The Single Resolution Fund and the Credit Default Swap: What is the Coasian fair price of their insurance services?

Naszodi, Anna

2 April 2019

The Single Resolution Fund and the Credit Default Swap: What is the Coasian fair price of their insurance services?

by

Anna Naszodi[1]

anna.naszodi@gmail.com

This paper develops an option-based model to analyze the relationship between two insurances both providing protection against bank failures. One of these insurances is offered to European banks by the Single Resolution Fund on a compulsory basis in return for their contributions to the Fund, while the other is by the CDS market. The model provides a theoretical framework for testing whether the contributions of banks are fair in the Coasian sense relative to the CDS spreads.

JEL: G28, G13

Keywords: bank resolution, resolution fund, CDS, Coasian tax, Merton model.

[1] Dedicated to the memory of my father, Laszlo Naszodi, who once dealt with taxing property while being employed by the Mesa County (CO) USA and addressed questions similar to those raised in this paper.

The author is grateful for comments from Harrison Hong and an anonymous reviewer.

The views expressed in this paper are those of the author's.

The first version of this manuscript was completed and circulated on the 6th October 2016.

1 Introduction

Since 1 January 2016, the Single Resolution Board (SRB) together with the National Resolution Authorities in the Member States are responsible for the resolution of credit institutions and investment firms (henceforth banks) domiciled in the European Union. It takes eight years to build up the *Single Resolution Fund* (SRF) backing SRB from the contributions of banks and to gradually phase out the national resolutions in the Banking Union. The contributions are determined by the Commission Delegated Regulation (EU) 2015/63.[2] Henceforth, we refer to it as the Regulation (with capital R). In return for the contributions, banks can benefit from the resolution service during the contribution period ending in 2023 and beyond when needed.[3]

In addition to the service provided by the SRB, insurance against bank failure can also be bought by investors from the market on an optional basis. The most common insurance provided by the market is the *credit default swap* (CDS) that gives the right to the buyer of the protection to swap the bond issued by the bank with its face value in case the issuer bank defaults on its repayment obligation.

As a first step, this paper investigates how much the bondholders of a covered bank benefit from two insurance schemes, i.e., the compulsory one provided by the SRF and the optional one offered by a CDS contract. Specifically, this paper derives the *functional relationship between*

[2] The Commission Delegated Regulation (EU) 2015/63 offers different methods for calculating the contributions of different financial institutions. This paper focuses on the risk-adjusted method applicable by big and/or risky banks. The corresponding formulas are presented in the appendix. The motivation for narrowing down the analysis to this method is that the contributions of the big and/or risky banks in 2016 make out 96% of the total ex-ante contributions to the Fund, although these banks represent only 20% of all the institutions under the jurisdiction of the SRB.
See: https://srb.europa.eu/sites/srbsite/files/single_resolution_fund.pdf

[3] More precisely, until 2023 the SRF together with the national resolution funds will be used for any bank resolution. However, the national resolutions are gradually phased out and the SRB will be solely responsible for bank resolutions after 2023. For the sake of simplicity, this paper neither models the intermediate period nor distinguishes between the national resolution funds and the supranational resolution fund by assuming that all the resolution service is provided by the SRB.

the values generated by the two insurances for the bondholders and finds this function to be highly non-linear. As a second step, the derived functional relationship between the values is used to impose a *normative criterion against the fees* charged for the insurance services. As a third step, the paper proposes a *test on whether the normative criterion* is met in practice.

Since the values are not observable, a theoretical single-bank model is built to derive those as a function of some bank-specific variables, such as the market price of the bank's total assets and its volatility, the leverage, and the maturity of the bank's liabilities. The model proposed in this paper describes the insurances as *options* using a *Merton-type model.* The advantage of this model is that its simplicity allows us to concentrate on the regulatory specificities.

Our model is similar in spirit to the model developed by Necula and Radu (2012) for valuing the liabilities of a recapitalization fund. The common features of these two models are that both rely on the Merton (1974) model, where the underlying asset of the options is the market price of total assets, while the value of the compulsory insurance is a non-linear function of it. The distinctive feature of the model in this paper is that the strike price and other characteristics of the option capturing the value of the compulsory insurance are chosen in this study so as to reflect the following regulatory specificities: (i) the SRB can intervene only after a bail-in has already taken place, (ii) there is a limit to the funding the SRB is authorized to provide to each bank, (iii) this funding is used for covering losses and not for recapitalizing the bank, and (iv) resolution can happen even without an explicit default.[4]

[4] Among these four differences between this paper and the paper by Necula and Radu (2012), the first two can be considered to be solely semantical. First, Necula and Radu (2012) model the intervention point by a threshold parameter (with no reference to the bail-in rule). However, their threshold parameter corresponds to a parameter determined by the bail-in rule in this paper. Second, the ceiling on the premium of the recapitalization service in their model is due to the co-existence of a deposits' guarantee fund and not to the regulatory limit on the intervention by the SRB as it is in this paper.

Another set of differences between this paper and the paper by Necula and Radu (2012) relates to the estimation of some parameters key to pricing the service provided by the SRB or the liabilities of the recapitalization fund. They calibrate the parameters of the market price of total assets of some banks and the corresponding volatilities to the monthly stock prices of the examined bank's and the historical equity volatilities by using the method proposed by Ronn and Verma (1986). In contrast, this paper estimates the above parameters from the actuarial spread calculated and published by the Credit Research Initiative (CRI) from a broad set of variables including CDS data.[5]

The choice of the applied method in this paper is motivated by the literature: Hull et al. (2005) compare two approaches for implementing the Merton's model. Of the considered approaches one is the same as used by Necula and Radu (2012). Whereas the other one is closer to the approach applied in this paper as both identify the key parameters of the Merton's model from certain market prices other than the stock prices.[6] Hull et al. (2005) find that the latter approach usually performs better when the basis of comparison is the goodness of fit of the implied credit spreads on the CDS spreads.

Once one is equipped with the option-based model, one can *compare the model implied values* of the insurance services provided by the SRF and a CDS contract. Suppose that the outcome of the comparison is that one of the insurances is twice as valuable as the other according to the theory. Provided that the fee charged for this insurance is the double of the fee charged for the other that would mean that the fees (or prices, or premia, or taxes, or levies) are in *parity* with the

[5] There is a growing literature on testing credit risk models using the information from the CDS market. Huang and Zhou (2008) give an overview of the literature and conduct a specification analysis of various structural credit risk models, including the Merton's model, using the term structure of CDS spreads and equity volatility from high-frequency return data.

[6] Hull et al. (2005) use the implied volatilities of options on the company's equity, while this paper exploits the information in the CDS spread.

theoretical values. Given that the service of the SRF is not market-based, and the fee charged for it is not determined by the logic of the market, but by law, no mechanism guarantees the parity condition to hold in reality.[7]

Why does the *parity condition qualify to be a normative criterion* against the Regulation determining the fee for the compulsory insurance? To answer this question, it is important to make the following remarks. First, theoretically, the debtholders of banks could voluntarily establish a resolution fund and could divide the related cost among themselves following the logic of the Coasian bargaining.[8] Second, the parity condition ensures that the fee charged by the resolution authority is equal to the value generated by the resolution service for the debtholders of each bank under the assumption that the CDS market is efficient. For the above two reasons, the parity condition offers a possible cake-cutting that provides at least as much utility for the players as the opt out from the Coasian game,[9] i.e., the resulting allocation of the cost is in the core of the game.

Why *the parity condition should not necessarily be a normative criterion* against the Regulation? First, the core of the Coasian game is not necessarily uni-element, but it can contain vectors of contributions other than the one fulfilling the parity condition. This is not surprising as the creation of a public good typically enhances the "cake". In our specific case of the SRF, the cake

---

[7] Another peculiarity of the contributions collected by the SRB on top of the fact that they should not necessarily meet any equilibrium conditions is that these are paid from the profit of the banks, while the primary beneficiaries of the service of bank resolutions are not the owners of the banks, but the debtholders as recapitalization of banks by the SRB involves writing down shareholders' value to zero. Investigating empirically whether the cost of insurance is passed over to the debtholders remains for future research.

8 As it is pointed out by Tirol (2010) (see page 3), a necessary assumption for the feasibility of a spontaneously developed vehicle for extending liability to a third party, such as a privately established resolution fund, is that this third party has sufficiently deep pocket to cover even the large damages occurring during a bank crisis. In other words, the market-based solution can work only if the resolution fund cannot be "judgment-proof", in legal terms.

[9] See Coase (1960).

is enhanced due to the positive externality of reducing the risk of contagion among banks and both the debtholders and the shareholders of each bank benefit from that other banks are also covered by the compulsory insurance. Second, besides the Coasian approach, its natural alternative, the Pigovian approach also offers a solution for internalizing externalities.[10]

The model in this paper disregards some of the externalities mentioned in the first point and assumes the total value created by the SRF to be equal to the direct benefits generated exclusively for the debtholders. Regarding the second point, the model is built on the assumption that the Regulation is on the ground of Coasian fair pricing.

The rest of the paper is structured as follows. Section 2 presents a simple analysis. Section 3 introduces the theoretical model. Section 4 derives some policy-relevant implications, proposes a test on whether the contributions are fair in the Coasian sense and presents an example for calculating the contribution of a hypothetical bank. Finally, Section 5 concludes.

