion, thereby capturing tails events that are otherwise difficult to model in the benchmark structural model. As described in Appendix 1, also these estimates are qualitatively similar to those of the benchmark model.

Conclusion

In this paper we provide a definition of bank resolution costs and construct a measure of them based on a structural modelling approach. More specifically, we define resolution costs as the cost that creditors are expected to bear in case of a bank failing. Our method has a number of advantages. First it uses bank market values, which are readily available and easily updateable. Second, the analysis of resolution costs can be conducted easily at several levels. Specifically, we can focus on individual banks, group of banks in any specific country and across countries or on system-wide resolution costs. Third, it measures market-implied resolution costs at each point in time and does not focus exclusively on tail events.

Our measure can be used to monitor bank resolution cost development over time. For policy makers this measure is particularly informative since it provides a yardstick to compare the amount of bail-inable debt decided according to the MREL requirement with the market expected resolution costs.

We apply the measure to Sweden and to other eleven European countries. We consider both EMU and non EMU countries: Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Switzerland and the UK. The estimates derived are then analyzed against a set of determinants as to pin down what are the key factors that drive bank resolution costs.

We find that following the global financial crisis a decade ago the resolution costs in Sweden have declined significantly more than the average European countries. A relatively more favorable economic development, higher bank capital and higher profitability appear to have contributed to the larger decline of Swedish bank resolution costs. In addition to those macro-financial factors, the announcement of the BRRD also has contributed to the decline of bank resolution costs in Sweden as in most of the European countries, thereby suggesting that the announcement of the new resolution framework marked a material shift in market perceptions and had an overall positive impact on the bank sector.

Appendix 1. Model and results

To measure bank resolution costs for each bank in our sample, we use a standard forward-looking model that is based on the contingent claim literature pioneered by Black and Scholes (1973) and Merton (1974).

The foundation of this approach lies in the relationship between bank equity and call options. Since equity is a junior claim to debt, it can be modelled as a European equity call option on the bank´s assets with exercise price equal to the face value of the debt. It follows that the expected cost of default, that is the resolution cost (the difference between the bank's asset value and debt value) is equal to the price of a put option on the firm's assets with the same exercise price.

Following standard option pricing methodology, in the calculation of the equity option we have followed a two-step approach. First, we have estimated bank asset value and asset volatility. Then, we have derived the so-called distance-to-distress (DD). Distance to distress has been widely adopted by academics in financial research and used in business applications by industry practitioners, notably in Moody's KMV model. Once DD is derived we can estimate the bank resolution cost as explained in section 4.1.

DD is a real-world probability measure that depends on the expected asset drift μ, on the liabilities F and on the asset volatility σ_A.

There are different methods for estimating μ (see Afik et al., 2012 and 2015).

We use the average return on assets over the 2005-2017 period as the expected asset drift. The return on assets measures the ability of the bank to produce income from its assets and it is therefore a standard measure of its profitability. As assets are expected to grow when the bank produces more income and profits, the long-term average of the return on assets is a good proxy of the expected asset growth. It also accounts for a bank-specific expected return on a risky asset that is higher than the risk-free rate.

DD also depends on the bank's liabilities. In the theoretical Merton (1974) model all debt is in the form of a zero-coupon bond. In reality the debt contracts are not all written with a single maturity date. To overcome this problem a common procedure used by Moody's KMV (Vasicek, 1984) and also employed in this paper is to take into account all of the short-term liabilities but to weight longer term debt at only 50 percent of the face value. However, taking all liabilities as default threshold does not change the results materially. Contrary to Moody's KMV, which adopts 1-year horizon, we adopt a five-year horizon (T=5) as a more appropriate choice when estimating resolution costs with all liabilities.

We use the implied volatility from equity options as the basic estimate for volatility. Compared to estimates based on historical volatility, this measure has the advantage of being forward-looking. Since bank distress are events that occur in the tail of the probability distribution we have chosen to use the implied volatility of deep out of the money equity put options (-150 delta). Alternatively, using at-the-money volatility produces estimates that are slightly lower, but overall the results are fairly similar.

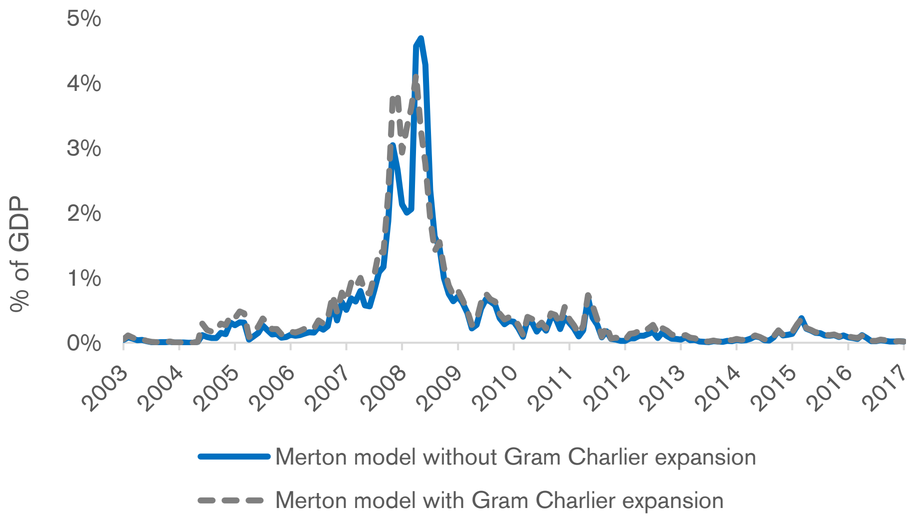
Appendix 2. The Gram-Charlier expansion

The Black-Sholes model has been criticized for its rather strong assumptions and lack of ability to capture a well-documented empirical regularity such as negative skewness and positive excess kurtosis. Following Backus, Foresi and Wu (2004), in this paper we employ a method that incorporates higher order moments (namely skewness and kurtosis). The method is based on Gram-Charlier probability density series expansion that is adjusted by non-normal skewness and kurtosis. The resulting approximation for the option call is:

$$
\begin{aligned}
C_{GC} = S\Phi(d_1) - Fe^{-r(T-t)}\Phi(d_1 - \sigma) \\
+ S\Phi(d_1)\sigma\left(\frac{Skew(2\sigma - d_1)}{3!} \right. \\
\left. - \frac{Kurtosis(1 - {d_1}^2 + 3d_1\sigma - 3\sigma^2)}{4!}\right)
\end{aligned}
$$

where C_{GC} is the price of the call option, F is the distress point. In addition, we have estimated skewness and kurtosis by using the implied volatility smile of the stock options. This method has been also applied as part of the IMF's FSAP stress tests in the case of the United States, Sweden and Germany, see Gray and Jobst (2013).

Figure A1. Swedish ex-ante resolution costs with Gram Charlier expansion



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The Swedish National Debt Office is the central government financial manager and the national resolution and deposit insurance authority. The Debt Office thus plays an important role in the Swedish economy as well as in the financial market.

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