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Whose Credit Line is it Anyway: An Update on Banks' Implicit Subsidies

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Abstract

The post-crisis financial sector framework reform remains incomplete. While capital and liquidity requirements have been strengthened, doubts remain over other aspects, including the fact that expectations of government support for systemically-important banks (SIBs) remain intact. In this paper, we use a jump diffusion option-pricing approach to provide estimates of implicit subsidies gained by these banks due to the expectation of protection to creditors provided by governments. While these subsidies have declined in the post-crisis era as volatility has declined and capital levels have increased, they remain non-trivial. Even conservative parameterizations of default and loss probabilities lead to macroeconomically significant figures.

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1 Introduction

Eight years after the peak of the global financial crisis (GFC), much uncertainty remains regarding both the extent of progress that has been achieved in reforming the financial system and the prudent steps to take going forward. A key sticking point that has yet to be resolved is the extent to which major financial institutions still benefit from their systemic importance to the global as well as the local financial system. This benefit stems from the fact that they are expected to be assisted in the case of solvency concern, thus allowing them to enjoy lower funding costs than their true fundamentals would suggest.

The reform agenda has focused on identifying which institutions are systemically-important and devising regulation to make these institutions less likely to fail on the one hand and less costly to resolve on the other.[1] However, there is a general consensus that this framework remains incomplete with further steps required in order to fully address the problem.[2] In this paper, we try to shed light on the extent to which these institutions still benefit from the negative externality introduced by their potential failure and the role played by factors such as increased capital and the decline of volatility.

It is safe to say that the recent designation of particular institutions as systemically important by regulators has had a non-negative impact on the perception that these institutions would be assisted in the event of a crisis. So-called living wills are intended to render the default of these institutions manageable but the process remains murky, failing to establish confidence that a default could be managed in a controlled manner. Indeed, U.S. regulators recently ruled that many of the current plans, submitted by the banks themselves, remain non-credible.[3] Therefore, the issue of preventing public sector involvement in the resolution remains unsolved. The other primary pillar of the reform agenda is to decrease the probability of such events occurring in the first place, most

[1]This agenda has been led by the BIS; see http://www.bis.org/bcbs/gsib/ for details.

[2]See, for example, Stein (2013), who concedes that policymakers have "made considerable progress with respect to SIFIs since the financial crisis. And we're not yet at a point where we should be satisfied." Vickers (2016) provides a more skeptical view from the U.K. perspective. The latest FSB report on resolution of G-SIBs in August 2016 acknowledged that the framework remained incomplete and that challenges remain in a number of areas. For example, further guidance is expected on resolvability of G-SIBs throughout 2017, while a review of TLAC implementation is expected by the end of 2019.

[3]See FDIC and Federal Reserve joint press release, April 2016, "Agencies Announce Determinations and Provide Feedback on Resolution Plans of Eight Systemically Important, Domestic Banking Institutions".

notably via higher capital requirements. In addition to the direct benefit of making the institutions safer, this reduction in default probabilities has the benefit of allocating potential losses to a greater extent to shareholders and thus reducing the implicit subsidies received by the institutions.

There are several ways at estimating these implicit subsidies, as discussed in Section 2. In this paper, we use the contingent claim analysis (CCA) methodology using option pricing models to estimate the fair value of credit risk insurance. We extend the standard Black Scholes methodology to allow for negative jumps in asset prices. The Gaussian assumption in Black Scholes models tends to underestimate the value of implicit subsidies as it neglects the empirically observed non-normal behavior of asset prices, particularly for banks. More concretely, crisis episodes are rendered extremely unlikely in the standard framework and we address this by implementing a jump diffusion model.

The literature on both option pricing estimates of implicit subsidies as well as other approaches is very clear on the sensitivity of empirical estimates to calibration and assumptions. As such, we focus less on a single baseline case and more on the effect of varying particular variables of interest, most prominently volatility and leverage. In order to achieve this goal, we try to simplify the model as much as possible, keeping peripheral variables in the background, while being wary of their potential effect.

Our results indicate that implicit subsidies have decreased post-crisis but remain non-negligible. While the estimates are, as predicted, sensitive to assumptions such as the likelihood and cost of crises, even conservative values for their variables result in non-trivial subsidies. We show that moving to a more empirically realistic framework of non-normal option pricing has a significant effect on the subsidy estimates. Higher equity levels and lower volatility have thus served to decrease the subsidies but have thus far not been successful in eliminating them.

The paper proceeds as follows. Section 2 looks at related studies and sketches results from previous estimates of implicit subsidies. Section 3 describes the model, its limitation, and data selection. Section 4 provides the basic results as well as extensions and sensitivity analysis. Section 5 concludes.

2 Related Literature

The literature on implicit subsidies and fair pricing of bank debt is vast and has grown considerably following the GFC. Most recent studies link back to the seminal work of Merton (1976). Similarly, we link the methodology in this paper to Merton and sketch the method in the next section. Here we mention a few related studies which entail a similar approach to the subsidy question although the methodology differs somewhat.