2 A simple analysis and its limitations

Suppose that the managers of a hypothetical bank A find the contribution payable by their bank to the SRF to be unfairly high and they propose a change in the parameters in the Regulation. Their argument is as follows. First, banks with zero market perceived risk should not pay any contribution. Henceforth, we refer to this criterion as the *"zero risk criterion"*. Second, the

[10] There is *disagreement in the academic literature* on whether the Coasian or the Pigovian approach should be followed. For instance, Goodhart and Schoenmaker (2009) explore possible ex-ante mechanisms for fiscal burden sharing in a banking crisis in Europe by expanding the model by Freixas (2003). Their mechanisms rely on the logic of the *Coasian* approach (although not declared explicitly) as those countries are assumed to shoulder a larger part of the burden that benefit more from the public good of financial stability. The option-based model by Necula and Radu (2012) also offers a method to determine the Coasian fair contributions. In contrast, Schoenmaker (2010) and Brunnermeier et al. (2009) advocates the *Pigovian* tax.

contribution (relative to the size of the bank) should be proportional to the CDS spread as both the CDS and the SRF provides insurance against the same event that is the failure of the bank. Henceforth, we refer to this criterion as the *"proportionality criterion"*. As a consequence of these criteria, the relationship between the CDS spreads and the contributions (normed by the bank size) should be linear with a zero intercept. Finally, by running a linear regression on bank-level data, the managers find that bank A is over-charged, while bank B is under-charged by the SRF relative to the market provided insurance as the former is above the regression line, while the latter is below. This is illustrated in Figure 1.

Is this argument correct? Should the "zero risk criterion" and the "proportionality criterion" be met? Should banks with higher market perceived risk (with higher CDS) contribute more in accordance with an intuitive criterion that we call the *"monotonicity criterion"*? Should the regulator consider changing the parameters of the Regulation if any of the above three criteria is violated? Should the regulator think that there is no need to revise the Regulation if the slope in the linear regression is positive and the goodness of fit is perfect or reasonably good?

As it is shown in this paper, the answers to the above questions are: no, no, no, no, and no, respectively. Although the argument of the bank managers is intuitive, it is wrong and their simple theory on fair pricing and their empirical analysis is misleading. What makes the intuition fail is that important differences between the two insurance services are overlooked. Still, their simple analysis shows clearly that *one needs to rely on some kind of theory* to be able to judge whether the contributions are fair. In the following, a theoretical model is developed that is more suitable to determine what the relationship should be between the fees.

3 Benchmark option-based model

This section develops a single-bank Merton's type model[11] in order to derive the values of two insurance services: one is offered by the CDS market, while the other is provided by the SRF. To do that, we impose the simplifying assumptions that the bank has only one type of debt which is a zero coupon bond. In this setup, a bank failure can happen only at the maturity of the bonds.

Under these assumptions, the classical Merton model suggests that the equity of the bank is a European-style call option on the total assets of the bank with the strike price being the face value of the debt. Similarly, going long on bonds is equivalent to holding the following portfolio. First, going short a European-style put option on the assets of the bank with the strike price being also the face value of the bonds. Second, going long the present value of the strike price. Formally,

$$Equity_t = Call_t^{European}(A_t, K, T-t, \sigma, r, q), \qquad \forall t \leq T, \tag{1}$$

$$Bonds_t = Ke^{-r(T-t)} - Put_t^{European}(A_t, K, T-t, \sigma, r, q), \qquad \forall t \leq T, \tag{2}$$

where A_t denotes the market price of total assets at time *t* and K is the face value of the debt, i.e., the principal amount that needs to be repaid to the debtholders at maturity T. The risk-free rate and the yield of return on the underlying asset are denoted by r and q, respectively. Finally, σ is a vector of parameters describing the process of the market price of total assets. For instance, if the process is determined by one of the simplest models, the Cox-Ross-Rubenstein (CRR) binomial model,[12] then σ captures only the volatility of the underlying asset.

[11] See Merton (1970), (1974).
[12] See Cox et al. (1979).

Now, let us see how one can model the values of the insurances by options. Suppose that one buys the bonds together with the insurance provided by the CDS and the bank defaults on the bonds at maturity. Then, the buyer and the seller of the CDS swap the defaulted bonds and money in the amount of the face value. More precisely, the buyer gives the defaulted bonds to the seller of the protection and in return receives the face value of the bonds. In the case of no default, the bank pays the face value of the bonds to the bondholder at the maturity. Either case, the owner of the portfolio of the bonds and the CDS gets the face value of the bonds:

$$Bonds_T + CDS_T^{value} = K. \qquad (3)$$

For the sake of simplicity, let us assume that the risk-free rate is zero:

$$r = 0. \qquad (4)$$

Under this assumption, the value of the risk-free portfolio consisting of the bonds and the CDS is equal to the face value of the bonds, K even for $t<T$:

$$Bonds_t + CDS_t^{value} = K, \qquad \forall t \leq T. \qquad (5)$$

By combining Equations (2), (4) and (5), we obtain that the value of the CDS is equivalent to the price of a European-style put option:

$$CDS_t^{value} = Put_t^{European}(A_t, K, T-t, \sigma, r, q), \qquad \forall t \leq T. \qquad (6)$$

Next, let us see how the insurance provided by the SRF can be modeled. Similar to the CDS, it can also be described as a put option, however, with some specific characteristics reflecting the differences between the conditions of payoffs of the two insurance schemes. There are three important differences that our model captures. The first is due to the bail-in rule, i.e., the SRB can intervene only after a bail-in of 8% of liabilities has already taken place. This shifts the strike price of the option describing the value of the service provided by the SRF relative to the strike price describing the CDS by 8% of the total liabilities. Second, there is a limit to the funding the SRB is authorized to provide. The funding cannot exceed 5% of the total liabilities including own funds and it is used only for covering losses and not for recapitalizing the banks. This is captured in the model by putting a cap on the value of the SRF. [13] Third, regarding the style of the put option that best describes the service provided by the SRF, we can say that it is an *American* one as resolution can happen anytime (even before an explicit default):

$$SRF_t^{value} = \min\left[Put_t^{American}(A_t, K - 0.08L, T - t, \sigma, r\,, q), 0.05L\right], \qquad \forall t \leq T, \tag{7}$$

where SRF_t^{value} denotes the time t value of the insurance provided by the SRF, while the book value of total liabilities of the bank is denoted by L.

Modeling how the above three specificities affect either the benefits that the SRF provides to the bondholders or the contingent liabilities of the SRF (which is just the mirror image of the benefits) brings us closer to understand the Regulation.[14]

As an alternative to the option-based approach, one could build a model from scratch, i.e., by using stochastic calculus to derive how the values of the insurances depend on the process of the

[13] In reality, there is no obligation for the SRB to intervene automatically after 8% of the liabilities are bailed-in and the SRB can spend less than the ceiling of 5% of the liabilities on a secured bank. The model in this paper disregards the possibility of any discretionary decision making from the side of the SRB. By that, the derived theoretical value of the compulsory insurance overestimates the corresponding value in practice.

[14] Due to the obvious limitation of the model, it does not account for some further specificities of the regulation. For instance, one could argue that the style of the option capturing the service of the SRF is exotic as once the bank is resolved, its compulsory insurance does not expire, but gets renewed automatically. This kind of renewability was typical to the practice of the national resolution authorities during the recent financial crisis. As it is noted by Gros and De Groen (2015) many banks needed capital support more than once during the crisis because the initial losses were not accurately estimated or the resolution required more money. Not modeling this kind of renewability makes the derived theoretical value of the compulsory insurance underestimate the corresponding value in practice.

market price of total assets. The main motivation for choosing the option-based model is that our general knowledge on option pricing provides us shortcuts to some results.[15]

3.1 Option valuation

This section elaborates on how one can value the options describing the insurances provided by the CDS and the SRF. First, let us make it explicit how the values of the options depend on the market price of total assets of the bank *at the maturity of the bonds* ($t=T$). By substituting the formula for the intrinsic value of the options into Equations (6) and (7),[16] we obtain:

$$CDS_T^{value} = \max(K - A_T, 0) \tag{8}$$

$$SRF_T^{value} = \min[\max(K - 0.08L - A_T, 0), 0.05L]\,. \tag{9}$$

Second, once an assumption is made on the process of the underlying asset, the price of the options can be derived even for $t<T$. However, Occam's Razor prevents us from making any assumption on the process before Section 4.6.

4 Implications of the option-based model

This section derives eight implications of the option-based model. The first three are *technical implications* about the *values of the insurances*, while the next five are written partially at a *non-technical* level and cover *normative implications about the fees*:

(i) Even when the option describing the service of the SRF is out of the money, i.e., when

[15] Naszodi (2010) develops another option-based model with the same motivation. That model describes the process of an exchange rate managed in a target zone with the help of two options. There the short cut offered by the option pricing literature is used to derive how the target zone exchange rate depends on the latent exchange rate, i.e., the exchange rate that would prevail under a free float.
[16] See Hull (2012), page 201 for the definition of the intrinsic value.

the price of the underlying asset of the corresponding put option exceeds the strike price, $A_t > K - 0.08L$, its value is positive before expiration ($CDS_t^{value} > 0$ for $t<T$).

(ii) The functional relationship between the value of the compulsory insurance (SRF_t^{value}) and the value of the optional insurance (CDS_t^{value}) is non-linear.

(iii) The leverage of the bank determines the exact shape of the above non-linear function.

(iv) Even the banks that seem very safe should contribute to the SRF under the Coasian approach as their benefit from the service provided by the Fund is strictly positive.

(v) A simple and seemingly tempting analysis approximating the empirical unconditional linear relationship between the contributions to the SRF and the CDS spreads is limitedly informative about whether the service of the SRF is fairly priced in the Coasian sense in practice,

(vi) while a modified version of this analysis is a better candidate for the same test.

(vii) If one finds that the fee charged by the SRB and the price paid by the protection buyer of the CDS are not in parity with the values of these insurances and there is political will for putting the Regulation on the ground of Coasian fair pricing,[17] then one possibility for that is to calibrate some of its parameters to the observed CDS spreads by using the option-based model sketched in this paper. In such an exercise, the parameters should be calibrated jointly due to some interdependencies among them. Once the parameters are calibrated, any change affecting only one single parameter could make the pricing deviate from the fair one.

(viii) The vintage of the data can affect whether calibrating the parameters to the CDS spreads is feasible.

---

[17] As it is discussed in the introduction of this paper, the Coasian fair pricing is not the only candidate for being the normative criterion against the Regulation.

These implications, with the exceptions of implications (i) and (iv), can be obtained by examining the theoretical values of the insurances at the maturity ($t=T$). As these values do not depend on the assumed process of the underlying asset (see Equations (8), (9)), the implications are robust to the process.

In addition, it is intuitive to say, although not proven here, that the above implications are also robust to whether an assumption of the Merton-type model is relaxed or not. Specifically, even if the secured bank has a more realistic liability structure than consisting of only a zero coupon bond, all the eight qualitative implications hold true.

4.1 The technical implications of the option-based model

Figure 2 illustrates how the values of the insurances depend on the market price of total assets both at the maturity of the bonds and before. What one can learn from this figure, besides the apparent presence of non-linearity, is that even when the market price of total assets is high, the value of the insurance provided by the SRF is positive for $t<T$. This phenomenon is a consequence of the style of the corresponding option.[18] Given that zero does not belong to the set of values of the function assigning the value of an American-style option to the price of the underlying asset for $t<T$, implications (i) is proven.

By inverting function (8) mapping the market price of total assets to the value of the CDS and substituting it to Equation (9), we obtain how the value of the insurance provided by the SRF

depends on the value of the CDS at the maturity of the bonds ($t=T$):

$$SRF_T^{value} = \min\left[\max\left(CDS_T^{value} - 0.08L, 0\right), 0.05L\right]. \tag{10}$$

[18] See Hull (2012), page 215.

Given that the resulting function in Equation (10) is non-linear, implication (ii) is proven.

To make the theory closer to the empirics, we scale both the value of the CDS and the value of the service of the SRF by dividing both by the face value of bonds (K). In addition, the obtained quantity for the CDS is multiplied by 10^4. As a result of these transformations, the theoretical value of the CDS is expressed as its price is quoted in practice, i.e., not in terms of money, but as a spread expressed in basis points (bps). Similarly, the value of the insurance provided by the SRF is also measured as a spread:

$$CDS_t^{value,\ spread\ in\ bps} = 10^4 \frac{CDS_t^{value}}{K}, \qquad \forall t \leq T \tag{11}$$

$$SRF_t^{value,\ spread} = \frac{SRF_t^{value}}{K}. \qquad \forall t \leq T. \tag{12}$$

By substituting Equations (11) and (12) into Equation (10), we obtain:

$$SRF_T^{value,\ spread} = \min\left[\max\left(10^{-4}\, CDS_t^{value,\ spread\ in\ bps} - 0.08\frac{L}{K}, 0\right), 0.05\frac{L}{K}\right]. \tag{13}$$

Equation (13) shows that the non-linearity is preserved by the functional relationship between the values of the insurances after being scaled. In addition, it shows that a specific measure of the *leverage* (i.e., the ratio of the total liabilities to the face value of bonds $\frac{L}{K}$) is an important determinant of the exact shape of this piecewise linear function, as it determines where the kinks are. This proves implication (iii).

4.2 The normative criteria and some implications of the model with direct policy relevance

This section defines formally three concepts: the efficiency of the CDS market, the parity condition and the fair pricing in the Coasian sense. Then, these definitions are used for proving implications (iv) and (v).

4.2.1 Normative criteria against the contributions

In order to facilitate the definition of the normative criteria and the efficiency of the CDS market, the assumption of having only one bank in the model is relaxed. Henceforth, it is assumed to have *N* banks. The yield on returns of the assets, the volatility of total assets and the leverage are allowed to vary across banks.

The *CDS market is efficient*, if the observed price (in other words, the fee charged for the market-based insurance) is equal to the corresponding theoretical value of the insurance service for each bank:

$$CDS_{t,i}^{fee} = CDS_{t,i}^{value}, \qquad \forall t \leq T, \quad \forall i \in \{1, .. N\}, \tag{14}$$

where $CDS_{t,i}^{fee}$ is the overall price of the CDS in terms of money providing protection against the default of bank *i* on its bonds.

The *normative criteria against the fees*, i.e., the *parity condition* is formalized as:

$$\frac{SRF_{t,i}^{fee}}{CDS_{t,i}^{fee}} = \frac{SRF_{t,i}^{value}}{CDS_{t,i}^{value}}, \qquad \forall t \leq T, \quad \forall i \in \{1, .. N\}, \tag{15}$$

where $SRF_{t,i}^{fee}$ is the contribution in terms of money that bank *i* pays to the Fund for the availability of the resolution service until the maturity of its debt.

Obviously, the *parity condition* can be written also for the spreads:

$$\frac{SRF_{t,i}^{fee,\ spread}}{CDS_{t,i}^{fee,\ spread\ in\ bps}} = \frac{SRF_{t,i}^{value,\ spread}}{CDS_{t,i}^{value,\ spread\ in\ bps}}, \qquad \forall t \leq T, \quad \forall i \in \{1, .. N\}, \tag{16}$$

where $SRF_{t,i}^{fee,\ spread} = \frac{SRF_{t,i}^{fee}}{K_i}$ and $CDS_{t,i}^{fee,\ spread\ in\ bps} = 10^4 \frac{CDS_{t,i}^{fee}}{K_i}$.

Under (14) and (15), the fee paid by each bank to the SRF is equal to the value generated by the SRF for the bondholders of the given bank:

$$SRF_{t,i}^{fee} = SRF_{t,i}^{value} \quad , \qquad \forall t \leq T, \quad \forall i \epsilon \{1, .. N\}. \tag{17}$$

If the externalities increasing the size of the cake are assumed away by $\sum_{i=1}^{N} SRF_{t,i}^{value} = \sum_{i=1}^{N} SRF_{t,i}^{fee}$,[19] then the above condition is not stricter than the condition of $SRF_{t,i}^{fee} \leq SRF_{t,i}^{value}$ guaranteeing the distribution of costs to be in the core of the Coasian game. Therefore, we will refer to Equation (17) as the criterion for the *fair pricing in the Coasian sense*.

4.2.2 The "zero risk criterion"

Implication (iv) suggests that even the least risky banks should contribute to the SRF under the Coasian approach. This implication is an immediate consequence of implication (i): if the value of the service provided by the compulsory insurance is positive ($SRF_{t,i}^{value} > 0$), then so should be the fee ($SRF_{t,i}^{fee} > 0$) under Equation (17). In other words, the "zero risk criterion" (proposed by the managers of bank A) and the Coasian fair pricing criterion are mutually exclusive.

4.2.3 Limitations of testing the normative criteria with the linear regression

Let us turn to implication (v) and investigate why, how and when a two variable linear regression (proposed by the managers of bank A) can mislead us on whether a bank is over-charged or under-charged by the SRB. First, let us derive how the Coasian fair price for the service provided

[19] De Groen and Gros (2015) calculate how much funding would have been needed from the SRF during the last banking crisis and find the total amount of about €72 billion, which is more than the target size of the SRF (€55 billion) determined by the Regulation, but less than the amount the SRF could draw on, if the ex-post levies are also taken into account. Their calculation can be thought of as a joint test on $\sum_{i=1}^{N} SRF_{t,i}^{value} = \sum_{i=1}^{N} SRF_{t,i}^{fee}$ and the contingent liabilities of the SRF represent the mirror image of the benefits.

by the SRF depends on the observed CDS price at the maturity of the bonds ($t=T$). From Equations (13), (14) and (17), we obtain:

$$SRF_{T,i}^{fee,\ spread} = \min\left[\max\left(10^{-4}\, CDS_{T,i}^{fee,\ spread\ in\ bps} - 0.08\frac{L_i}{K_i}, 0\right), 0.05\frac{L_i}{K_i}\right], \quad (18)$$

Now, let us highlight by two examples, what the limitations of the two-variable linear regression are at analyzing whether a "cake-cutting" is fair. In both of the examples, the banks in the hypothetical samples distribute the cost of establishing the SRF fairly among themselves. In other words, the bank level observations fulfill Equation (18) under the efficiency of the CDS market.

In our first example, the banks operate with the same leverage and there is a non-linear relationship between their CDS spreads and contributions as it is depicted by Figure 3. Now, running a linear regression and investigating the residuals would falsely suggest that banks with moderate market perceived risk (lower CDS) tend to be under-charged (as these, although not all of them, are typically below the regression line) relative to the banks with high market perceived risk (as most of the banks with high CDS, although not all, are above the regression line).

In our second example, there are only two banks operating with different leverages. The bank level observations (the pair of $CDS_{T,i}^{fee,\ spread\ in\ bps}$ and $SRF_{T,i}^{fee,\ spread}$) are depicted by Figure 4. This figure illustrates that the simple analysis with linear regression is not adequate in this set up either due to the omitted variable bias. Specifically, if not controlling for the leverage, then the slope of the regression line can be even negative. In other words, the unconditional version of the "monotonicity criterion" does not qualify to be a normative criterion.[20]

[20] Equation (18) suggests that in contrast to the unconditional version of the "monotonicity criterion", the conditional version of it does qualify to be a normative criterion against the contributions. The conditional

4.3 The extended option-based model and an alternative test

This section first extends the option-based model in order to account for the interaction between the compulsory insurance and the market-based insurance. Then, it proposes a test for the normative criterion of the Coasian fair pricing using the extended option-based model. This test addresses both the misspecification error (i.e., due to working with a linear model in the empirics, while the right model is non-linear) and the omitted variable problem (not controlling for the leverage of the banks) discussed already in Section 4.2.3.