The earliest attempts of such estimation came amidst renewed interest in the topic due to the rise of bank failures in the 1980s, especially in the U.S., and include Marcus and Shaked (1984) and Ronn and Verma (1986). The latter use a traditional normally-distributed option pricing framework and find that the industry-wide weighted average fair value for deposit insurance is 8 bps. The former, focusing more on fair value, find an even lower estimate for a sample of 40 U.S. banks. These findings reflect both the sample selection of US banks in the late 1970s and early 1980s as well as the log-normal asset price distribution assumption.

More recently, attempts to quantify the implicit subsidy have again gained traction along with greater methodological variety. Noss and Sowerbutts (2012) use both a ratings-based and CCA approach to estimate the subsidy for four large U.K. banks in 2010. The latter approach is similar in nature to the one used in this paper while the former entails looking at potential ratings uplifts that systemically important institutions receive due to expected support. Their estimates range from 30bn GBP to 120bn GBP, depending on method. Given that the banks' total debt amounted to roughly 6tn GBP at the end of the year, a comparative figure to the results presented below yields a subsidy of 50 to 200 bps.

Similarly, IMF (2014) use multiple approaches to estimate the value of the subsidy. First of all, a bond spread differential that attempts to eke out the difference between systemically important institutions and others. Secondly, a CCA, roughly akin to the approach taken in this paper and, finally, a ratings-based approach. Their results again suggest a non-trivial number for implicit subsidies, although the estimates vary by region and method. For G-SIBs in the Euro Area, for example, the nominal amount comes in at roughly 90 bps in 2013 using the CCA approach and 60 bps using the ratings-based approach. The results for other areas are somewhat lower with the lowest amount being 15 bps for the U.S. using both CCA and the ratings-based approach. Finally, the bond spread differential approach suggests an advantage of SIBs of 25 bps in advanced economies and 125 bps in emerging markets over the 2003-2013 period.

Ueda and di Mauro (2012) use the aforementioned ratings-based approach for 2007 and 2009 using a sample of almost 900 banks. Their results indicate a 3-4 notch increase in ratings for systemic banks. In turn, using average funding advantages stemming from an upgrade in ratings, they estimate the overall funding cost advantage of systemically-important institutions at 60 bps in 2007 and 80 bps in 2009. Kelly et al. (2016) represents a somewhat different approach as they compare actual option prices of individual institutions and financial sector indices. They conclude that financial sector equity holders enjoy a sizable government subsidy due to government policy that aims to protect debt holders. Their quantitative estimates imply that this free insurance was worth 16.4 percent of the total equity value of the financial sector. Note that this subsidy comes *in addition to* the estimates of implicit subsidies due to debt. In addition to their baseline results, Kelly et al. are amongst a select few who point out that the standard approach of using equity prices leads to a "contamination", as expectations of public sector assistance are already embedded in these prices, thus biasing downwards estimates of implicit subsidies.

Summing up, we see that while estimates of the implicit subsidy vary somewhat, the recent evidence suggests that it is most certainly non-trivial and most likely underestimated in the earlier literature.[4] The range of the more recent studies puts the subsidy at approximately 15-200 bps. These estimates are substantial for many economies in which both the concentration of the financial system and its size have increased in recent years and decades. For example, a subsidy of 70 bps in a country where SIFIs' debt amounts to 100 percent of GDP results in an annual subsidy of 0.7 percent of GDP. Several countries, including most prominently the U.K. and Switzerland, have SIFIs with debt amounting to several multiples of GDP, giving rise to an implicit subsidy of several percentage points of GDP, assuming the empirical estimates above.

3 Model and Data

The method of estimating the value of liability insurance via option pricing dates back to Merton (1977). As Merton demonstrates, a guarantee against default can be viewed as a put option where the strike price corresponds to the value of the insured liabilities and the underlying asset is the

[4]This is in line with OECD (2014) which provides wide-ranging evidence in favor of substantial subsidies, or guarantees, for 35 countries across multiple techniques.

market value of total assets. In effect, an insurer pays for the option of selling his investment at a predetermined price at a future date.

We set the maturity of the put option to one year which is generally interpreted as the next audit that the bank undergoes and thereby the "check-point" for whether the bank's operations are satisfactory. As per the standard Black Scholes model, we assume that the underlying asset exhibits geometric Brownian motion. This means that very large gains or losses, in any given time period, are very unlikely and expected returns are symmetric. The ex-post value of a standard put option on the equity is thus

$$P(t) = Max[0, X - S], \tag{1}$$

where X is the strike price and S is the current price of the asset. Hence, when the contract expires, if the option price is higher than the current price the contract has a positive value equal to the difference between the two.

The traditional Black-Scholes formula subsequently follows as:

$$P(T) = Ee^{-rT}\Phi(y_2) - S\Phi(y_1) \tag{2}$$

Where $y_1 = \frac{ln(E/S)-(r+\frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$ and $y_2 = y_1 + \sigma\sqrt{T}$.