4.3.1 The extended option-based model

The extended option-based model accounts for that once a credible resolution fund is established, the insurance bought from the market offers only an additional service on top of the compulsory one. If every single euro injected by the resolution fund to the bank decreases the burden on the seller of the CDS, [21] then the value of the CDS is:

$$CDS_{t,i}^{value,\ with\,SRF} = CDS_{t,i}^{value,\ without\,SRF} - SRF_{t,i}^{value} \quad , \tag{19}$$

where $CDS_{t,i}^{value,\ with\,SRF}$ denotes the value of the insurance offered by the market when the SRF already operates. While $CDS_{t,i}^{value,\ without\,SRF}$ would be the value of the optional insurance in the absence of the compulsory one, i.e., when a resolution fund is not even foreseen to start operating until the CDS contract expires. As the benchmark option-based model disregards the interaction between the insurances by construction, $CDS_{t,i}^{value,\ without\,SRF}$ in the extended model is identical to the $CDS_{t,i}^{value}$ in the benchmark model.

---

version of the "monotonicity criterion" can be defined as follows: among banks that are identical in almost all relevant characteristics (leverage, maturity of the outstanding debt, volatility of the market price of total assets, etc.), those should contribute more to the Fund that have higher CDS spreads.

[21] The implicit assumption here is that the SRF is used only for covering losses and not for recapitalizing banks. This is realistic if recapitalization is not costly: every euro injected into the capital stock of a failing bank by the SRB pays back once the SRB sells its shares in the resolved bank.

4.3.2 A test on whether the contributions are fair in the Coasian sense

This section proposes an empirical test on whether the contributions are fair in the Coasian sense. Formally, the hypothesis to be tested is $\alpha_0 = 0$ and $\alpha_1 = 1$ in the following equation:

$$SRF_{t,i}^{fee} = \alpha_0 + \alpha_1\, SRF_{t,i}^{value} \qquad \forall t \leq T, \quad \forall i \epsilon \{1, .. N\}. \tag{20}$$

Under H_0, Equation (20) is equivalent to Equation (17) which is the formal criteria for the Coasian fair pricing. The alternative hypothesis is that the cake cutting is too generous either with the more risky banks ($\alpha_0 > 0$ and $\alpha_1 < 1$), or with the less risky banks ($\alpha_0 < 0$ and $\alpha_1 > 1$) at the expense of the other banks.

Unfortunately, as $SRF_{t,i}^{value}$ is not observable, it is impossible to estimate α_0 and α_1 directly.[22] The following approach can be used to circumvent this problem. As a first step, one needs to estimate the CDS spreads of the European banks under the counterfactual that the SRF was not set up using the hedonic pricing method. That we denote by $CDS_{t_1,i}^{fee,\ spread\ without\ SRF}$ for bank i at time t_1 corresponding to the year after the SRF was established. It can be approximated by

$$\widehat{CDS}_{t_1,i}^{fee,\ spread\ without\ SRF} = CDS_{t_0,i}^{fee,\ spread} + \hat{\delta}_i, \ , \tag{21}$$

where $CDS_{t_0,i}^{fee,\ spread}$ denotes the observed CDS spread of bank i at time t_0, the year when the

[22] In contrast to $SRF_{t,i}^{value}$, $SRF_{t,i}^{fee}$ is observable, although not for the general public. The SRB publishes data on the contributions only at an aggregated level.
See:https://srb.europa.eu/sites/srbsite/files/srf_contributions_2017.pdf.
By browsing the publically available annual reports of the large banks, we can find some data on the contributions of a few big banks. For instance, BNP Paribas SA (508 million €), Deutsche Bank AG (280.4 million €), Intesa Sanpaolo (578 million €), ING Bank NV (176 million €) and Banco Bilbao Vizcaya Argentaria SA (137 million €) disclosed some information on their levies paid in 2016. However, some of these figures in parentheses are not net of other bank levies, such as the contributions to the deposit guarantee funds, for instance. Therefore, these figures are of limited use for testing whether the contributions of the banks are fair in the Coasian sense.

SRF was not even anticipated to be set up. And $\hat{\delta}_i$ is an estimates on the potential change in the CDS spread of bank *i*, between t_0 and t_1, which is due to all of the factors except the investigated regulatory change. Inter alia, it captures the effect of the changing risk appetite of the investors between t_0 and t_1. One option for identifying δ_i is to estimate it from the CDS spreads of banks in a country outside the juris diction of the SRB.

If this country is the UK, then $\hat{\delta}_i = CDS_{t_1,j}^{fee,\ spread} - CDS_{t_0,j}^{fee,\ spread}$, where bank *j* is a UK bank which has similar characteristics to bank *i* and its observed CDS spread is denoted by $CDS_{t_0,j}^{fee,\ spread}$ and $CDS_{t_1,j}^{fee,\ spread}$ at times t_0 and t_1, respectively.

As a second step, the regressions corresponding to Equations (22) and (23) needs to be run using the estimates on $CDS_{t_1,i}^{fee,\ spread\ \ without\,SRF}$ obtained in the first step.

$$SRF_{t_1,i}^{fee,\ spread} = \beta_0 + \beta_1 \left(\widehat{CDS}_{t_1,i}^{fee,\ spread\ \ without\,SRF} - 0.08 \frac{L_i}{K_i} \right) + \varepsilon_i \ , \tag{22}$$

$$SRF_{t_1,i}^{fee,\ spread} = \gamma_0 + \gamma_1 \left(CDS_{t_1,i}^{fee,\ \ spread} - 0.08 \frac{L_i}{K_i} \right) + \omega_i \ . \tag{23}$$

As it is apparent from Equations (22) and (23), the leverage of the banks is controlled for by the term $\frac{L_i}{K_i}$. While the misspecification problem can be handled to some extent by restricting the sample to those banks with censoring neither in the dependent variable nor in the independent variable.

It is easy to see that testing H_0 is equivalent to testing $\widetilde{H_0}$: $\beta_0 = \frac{\gamma_0}{1+\gamma_1}$ and $\beta_1 = \frac{\gamma_1}{1+\gamma_1}$ under Equation (14), (19) and (21).[23] The proposed test is a *joint test* on whether the contributions are

[23] If heterogeneity among banks is coming only from the differences of their leverages, then the conditional version of the "monotonicity criterion" (defined in footnote 20) is equivalent to $\gamma_1 > 0$. It is

fair in the Coasian sense, the CDSs are priced efficiently, the counterfactual is constructed properly, the size of the cake is unaffected by establishing the SRF, i.e., $\sum_{i=1}^{N} SRF_{t,i}^{value} = \sum_{i=1}^{N} SRF_{t,i}^{fee}$, the fund used for covering losses as a fraction of the total liabilities does not vary across banks, i.e., being 5% for each secured banks, and the market prices the CDS as an additional insurance after the SRF is established. Therefore, it is important to note that the rejection of $\widetilde{H_0}$ would not imply automatically the rejection of H_0, since it could also be due to the violation of any of the latter five criteria.

It is also important to note, that there are at least three potential sources of the type I and type II errors of the proposed test. First, the omission of some important variables, like the maturity of bonds (T_i) and the parameters describing the process of the market price of total assets (σ_i).[24] Second, the way how the leverage is controlled for and the non-linearity is treated in the test is adequate for $t=T$, but might not be perfectly adequate for $t<T$. Third, as the proposed test is based on some aggregate statistics, it is limitedly informative about whether the contributions paid by each individual banks are fair. These caveats will be addressed in Section 4.6.

---

easy to see that $\gamma_1 > 0$ together with $\gamma_1 > \beta_1 > 0$ implies $\alpha_1 > 0$ which is a necessary, but not a sufficient condition for fair pricing in the Coasian sense.

[24] By using the Black-Scholes model, we illustrate how the maturity of bonds (T_i) and the volatility of the underlying asset affects the functional relationship between the CDS spreads and the contributions for $t<T$. In order to obtain an analytical solution, one can use the Brenner and Subrahmanyam (1988) approximation for the price of the CDS: when $A_{t,i}$ is close to K_i, $CDS_{t,i}^{fee} \approx K_i - \big(1 -$ *0.4 σiTi−tAt,i.* After substituting the inverse of this function to the Black-Scholes option pricing formula, we obtain:

$SRF_{t,i}^{fee} \approx -\Phi(-d_1)\frac{CDS_{t,i}^{fee} - K_i}{0.4\,\sigma_i\sqrt{T_i - t} - 1} + \Phi(-d_2)K_i$, where Φ is the cumulative distribution function of the standard normal distribution, $d_1 = \frac{1}{\sigma_i\sqrt{T_i - t}}\left[ln\left(\frac{\frac{CDS_{t,i}^{fee}}{K_i} - 1}{0.4\,\sigma_i\sqrt{T_i - t} - 1} + \frac{\sigma_i^{2}}{2}(T_i - t)\right)\right]$ and $d_2 = d_1 - \sigma_i\sqrt{T_i - t}$.

4.4 Implications of the model on the calibration of the parameters

This section discusses implications (vii) and (viii) on how some parameters of the Regulation can be calibrated to preserve or achieve the Coasian fair pricing.

Suppose that the contributions meet the normative criterion of the Coasian fair pricing and someone proposes to change one single parameter in the regulation. For the sake of the thought experiment, suppose that this parameter is the one that determines the maximum extent of intervention by the SRB which is set to 5% of the total liabilities. Increasing this ceiling affects the contingent liabilities of the SRB making it necessary to adjust the target size of the Fund in order to maintain the credibility of the SRB.

Similarly, such a modification in the ceiling increases both the value of the compulsory insurance generated for the bondholders (SRF_t^{value}) and also its maximum, that is $5\%L$ before the hypothetical regulatory change. If the regulator wishes to preserve the Coasian fair pricing captured by Equation (17), then the maximum of the fee charged for the compulsory insurance should be modified as well. As it is shown in the appendix, the fee charged by the SRB in terms of spread ($SRF_t^{fee,\ spread}$) is proportional to the so-called *rescaled final composite indicator* defined by the Regulation.[25] Therefore, a change in the parameter determining the maximum extent of intervention by the SRB should be accompanied by adjusting the cap parameter of the rescaled final composite indicator.[26] The above example illustrates that the parameters should be calibrated jointly as it is suggested by implication (vii).