Here, E is the exercise price of the option, S is the current price and Φ represents the cumulative standard normal distribution. The exponential term represents standard discounting procedures. The well-known appeal of this approach is its simplicity. Assuming normality and a known constant volatility parameter, the parameters required are essentially only the leverage of the firm in question and its volatility.[5]

Following the representation of equity as a non-negative residual, the value of the liabilities can be written as $min[L, A]$. Without any insurance, on the maturity date, if the firm is still solvent the payout to the creditors is what they were owed, L. If, however, the firm is bankrupt, i.e. $L > A$, then the creditors only recover what is left of the assets. If we introduce a guarantee, we can view the realized, ex-post cost to the guarantor as the stop-gap in case of default and zero otherwise: $C(0) = Max[0, L - A]$. If the firm is solvent at maturity, then $A > L$ and the payout is 0. If the firm is insolvent the guarantor pays the outstanding amount to the creditor, $L - A$.

[5]See Black and Scholes (1973) for the original formulation and derivation.

Viewed in this way, the creditor guarantee is equal to a put option with A as the current price and L as the strike price. Using (3) above, we can now write the value of the liability guarantee (as opposed to an equity guarantee) as:

$$G(T) = Be^{-rT}\Phi(x_2) - V\Phi(x_1) \tag{3}$$

Where $x_1 = \frac{ln(B/V)-(r+\frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$ and $x_2 = x_1 + \sigma\sqrt{T}$.

As we use the standard method of time of one year (or to the next audit), we can drop all time notations and rewrite the model as

$$G = Be^{-r}\Phi(x_2) - V\Phi(x_1) \tag{4}$$

Where $x_1 = \frac{ln(B/V)-(r+\frac{\sigma^2}{2})}{\sigma}$ and $x_2 = x_1 + \sigma$.

This formation is very similar to the initial notation except primarily that we now have B as the face value of debt and V the market value of assets. We can see that the value of the guarantee lies in the probability of the debt being higher than the value of assets when the option expires.

While this approach requires relatively few parameters to be estimated, its main obstacle lies in the fact that the market value of the bank's assets, V, and the firm's total volatility, σ, are unknown parameters. The solution to this is to use data that actually is observable, i.e. the equity price, to infer the value of the two missing parameters.

Denote the two missing parameters, the market value of assets and the asset volatility, as A and σ_A respectively. The relationship between σ_A and the observable equity volatility, σ_E, can be stated as follows:

$$\sigma_E = \frac{A}{E}\frac{\delta E}{\delta A}\sigma_A \tag{5}$$

This implies

$$\sigma_E = \frac{A}{E}N(x)\sigma_A \tag{6}$$

Using the above formula, along with (5), we can approach the values of A and σ_A numerically through computational iteration.[6] The number of iterations required generally does not exceed

[6] In the case of zero risk-free rates, which we use in our baseline results, the relationship between asset volatility and equity volatility simplifies to being proportional to the debt-to-equity ratio.

300. We then have all the required parameters in place.[7]

The use of Merton-type models to estimate fair value pricing for bank liabilities also has a rich history. As mentioned in the previous section, Ronn and Verma (1986) are amongst the first to do so. Using a slightly modified framework from the Merton approach, they use data on US banks to calculate the fair value of risk-adjusted creditor insurance premiums.[8] Several similar studies were undertaken with subsequent papers often focusing on relaxing the simplicity of the assumptions, including the distribution of returns. We follow this tradition here, using the jump diffusion approach to focus on empirical estimates of the development of implicit subsidies since the pre-crisis era and attempt to evaluate the quantitative effect of various parameters.

The jump diffusion model combines the Brownian motion specification of the Merton model with a Poisson process which specifies the probability of a large decrease in asset value at any given time. Jump diffusion models have in recent years become an increasingly popular way to deal with the fact that asset returns are non-continuous and non-normal. Again the framework was put in place by Merton (1976) in order to relax the prior assumption that trading was continuous and that "the price dynamics of the stock have a continuous sample path with probability one". The following model builds on Merton's paper as well as Dahlfors and Jansson (1994).[9] For the purposes of this paper, the jump diffusion approach can be thought of as a two-fold state. In the "normal" state we witness the same distribution of asset returns as in the previous section where returns are symmetrically located around the regular mean and large deviations are extremely rare. The second possible state is the jump-state as returns exhibit a Poisson distribution with a non-zero probability of a large and negative return.[10] The model thus entails a combination of the two possible states.

Re-writing equation (4) above from the Merton model, we have

$$G = Be^{-r}\Phi(x_2) - V\rho\Phi(x_1), \tag{7}$$

[7] See Huynh et al. (2008) for an applied exposition of this method.

[8] Most notably, their modification involves a policy parameter to capture regulatory forbearance whereby the regulator does not step in until there is considerable certainty that the bank is insolvent. We omit this parameter in our approach to simplify the exposition but note that inclusion of the parameter would increase the value of the implicit guarantee.

[9] Kou (2002) is also a popular reference point for jump diffusion models. Away from financial institutions, Barro (2005) remains an important paper on the importance of allowing for jumps in the wider macroeconomic environment.

[10] We exclude the possibility of a large positive return in the model. This corresponds to empirical evidence whereby large "jumps" are negative and sudden while positive developments happen gradually.

With $x_1 = \frac{ln(B/V\rho)-(r+\frac{\sigma^2}{2})}{\sigma}$ and $x_2 = x_1 + \sigma$.

We now want to add the jump component of the model, in addition to the diffusion represented above. As we are using a simplified version of the model we omit time parameters, as before, as well as using a range of the crisis parameter λ, (explained below) which all but excludes multiple crises in a given time period, we can write down a simplified version of a standard jump diffusion model with easier notation. The result is as follows

$$JD = \sum_{n=0}^{1} e^{-\lambda} \cdot \lambda^n \cdot [B \cdot e^{-r} \cdot \Phi(y_2) - V \cdot e^{-\lambda \cdot k}(1+k)^n \cdot \Phi(y_1)] \tag{8}$$

Where $y_2 = \frac{ln\frac{B}{V}-(r-\lambda \cdot k-\frac{\sigma^2}{2})-n \cdot ln(1+k)}{\sigma}$ and $y_1 = y_2 - \sigma$.

The main additions here are three variables; λ, n and k. The first one, λ, represents the annual probability of a large, negative jump in asset values - i.e. a financial crisis or other unexpected shocks that negatively affects the banks' balance sheets. Intuitively, setting $\lambda = 0$ reduces the model to that of the original Merton case where prices simply follow a Normal distribution.

Another way of seeing that the Merton model can be seen as a generalization of the jump diffusion model is by looking at what happens to the model itself in the case where crises do not occur. First, we exclude any setting where there is a positive number of crisis, i.e. $n = 0$.[11] Doing so, the above changes so that we get the following expression:

$JD_a = e^{-\lambda}\lambda^0 \cdot [B \cdot e^{-r} \cdot \Phi(y_2) - V \cdot e^{-\lambda \cdot k}(1+k)^0 \cdot \Phi(y_1)]$,

Or

$$JD_a = e^{-\lambda}[B \cdot e^{-r} \cdot \Phi(y_2) - V \cdot e^{-\lambda \cdot k} \cdot \Phi(y_1)] \tag{9}$$

Finally, setting λ and k to zero as well gives

$JD_b = e^{-0}[B \cdot e^{-r} \cdot \Phi(y_2) - V \cdot e^{-0 \cdot 0} \cdot \Phi(y_1)]$

Or

$$JD_b = B \cdot e^{-r} \cdot \Phi(y_2) - V \cdot \Phi(y_1) \tag{10}$$

Which is of course the same as the original Merton model above. Going back to the original jump diffusion model, the term outside of the brackets can be thought of as the possibility of a crisis or no-crisis, given by λ. Calibrating the crisis probability, λ, to match empirical evidence is quite tricky, however, to say the least. Taking the approach of counting the number of past financial

[11] We perform this exercise as a two-step process of setting n and λ to zero simultaneously does not compute.

crises and thereby matching λ to the data is one possibility. The fact that crisis parameters vary substantially and that the loss conditional of crisis is a constant in the model makes this approach problematic, however.

Furthermore, there exist few attempts of empirical application of the above model, as opposed to numerous such cases with the Merton model. Cummins (1988) provides some numerical applications but does not calibrate the model to realized data while Haldane (2011) does try to contextualize the model towards the recent crisis without expanding fully. Additionally, there is also an important endogeneity problem to think of as governments' past involvement and presence has reduced the number of full-blown crises and dampened the effects of those that did happen. The effect of this endogeneity is that realized, historical volatility and returns can reliably be thought to be lower than in the case of no public sector involvement. Again, this has the effect of skewing the fair value estimate of the subsidies downwards.[12]

Counting the number of crises and their severity thus does not represent a true estimate of crisis probabilities and costs without government assistance. Hence we adopt a simpler approach here of initially choosing $\lambda = 0.01$, which represents a 1 percent annual probability of a severe crisis. This value is quite conservative and certainly underestimates the historical rate of crises occurences. We consider this a sensible first approach, however, as the model is very sensitive to changes in λ. Our initial conclusion thus relates to the fact that despite the vast uncertainty regarding crisis occurrences, even a very small probability of crisis presents a large potential cost to the guarantor. In Section 4 we relax this assumption and present results for other values of λ.

The second main addition that the model presents, n, is the number of such large shocks each year. This means that we have not just a probability that a single negative shock will happen within the time period but also that multiple shocks will happen. As the λ we use here is so low that the probability of multiple-crisis per year is infinitesimal, the summation through n goes from 0 (no crisis) to 1 (crisis). We can therefore separate the part of the insurance that is due to normal market fluctuations (n=0) and the part that arises because of the possibility of a deep crisis (n=1).