[25] See the appendix about the definition of the rescaled final composite indicator. In addition, its Equation (A5) presents how the SRF spread relates to the rescaled final composite indicator.

[26] The Regulation determines the maximum of the rescaled final composite indicator to be 1.5. See Equation (A2) in the appendix. According to Equation (A2), the minimum of the rescaled final composite indicator is 0.8. It is important to note that Figure 3 suggests falsely the minimum to be 0 merely due to

Finally, let us turn to implication (viii). We use the extended option-based model introduced in Section 4.3.1 to prove that the vintage of the data effects the feasibility of calibrating the contributions to the CDS spreads. We assume that the market applies the benchmark model in the pre-SRF era, while it uses the extended model for pricing the CDS after the SRF is already set up. Figure 5 shows that at the maturity of the bonds ($t=T$) the value of the insurance provided by the SRF reacts much more to changes in the value of the CDS in the extended model than in the benchmark model. The same holds for the fees under the Coasian fair pricing and the efficiency of the CDS market. In addition, it is intuitive to say that setting up a resolution fund makes the functional relationship between the fees steeper not only at the maturity of the bonds ($t=T$) but also before ($t<T$). Obviously, the steeper this function is, the less robust the calibration is. In other words, data from the pre-SRF era, when some banks were considered to be too big to be rescued, can facilitate the calibration of their contributions to CDS spreads. However, once a resolution fund (national or supranational) is expected to cover at least a portion of the losses of some debtholders, the calibrated contributions become sensitive both to the changes and the observation errors in the CDS spreads.

The next section provides a rough empirical analysis on when the CDS market had started to price in that the SRF was going to be established.[27]

some simplifying assumptions of the model in this paper. First, the option-based model disregards that the small and moderately risky banks calculate their contributions with a method different from the "Risk Adjusted Contribution" method. Second, Figure 3 depicts the relationship between the insurances at the maturity of the bonds and not before.

[27] Naszodi and Katay (2019) provide a more detailed analysis of the time series of the CDS spreads of some European banks with the purpose of quantifying to what extent has the SRM enhanced the financial stability in the Banking Union.

4.5 Structural break in the CDS spreads

This section identifies a structural break in the CDS spreads of the European banks that is indicative of that when the pre-SRF era has ended. By looking at the time series of the CDS spread indicator of some European banks and that of some UK banks depicted by Figure 6, it becomes apparent that the CDS market started to price in the expected change in the regulation around 10th of July 2013, when the European Commission presented detailed legislative proposals on the SRM and the SRF.[28] Before that date the aggregate CDS spreads seem to have had parallel trends in the UK and in the BU. After July 2013, the difference between the spreads started to shrink.

Based on this simple analysis, we might conclude that if one would like to test the contributions of the banks to the SRF against the criterion of fair pricing in the Coasian sense by using CDS data, then the CDS spreads from the period preceding July 2013 are preferable to be used for this purpose.

4.6 Calculating the Coasian-fair contribution of a hypothetical bank from its actuarial spread

To illustrate, how the benchmark model can be used in practice, this section presents the calculation of the Coasian-fair contribution of a hypothetical bank. In this example, the *leverage of the hypothetical bank* and the *maturity of its bonds* are taken into account, and an assumption is made on the *process of the market price of its total assets*. The focus is on one bank since the concept of fairness is applicable to *individual entities* rather than to groups. Furthermore, the

[28] See:
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013PC0520&qid=1499762308645&from=EN

contributions are calculated from the *actuarial spread (AS)* estimated and published by the Credit Research Initiative (CRI) and not from the observed CDS spreads.

Using the actuarial spreads from the CRI has some advantages relative to the market-based CDS spreads. First, the actuarial spread captures the solvency risk in relation to the failure of the bank. At the same time, it is free from various premia, i.e., the premia compensating for the illiquidity of the CDS market and the bond market, and the premia capturing the market power of protection sellers and their solvency risk. Second, it is plausible that the contribution of a secured bank determined under the Coasian perspective is linked to the solvency risk of the given bank, but it is not plausible to be linked to the premia listed above. Third, the actuarial spread does not account for any kind of public intervention explicitly.

Let us turn now to the numerical example. In this example, the process of the bank's market price of total assets is assumed to be described by the CRR binomial model.[29] Its two parameters, the market price of total assets (A_t) and its volatility (σ) are chosen so as to fulfill:

$$\frac{AS_t^{fee,\ spread\ in\ bps}}{T-t} =$$

$$= \frac{10^4}{K(T-t)}\, Put_t^{European}(A_t, K = 1{,}374\ €\ bn, T-t = 0.5\ yr, \sigma, r = 0\ , q = 0.04\%), \qquad (24)$$

[29] This simple process facilitates the valuation of even exotic options by a numerical method (by backward induction) under the no-arbitrage condition. Our approach for calculating the contributions can be further refined along the works by Merton (1976), Duan et. al (2012), Duan and Fulop (2013) and Duan (2014). These papers model the default probability not only with the leverage of the bank and the volatility of its market price of total assets but also with at least five factors neglected by this paper. These are the jumps in the stock price, correlation among default probabilities of different banks, the defaults over multiple horizons, the changes in the interest rate and the risk aversion of investors. As the above models have richer structures than the one in this paper, those are likely to perform better when the basis of comparison is the in-sample fit, but it is not necessarily the case for the out-of-sample fit. For instance, Hull et al. (2005) find that the more complex Merton's (1976) "model has statistically significant explanatory power, but in all cases the Merton (1974) model provides significantly better predictions of default probabilities and credit spreads at the 1% level." See page 22.

where the choice of the values for the strike price (K), the time until maturity $(T - t)$ and the yield on the underlying asset (q) are motivated by the corresponding characteristics of Deutsche Bank AG at the end of 2015.[30] Similarly, the left-hand-side of Equation (24) is set equal to the actuarial 1 year spread (in bps) of Deutsche Bank AG on the day 31/12/2015,[31] i.e., $\frac{AS_t^{fee,\ spread\ in\ bps}}{T-t} = 29.86$.

As a first step, we solve Equation (24) and obtain $A_t = 1{,}567\ €\,bn$ and $\sigma = 10.78\%$. As a second step, the above parameters are used to calculate the Coasian-fair price for the service provided by the SRF to the hypothetical bank. This calculation involves the pricing of an American-style put option with the numerical binomial option valuation method along the lines of Equations (7) and (16). We obtain the Coasian-fair price for the annual coverage $\frac{SRF_t^{fee}}{T-t}$ to be around 57 million €.

How would some of the omitted factors modify the above figure? As it is shown next, our method offers a lower bound for the fair contribution for three reasons. First, the calculation above does not account for that coverage will be provided not only during the eight years of contribution period but also beyond. In order to count with it, the above figure should be scaled

[30] All the bank-specific information used in this exercise are publically available and coming from the Deutsche Bank's Annual Report 2015. The yield of the underlying asset (q) is set equal to the ROA. The strike price (K) is set to be equal to the book value of total liabilities reduced by the sum of liabilities that are less senior than the long term debt guaranteed by the CDS. These liabilities include the total equity, other liabilities, other financial liabilities and trust preferred securities. The time until maturity $(T - t)$ is set to be the weighted average of the midpoints of each maturity intervals reported. (The midpoint is replaced by 5 years in the case of the maturity category of "over 5 years".) When calculating the duration of the liabilities, covered deposits (that are rarely withdrawn at their expiration date) are not differentiated from other types of liabilities as the zero coupon bonds are assumed to be the only type of external liabilities in the model.

[31] Source of data: National University of Singapore, Risk Management Institute, CRI database. Available at: http://rmicri.org [Accessed on 20 February 2019].

up by approximately $\frac{8+h}{8}$, where h denotes the assumed number of additional years for which the resolution service is offered without any further contributions.

Second, as it is discussed in Section 4.3.1, it does matter whether the interaction between the insurances are taken into account or not. Although the actuarial spread calculated and published by the CRI does not account for any kind of public intervention explicitly, it might not be perfectly immune to the changes in the bank regulations. For instance, it might factor in the enhanced financial stability due to the established SRB via being calculated from higher recovery rates. In the latter case, one might underestimate the fair contributions with the method presented above.

Third, while certain premia present in the CDS spreads might be considered not to be adequate to be built in the contributions payable to an ex-ante resolution fund, some others might qualify to be charged for despite the actuarial spread does not capture them. The types of premia falling into the latter category are those that compensate for the risk of illiquidity of the secured bank,[32] and the systemic risk generated by the secured bank that effects the same bank.[33] If the latter two premia are negligible in magnitude, then it is adequate to calibrate the contributions to the actuarial spread capturing only the solvency risk. However, if these premia are large, then the CDS spread might serve to be a better reference. What period the CDS spread is sampled from for such an exercise might not be neutral according to the theoretical finding of Section 4.3.1.

[32] If banks become more resilient against liquidity shocks by relying on more stable funding and decreasing their maturity mismatch, then the bondholders can be compensated with lower risk premium. How this effects the liquidity premium charged on the CDS market is not evident.

[33] The CDS spread of a given bank captures that slice of the systemic risk that is due to shocks generated by the bank in question and effects the very same bank via the feed backs from the other banks to the initiator of the shock. By decomposing the CDS spreads of banks, Keiler and Eder (2013) find the relative weight of the systemic risk component to be around 10 %. As a matter of fact, the third risk pillar (called "importance of an institution to the stability of the financial system or economy") used in the Regulation for determining the risk profile of the banks is happen to be assigned also the weight of 10%.