The third new variable of significance is k. This variable represents the jump intensity and can be thought of as a percentage loss in the event of a crisis. A k value of 0.3, for example, would mean that in the event of a crisis, assuming the public sector does not step in to help, the bank

[12]This point is emphasized by Kelly et al. (2016) as discussed in the previous section.

would experience a 30 percent decline in the value of its assets. This parameter is quite problematic for a number of reasons. Firstly, there are the normal reservations that the value of k is neither known nor constant through time. Moreover, on a more philosophical note, absent government intervention, the bank can be expected to go through an unmanaged default whereby the loss then hinges on the recovery rate of creditors which in turn is a function of the cost of bankruptcy.

To illustrate the importance of this point, imagine a bank that is slightly insolvent but is nonetheless allowed to operate as a "going concern" indefinitely. Imagine that in the long run the bank can - in the absence of a run - expect to pay back 90 percent of its assets.[13] However, if the bank is forced into default and files for bankruptcy, the expected recovery rate would presumably be much lower. Historical recovery rates for large financial institutions vary but can generally be thought to be approximately 50 percent.[14] This means that the bankruptcy process itself introduces severe costs to creditors. This value destruction has been explained by many factors such as the shut-off of working capital, breakdown of contracts, and general disruption to operations that the bankruptcy process itself introduces.

In addition to these factors, banks serve a unique role in transmission of credit which introduce the traditional argument for lender of last resort facilities where public assistance is provided to illiquid but solvent entities to prevent systemic risk from materializing.[15] Taken together, however, the value destruction of bankruptcy and unique nature of banks ultimately increases the importance for - and pressure on - the lender of last resort to do all it can to prevent full-on bankruptcy.[16]

[13] In fact, Bennett and Unall (2015) suggest that the FDIC was willing to pay the equivalent of 12.4 percent of assets at failure to acquirers of failed bank in order to achieve re-capitalization in book value terms. Overall, between 1986 and 2007, banks with assets of 216.4 bnUSD were placed into FDIC receivership with an estimated cost of resolution at 30 bnUSD.

[14] Altman et al. (2005), amongst others, look at recovery rates on corporate bonds. The lack of defaults of relatively large financial institutions, which in turn is partially explained by lender of last resort operations, means that data on recovery rates is sparse.

[15] There is a long tradition in the literature of banking panics and the appropriate policy response. This literature is beyond the topic of this paper but key references include Diamond and Dybvig (1983) who provide the canonical approach on the potential for self-fulfilling banking crisis. More fundamentally, Dewatripont and Tirole (1994) provide the building blocks for why banks are unique and their key characteristics. Goodhart and Illing (2002) subsequently provides fundamental arguments for why orderly resolution and public sector support are essential to some extent. Grossman (2010) in turn reviews the history of thought regarding the lender of last resort while Redish (2001) covers the evolution of the lender of last resort role.

[16] See Gruber and Warner (1977) as well as Altman (1984) for discussions on these costs.

Whether one should interpret these high costs of bankruptcy as the government providing a safety net that leads to a k of 0.5 is debatable, as the government's actions do not cost it 50 percent of the bank assets. Another complicating factor is the fact that the recovery rate excludes lost returns and can accumulate quickly, especially for large financial institutions, which are the subject here, as the recovery process is generally cumbersome. A notional claim of $10 returning $5 can thus be interpreted as a 50 percent recovery rate but, due to time value of money considerations, the true recovery rate would be substantially lower if consideration was taken to the foregone interest on the initial amount over several years.

Indeed, Federal Reserve Bank of New York estimates put the payout ratio to Lehman creditors in 2014 at 28 percent.[17] In addition to being a very low nominal amount, a 5 percent expected rate of return on each dollar invested would put the opportunity cost recovery rate at an even lower 21 percent. Furthermore, market prices of defaulted instruments often exhibit even more dramatic recovery rates in the aftermath of the defaults. According to Moodys, the range of market prices for debt of the systemically-important Icelandic banks as well as Lehman Brothers was 3-9 percent a month after each institutions default.[18,19]

To counter these difficulties, some studies use empirical estimates of losses such as from Moodys KMV.[20] This is again somewhat problematic for G-SIB banks due to the inherent lack of historical episodes of their failure as well as the lower recovery rate when they have indeed failed. Due to all of the aforementioned limitations and complications, and for our purposes below, we initially apply a conservative value for k before relaxing the assumption and looking at the effects of applying a value more in line with isolated cases of failures for systemically-important institutions.

Our sample consists of the 11 global systemically-important (G-SIB) banks with a surcharge of 1.5 percent or higher, as defined by the FSB in 2015. The Appendix lists the banks included and selected statistics for each bank. We exclude the 19 banks in the lowest bucket of 1 percent as and their status as globally important is by definition less definite.[21] The G-SIB designation follows the

[17] See Fleming and Sarkar (2014).

[18] See Moody's (2009).

[19] This drawn-out resolution period also applies to Iceland, one of the very few recent cases of systemically-important institutions being allowed to fail, where final resolution is yet to take place eight years after default. See Moody's (2015).

[20] See Arslanalp and Liao (2015)

[21] The less systemically important banks do not exhibit materially different characteristics in terms of leverage and volatility. Robustness checks also indicate results for those 19 banks that are in line with those included in the

introduction of an integrated set of policy measures by the FSB intended to address the systemic and moral hazard risks associated with systemically-important financial institutions.[22]

From the point of view of the home country's government, the main benefit of a designation of a bank as globally systemically-important is that the extra surcharge reduces the probability of a loss, corresponding roughly to a reduction in λ in the setup above. Additionally, the resolution framework for G-SIBs is intended to also lower k, although doubts remain about progress on that front, as mentioned earlier. However, the ultimate subsidy may also increase due to the explicit nature of said institution as systemically-important and thereby lowered ambiguity about public sector assistance.[23]

We obtain balance sheet data from Bloomberg, including total equity and total debt, as well as interest expenses and equity volatility, which is used to compute asset volatility as described above. The sample period used is 2005-2015, in order to capture the pre-crisis, crisis, and post-crisis dynamics. For reasons of simplicity, we focus on leverage ratios rather than risk-weighted adjustments. Furthermore, regulatory reform during the period means that measures of RWA are sensitive to changing weights. Finally, evidence suggests that simple leverage ratios are a more important factor for returns than risk-adjusted ratios, see e.g. Demirguc-Kunt et al. (2013) and Hellwig (2010). To maintain conservativeness, we include all equity, including preferred equity and others, despite uncertainty regarding the true loss-absorbing capacity. Non-common equity amounted to as much as half of total equity for some G-SIBs during the crisis. Also for sake of conservativeness, we use book value of equity although market values may better reflect the true value of equity. The difference is non-trivial, particularly in the post-crisis era where banks often trade at a significant discount to book value.[24]

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sample.

[22]FSB 2015 update of list of G-SIBs, http://www.fsb.org/wp-content/uploads/2015-update-of-list-of-global-systemically-important-banks-G-SIBs.pdf.

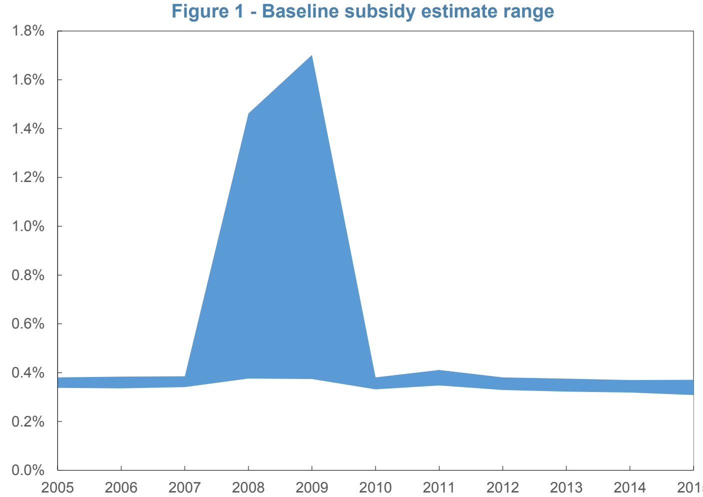
[23]Additionally, one could distinguish between a SIB and a G-SIB in terms of outcomes for host country authorities. The implication that the failure of the latter has consequences beyond the local borders could create an opportunity for host countries to share the burden of guaranteeing the institution's safety. Gelpern (2014) addresses these issues in detail and provides examples. Gelpern highlights the added complexity of cross-border failures and argues that "distribution [note: of losses] remains the most vexing question in crossborder bank failure" (p.372).

[24]See e.g. Sarin and Summers (2016) who look at the difference between the two and potential explanations for the gap.

4 Empirical Results and Extensions

Figure 1 below shows initial baseline estimates for implicit subsidies for the G-SIB sample. The figure shows the range of estimates for each of the 11 banks and for each of the 11 years in the sample. Our baseline estimate assumes a fixed (real) risk-free rate of 0 percent and, as per usual, τ of 1. Robustness checks show that altering the risk-free rate within any plausible estimate range does not materially affect the results, as expanded on below. Furthermore, we ascribe a conservative value of 0.01 for λ and -0.4 for k.