5 Conclusions

This paper presented a Merton-type model describing both the value of the compulsory insurance provided by the Single Resolution Fund and the value of the optional insurance provided by the CDS market as put options. This model offers a framework for testing whether the contributions of banks to the Fund satisfy a normative criterion. The normative criterion analyzed in this paper is the Coasian fair pricing under which the bondholders of each bank benefit from the existence of a resolution fund at least as much as their banks contribute to the Fund.

The option-based model and the concept of fair pricing can help the regulator decide what proposals on the changes in the Regulation determining the contributions are worth to be considered. If there is political will for changing some parameters in the Regulation, then one possibility is to calibrate the parameters either to the CDS spreads or the actuarial spreads, for instance, by using a concept of fair pricing and a model similar to the one sketched in this paper.

This paper presented some advantages and some potential limitations of such a calibration. It highlighted that in such an exercise, the parameters should be estimated jointly. When those are calibrated to the CDS spreads, then it is advised to use data from the pre-SRF era, prior to July 2013. Once the parameters are calibrated, any change affecting only one single parameter could make the pricing deviate from the fair one. Whether these implications are robust to the assumed normative theory forming the basis of the Regulation is the subject of future research.

References

Brenner, M., Subrahmanyam G. M., 1988. A Simple Formula to Compute the Implied Standard Deviation. Financial Analysts Journal 44(5), 80-83

Brunnermeier, M., Crockett, A., Goodhart, C., Persaud, A., Shin, H., 2009. The fundamental principles of financial regulation. Geneva Reports on the World Economy 11.

Coase, R. H., 1960. The Problem of Social Cost. Journal of Law and Economics 3, 1–44.

Cox, J. C., Ross, S. A., Rubinstein, M., 1979. Option pricing: A simplified approach. Journal of Financial Economics 7 (3), 229–263.

Duan, J.-C., 2014. Actuarial Par Spread and Empirical Pricing of CDS by Decomposition. In: Global Credit Review. World Scientific Book Chapters. World Scientific Publishing Co. Pte. Ltd., Ch. 3, pp. 51–65.

Duan, J.-C., Fulop, A., 2013. Multiperiod Corporate Default Prediction with the Partially-Conditioned Forward Intensity. RMI working paper.

Duan, J.-C., Sun, J., Wang, T., 2012. Multiperiod corporate default prediction – A forward intensity approach. Journal of Econometrics 170 (1), 191–209.

Freixas, X., 2003. Crisis Management in Europe. In: Kremers, J., Schoenmaker, D., Wierts, P. (Eds.), Financial Supervision in Europe. Cheltenham: Edward Elgar, pp.102–119.

Goodhart, C., Schoenmaker, D., 2009. Fiscal Burden Sharing in Cross-Border Banking Crises. International Journal of Central Banking 5 (1), 141–165.

Gros, D., De Groen, W. P., 2015. Estimating the Bridge Financing Needs of the Single Resolution Fund: How expensive is it to resolve a bank? CEPS Special Report 122, Centre for European Policy Studies.

Huang J.-Z., Zhou H., 2008., Specification Analysis of Structural Credit Risk Models. Board of Governors of the Federal Reserve System (US).

Hull, J. C., 2012. Options, futures, and other derivatives, 8th Edition. Upper Saddle River: Pearson Prentice Hall.

Hull, J., Nelken, I., White, A., 2005. Merton's Model, Credit Risk and Volatility Skews. Journal of Credit Risk. 1.

Merton, R. C., 1974. On the pricing of corporate debt: The risk structure of interest rates., Journal of Finance, 29, p. 449–470.

Merton, R. C., 1976. Option pricing when underlying stock returns are discontinuous. Journal of Financial Economics 3, 125–44.

Merton, R. C., 1970. Dynamic general equilibrium model of the asset market and its application to the pricing of the capital structure of the firm. SSM W.P. #497-70, M.I.T. (December 1970).

Naszodi, A., 2010. The options-based model of the target-zone and its application to the French franc in the EMS. Journal of Derivatives and Hedge Funds.

Naszodi, A., Katay G. 2019. Has the Single Resolution Mechanism enhanced financial stability in Europe? Evidence from CDS data, unpublished manuscript.

Necula, C., Radu, A.-N., 2012. Quantifying the recapitalization fund premium using option pricing techniques. Economics Letters 114 (3), 249–251.

Perotti, E., Suarez, J., 2010. Liquidity risk charges as a primary macroprudential tool. DSF Policy Paper, No. 1, January.

Ronn, E.I., Verma, A.K., 1986. Pricing risk-adjusted deposit insurance: an option-based model. Journal of Finance 41, 871–895.

Schoenmaker, D., 2010. Do we need a separate resolution fund? Voxeu 14 January 2010. http://voxeu.org/article/against-separate-resolution-fund

Tirole, J., 2010. From Pigou to Extended Liability: On the Optimal Taxation of Externalities Under Imperfect Financial Markets, Review of Economic Studies, Oxford University Press, vol. 77(2), pages 697-729.

Appendix

This appendix presents some formulas of the *risk-adjusted method* in the Regulation. Then, it derives how the *SRF spread* relates to the *rescaled final composite indicator* defined by the Regulation.

The risk-adjusted method is applicable to big and/or risky banks to calculate their contributions to the SRF. The formulas for computing the annual contributions defined by Annex 1, Step 6, paragraph 1 and 2 of the Regulation are:

$$c_i = Target \, \frac{\frac{B_i}{\sum_j B_j} \cdot \tilde{R}_i}{\sum_j \left(\frac{B_j}{\sum_m B_m} \cdot \tilde{R}_j \right)} \,, \tag{A1}$$

$$\tilde{R}_i = (1.5 - 0.8) \, \frac{FCI_i - \min \; FCI_j}{\max \; FCI_j \; - \min \; FCI_j} + 0.8, \tag{A2}$$

where i, j and m index financial institutions. The annual contribution in terms of money payable by bank i is denoted by c_i. The rescaled final composite indicator of bank i is $\tilde{R}_i$. $Target$ is the annual target level of the total contributions collected from those banks that calculate their individual contributions with the risk-adjusted method (and not with any of its alternatives, i.e., the partial risk-adjusted method or simply contributing by a lump sum.). B_i is the amount of liabilities (excluding own funds) less covered deposits of institution i. Finally, FCI_i is the *final composite indicator* to be calculated from a number of components. See the Regulation for further details.

How these notations far with the notations in this paper? First, if liabilities consist only of zero coupon bonds and own funds, then

$$B_i = K_i \tag{A3}$$

Second, both c_i and SRF_i^{fee} denote certain kinds of contributions payable by bank *i*. Their functional relationship can be obtained after transforming both to annuities:

$$c_i \frac{8}{8+h} = \frac{SRF_i^{fee}}{T_i - t}, \tag{A4}$$

where the annual contribution c_i (used in the Regulation) should be paid only during the eight-year transition period which is assumed to be followed by h years of contribution holidays. We can think of this period of h years as first having *h-1* years of tranquility that is followed by 1 year of severe bank crisis consuming all the Fund. For instance, if severe bank crises are believed to take place in every 70 years and the eight-year transition period is free of crises, then h should be 62.

Finally, using the above formulas in the appendix and the terminology in the Regulation, one can give a new interpretation to the annualized SRF spread:

$$\frac{SRF_{t,i}^{fee,\ spread}}{T_i - t} = \frac{SRF_{t,i}^{fee}}{K_i} \frac{1}{T_i - t} = \frac{c_i}{K_i} \frac{8}{8+h} = \frac{8}{8+h} Target \ \frac{\frac{1}{\sum_{j=1}^{N} K_j}}{\sum_{j=1}^{N} \left(\frac{K_j}{\sum_{m=1}^{N} K_m} \tilde{R}_{t,j} \right)} \tilde{R}_{t,i} \ = M_t \tilde{R}_{t,i} \tag{A5}$$

where $\tilde{R}_{t,i}$ is the time and bank specific *rescaled final composite indicator* defined by Equation (A2), while the *multiplier* M_t is the same across all banks: $M_t = \frac{8}{8+h} Target \ \frac{\frac{1}{\sum_{j=1}^{N} K_j}}{\sum_{j=1}^{N} \left(\frac{K_j}{\sum_{m=1}^{N} K_m} \tilde{R}_{t,j} \right)}$.