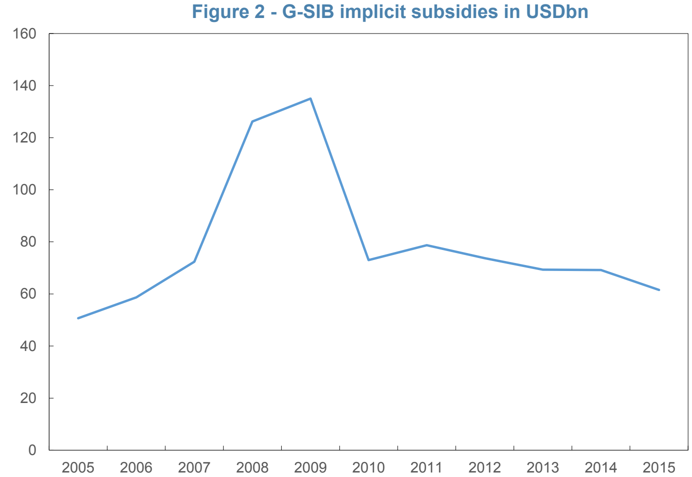
Figure 1 - Baseline subsidy estimate range



Looking at Figure 1, we see that implicit subsidies rose dramatically during the crisis years of 2008 and 2009 but have since retreated to pre-crisis levels. The range of values is quite narrow in both pre- and post-crisis years with values of approximately 30-40 bps per unit of debt. The fact that implicit subsidies rose during the crisis may seem counterintuitive as it could be argued that they were fully in place before the crisis and may have in fact led to excessive risk taking. However, this is a feature of option pricing models whereby the structure of the bank in any period is given by the volatility in that same period, thereby using only available information at each time. As volatility was very low pre-2008, this would suggest that third party guarantees of credit risk were of limited value, given beliefs at the time that banks' underlying business was both profitable and safe. To counter this, one could alter the parameters of the model so as to indicate a higher probability of default in the pre-crisis years. However, we take the conservative approach here of not adjusting pre-crisis levels of volatility. In that sense, these estimates presented can be interpreted as a lower bound for subsidies, taking the low volatility in specific years as fairly representing the underlying data generating process.[25] Below we also present results whereby volatility is assumed higher and more permanent.

The estimates for the crisis years are levels of magnitudes higher, reaching up to 170 bps. Compared to previous studies, such as IMF (2014) and Ueda and di Mauro (2012), this range is similar, albeit slightly lower for non-crisis years. The conservative choice for probability and cost of negative jumps has a large effect here, as shown below. To put the figures in perspective, Figure 2 presents the subsidies in nominal terms for the sample period using the baseline parameterization. The baseline corresponds to total subsidies for the 11 banks peaking at 135bn USD in 2009 before declining to 62bn USD last year.

Figure 2 - G-SIB implicit subsidies in USDbn

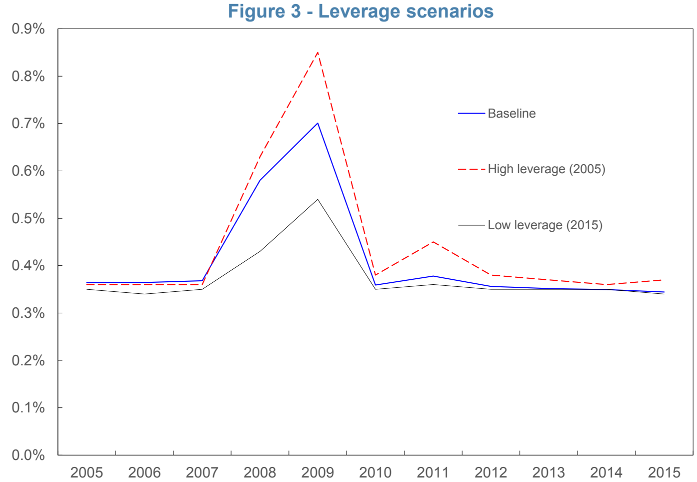


We now look at what effect the various inputs of the model have on the results. Firstly, we look at to what extent higher capital ratios have reduced the implicit subsidy. In Figure 3 below, we show the baseline results using a weighted-average, as opposed to the range as in the Figure 1, as well as

[25] An endogeneity argument could be made whereby the estimated risk was considered low because of an expected guarantee. However, the pre-crisis literature does not support a general view that banks were taking outsized risks and were merely low-risk because of expected external support.

scenarios whereby leverage is kept fixed throughout the sample at 2005 and 2015 levels, indicating high- and low-leverage states respectively. We see that higher capital requirements would indeed have prevented a significant part of the rise in subsidies due to capital's loss-absorbing function and that subsidies would remain higher throughout if equity ratios had remained at their low pre-crisis level. However, keeping capital at current levels would neither eliminate the subsidy in calm times nor render them trivial during volatile times.

Figure 3 - Leverage scenarios



Would further increases in capital requirements, as advocated most prominently in Admati & Hellwig (2013), render the subsidies immaterial? Inserting a dramatically higher capital ratio, corresponding to 30 percent equity, does indeed lower the subsidy to practically zero in normal times and very low numbers even during the crisis. For example, using 2015 data, a 20 percent equity ratio reduces the weighted average subsidy considerably, from 34 bps to 25 bps. A 30 percent equity ratio reduces the figure significantly further. The costs and benefits with regard to other potential effects of higher capital requirements, such as potentially lower credit growth, are evidently not considered in this exercise but in terms of the bank-sovereign nexus it does seem clear that high equity levels can serve to drastically reduce the problem.