Figures

Figure 1: The regression line fit on data of two hypothetical banks

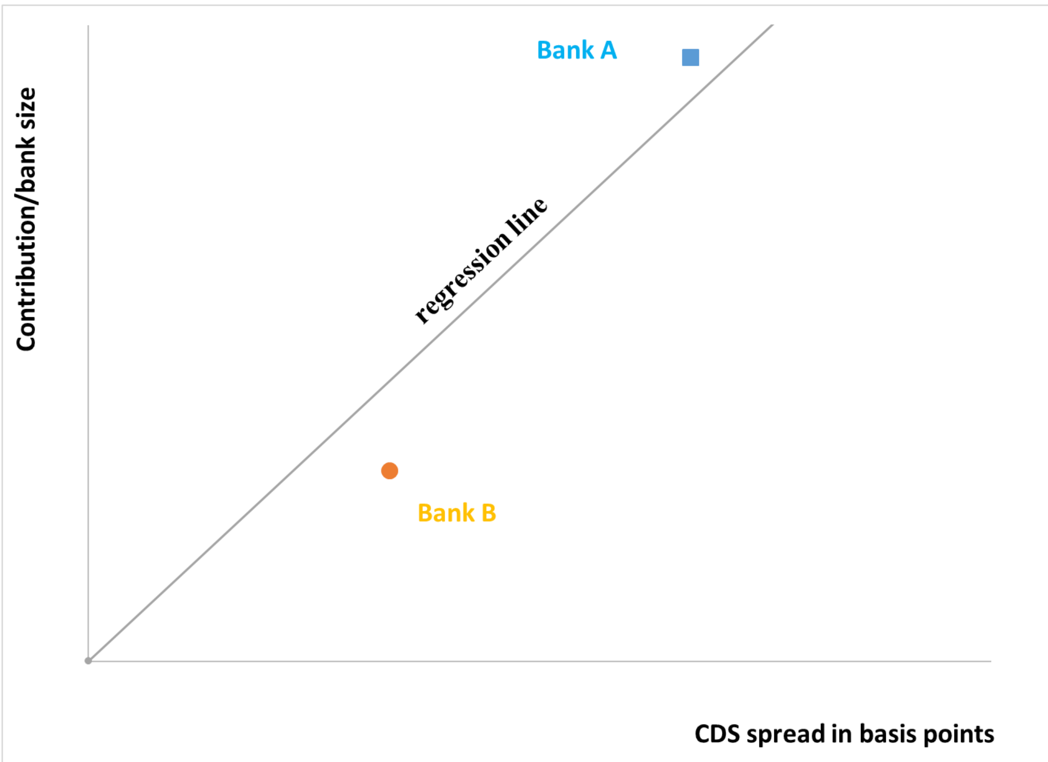
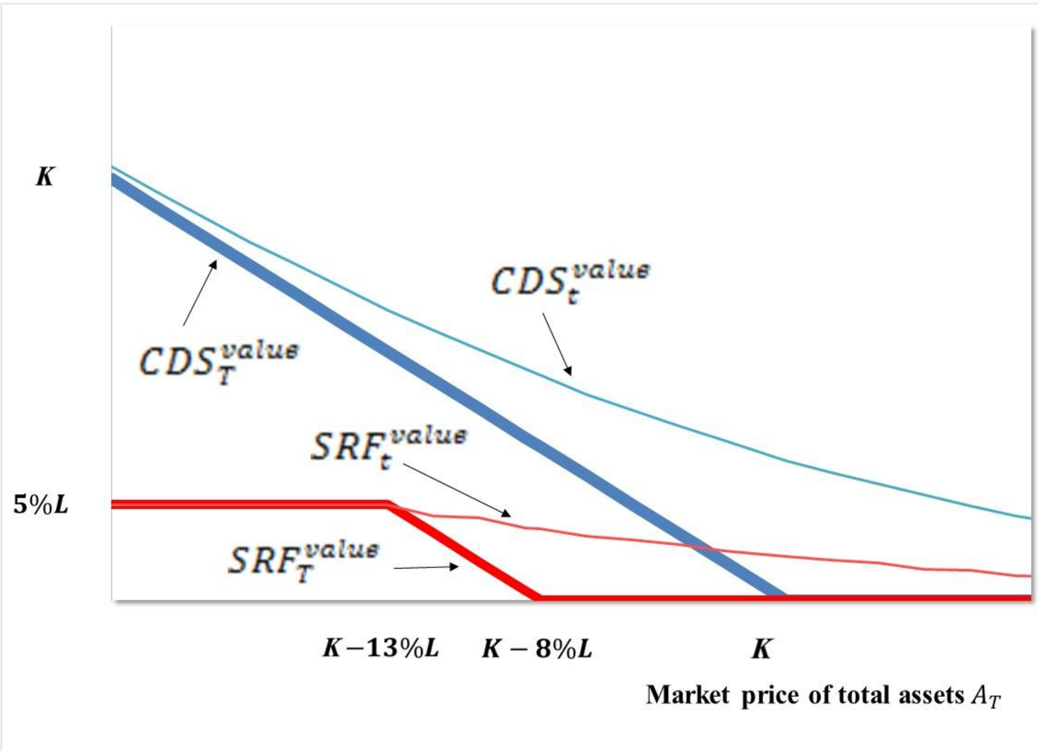
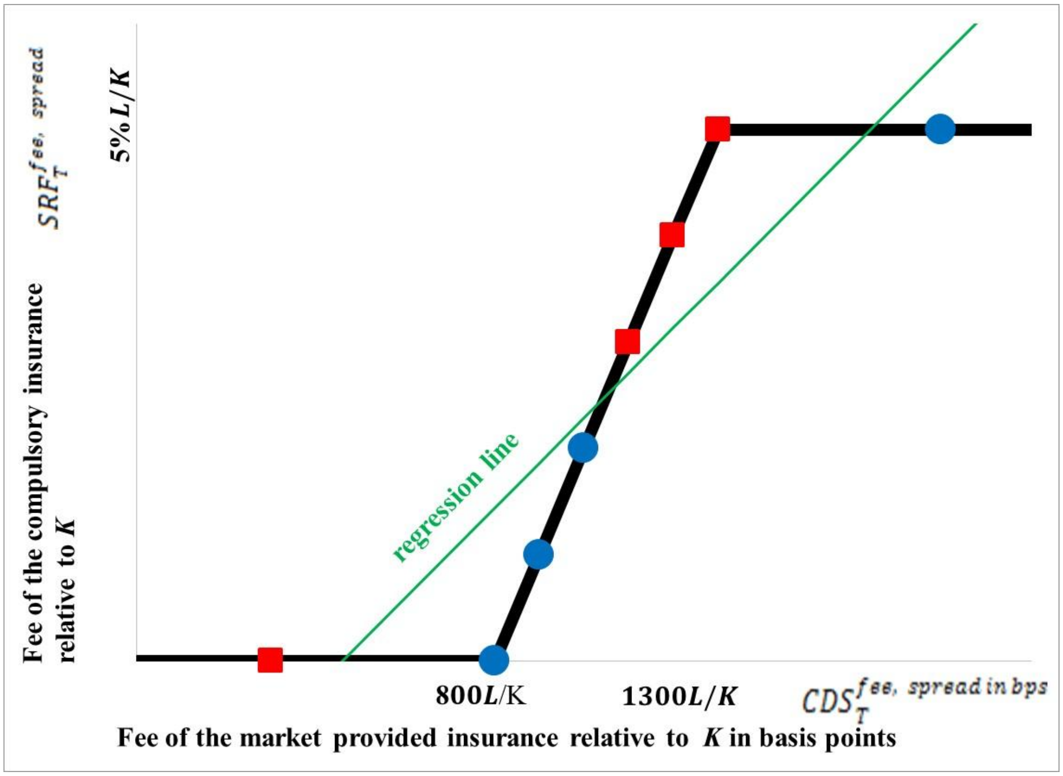


Figure 2: The theoretical values of the two insurances as functions of the market price of total assets both at the maturity of the bonds (*t*=*T*) and before (*t*<*T*)



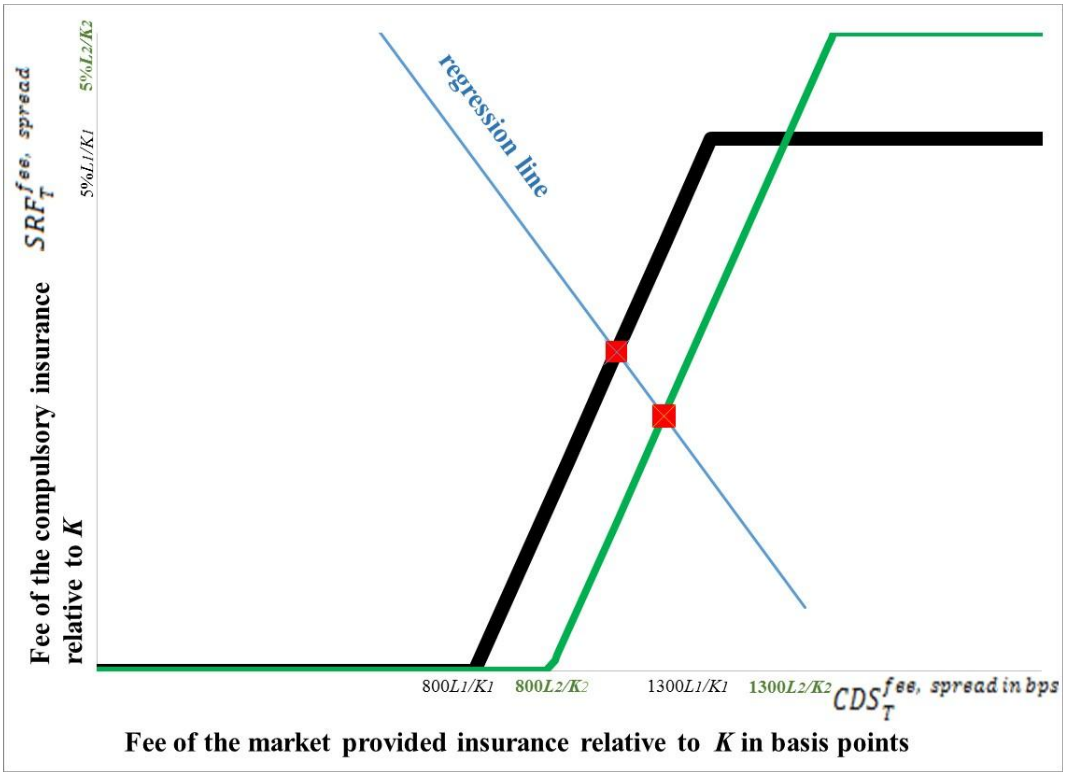
Notes: both the value of the CDS and the value of the insurance provided by the SRF are in terms of money. The process of the market price of total assets is assumed to be described by the CRR binomial model. Its parameters, namely the volatility of the underlying asset, the time to maturity, the risk-free rate, the yield on returns and the time steps are set to 20%, 1 year, zero, zero and 30, respectively. Lack of smoothness of the curves representing the values of the insurances before maturity is due to the imprecision of the applied numerical method.

Figure 3: Illustration of the linear regression on data with non-linear relationship



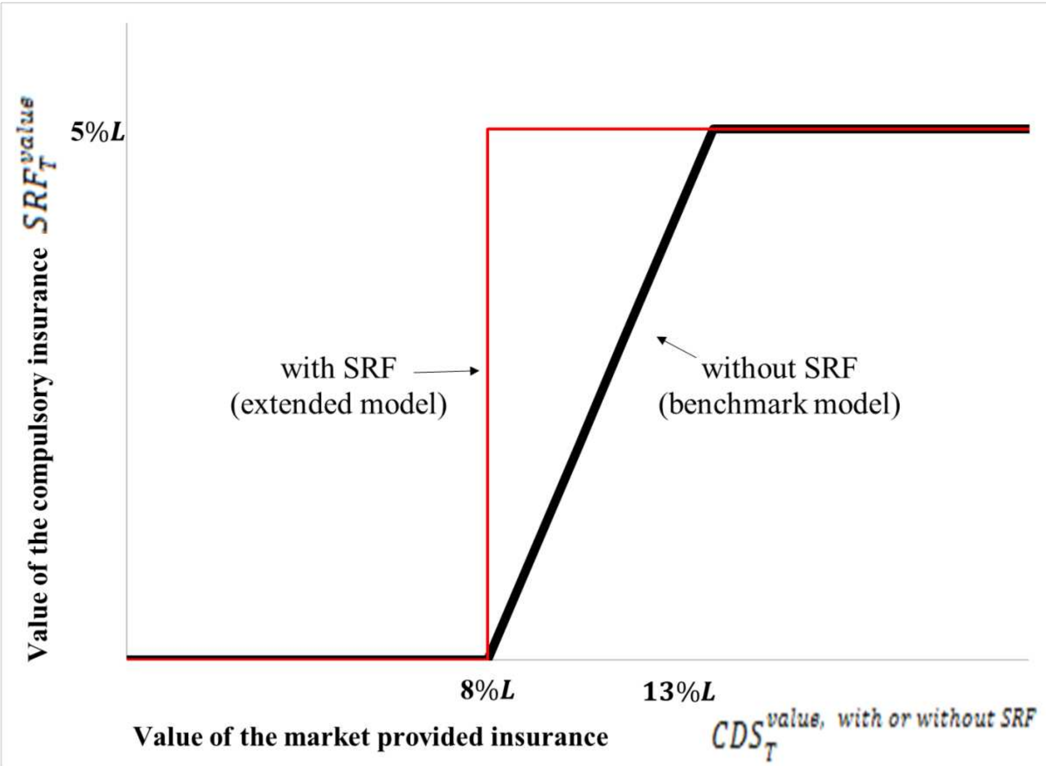
Note: Each box and each circle correspond to a hypothetical bank. Boxes are above the regression line, while circles are below it. The banks are assumed to distribute the cost of establishing the SRF fairly among themselves, and they are identical in many of their relevant characteristics (leverage $\frac{L_i}{K_i} = \frac{L}{K}$, *maturity date of their zero coupon bonds* $T_i = T$ *for* $\forall i \epsilon \{1, .. N\}$*), however, their default risks are perceived to be different by the market (*$CDS_i^{fee,\ spread\ in\ bps} \neq CDS_j^{fee,\ spread\ in\ bps}$ *for* $\forall i, \forall j \epsilon \{1, .. N; i \neq j\}$*). Evidently, these assumptions guarantee that at the maturity of the bonds (t=T) all the bank level observations (the pair of CDS spreads and the price of the service provided by the SRF) are on the same piecewise linear function representing Equation (18) under no variation in the leverage.*

Figure 4: Illustration of the two-variable linear regression with uncontrolled heterogeneity



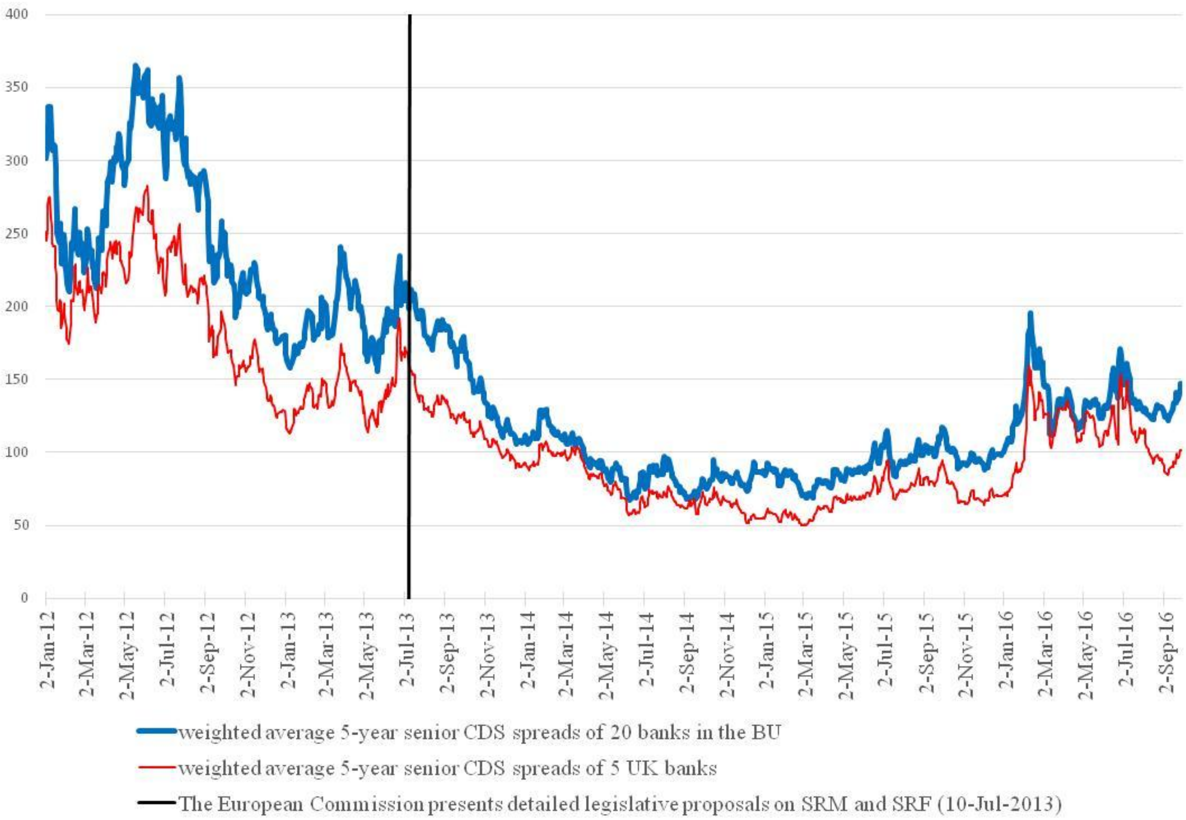
Note: The boxes correspond to two hypothetical banks with different leverages $\frac{L_1}{K_1} \neq \frac{L_2}{K_2}$*. Their CDS spreads are not the same either* $CDS_1^{fee} \neq CDS_2^{fee}$*, while* $800\frac{L_1}{K_1} < CDS_1^{fee,\ spread\ in\ bps} < 1300\frac{L_1}{K_1}$ *and* $800\frac{L_2}{K_2} < CDS_2^{fee,\ spread\ in\ bps} < 1300\frac{L_2}{K_2}$*. Their zero coupon bonds have the same maturity date* $T = T_1 = T_2$*. These banks are assumed to distribute the cost of establishing the SRF fairly between themselves. Evidently, these assumptions guarantee that at the maturity of the bonds (t=T) the bank level observations (the pair of CDS spreads and the price of the service provided by the SRF) are in the middle part of a piecewise linear function representing Equation (18). However, each is on a different one due to the difference in their leverages. The thick piecewise linear functions represent Equation (18) when the leverage is* $\frac{L_1}{K_1}$*, while the thin one represent the same Equation when the leverage is* $\frac{L_2}{K_2}$*.*

Figure 5: The value of the insurance provided by the SRF as a function of the value of the CDS in the benchmark model and in the extended model at *t=T*



Note: The function corresponding to the benchmark model is the one in Equation (10), while the function corresponding to the extended model can be obtained as follows. First, we substitute Equation (8) and (9) into (19) and get $CDS_T^{value,\ with\ SRF} = max(K - A_T, 0) - min[max(K - 0.08L - A_T, 0), 0.05L]$. *Second, by inverting the above function and substituting it to Equation (9), we obtain how the value of the insurance provided by the SRF depends on the value of the CDS at t=T in the extended option-based model.*

Figure 6: An important milestone towards the Single Resolution Mechanism and the weighted average CDS spreads of some large banks in the Banking Union and in the United Kingdom between 2-Jan-2012 and 27-Sept-2016



Notes: the weights represent the relative size of the bank in the Banking Union or in the UK in terms of total assets. The 20 banks in the Banking Union are: AXA Bank Europe SA/NV, Banca Monte dei Paschi di Siena SpA, Banca Nazionale del Lavoro SpA, Banco Bilbao Vizcaya Argentaria SA, Banco Comercial Português SA, Banco Popolare, Banco Santander SA, BNP Paribas SA, BNP Paribas Fortis SA/ NV, Commerzbank AG, Crédit Agricole S.A., Deutsche Bank AG, ING Bank NV, Intesa Sanpaolo, Mediobanca SpA, Novo Banco SA, Rabobank Nederland, Société Générale, and UniCredit SpA. The 5 UK banks are: Barclays Bank PLC, HSBC Bank PLC, Lloyds Bank PLC, Royal Bank of Scotland Plc and Standard Chartered Bank

Source: Naszodi and Katay (2019), who used CDS data from CMA Datavision for the period preceding the year 2014, and CDS data from Bloomberg for the period afterwards.