This argument could be countered by the possibility that higher capital could increase the cost of credit and reduce economic activity. As such, IMF (2016) finds that risk-weighted levels of capital above 15-23 percent would be sufficient to absorb losses in most crisis and that additional capital would have only marginal effects. However, the aforementioned endogeneity issue whereby realized losses are not adjusted for actual public support measures taken means that estimates of required loss-absorbing capacity could be lower than in a no-support scenario. Furthermore, and as argued for example by Turner (2010), the actual cost of higher capital may be due to the tax treatment of debt or other factors which reflect private costs but not necessarily social costs. As noted by IMF (2016), these costs may also be transitory in nature and decline after banks adjust to the new environment. Bridges et al (2014) provide some empirical evidence to support this notion.

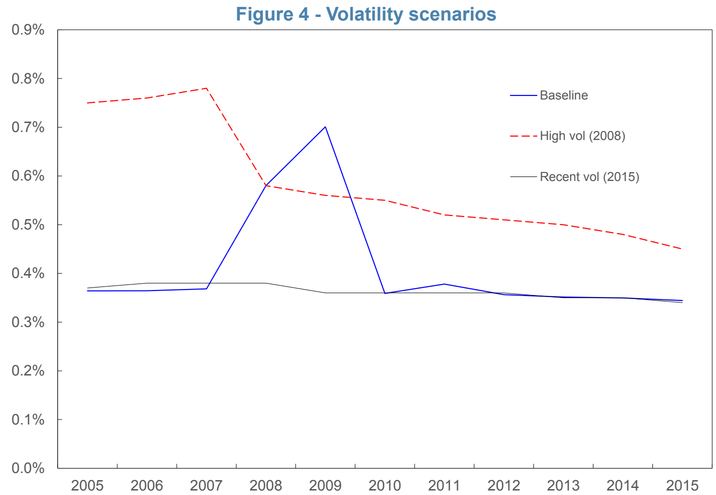
Moving to the effects of volatility, Figure 4 shows the baseline results compared to scenarios where volatility is permanently high (at 2008-levels) and permanently at levels seen recently (2015-levels). As expected, the subsidies remain higher throughout with volatility at 2008 levels as high volatility renders the probability of insolvency more likely. The subsidy in the high-volatility scenario is thus 59 bps on average throughout the sample period.[26] We see however, that higher equity levels have served to decrease the subsidy in this fixed-volatility scenario.[27] Fixing volatility at 2015 levels, on the other hand, negates the jump in subsidies during the crisis but they remain non-trivial nonetheless at approximately 36 bps throughout the period.

In the examples above, the jump parameters and the risk-free rate were kept fixed at their initial levels. Figure 5 below shows the effect of altering these parameters compared to the baseline. First of all, as mentioned above, raising the risk-free rate has a minimal effect on the subsidy estimates. A (real) risk-free rate of 1 percent, as opposed to 0 percent, decreases the subsidy marginally as the alternative to investing in risky bank debt becomes more attractive and the subsidy thus less valuable. However, the difference is both small in size and does little to alter the dynamics over time.

Increasing k from a 40 percent drop to a 50 percent drop has a significantly larger effect on

[26]One possibility is that a move from a low-volatility to high-volatility state is not a reflection of a deteriorating perception of bank fundamentals but rather updated (and lower) beliefs about public assistance. Identifying the true reason for such moves in market prices is tricky but Kelly et al (2016) suggest that differences in sector-wide options and individual banks during the crisis show that there was indeed some heightened recognition of expected systemic support.

[27]The high level of subsidies found in the pre-crisis period using the high volatility scenario points to the benefits of evaluating such models with longer-term data. Given that asset return distributions are non-normal over the medium term, superimposing a high volatility parameter onto asset pricing models during a low-volatility environment can serve both as a resilience check and an early-warning exercise in terms of scenario analysis.

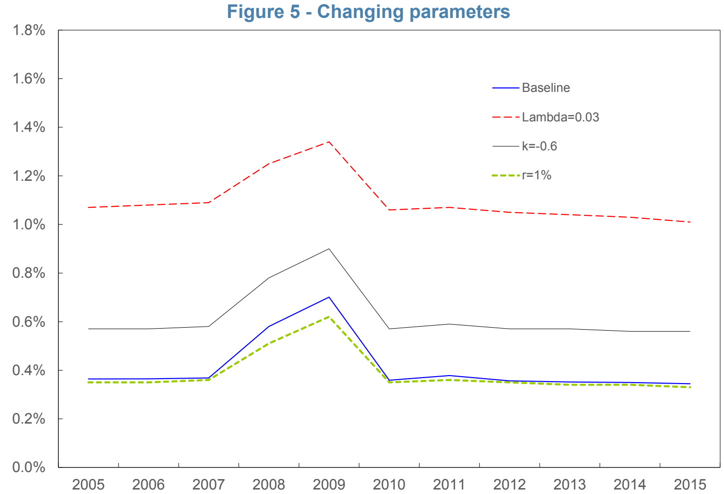


the other hand. As discussed above, the value for the parameter will always be an imprecise one but recovery rates for systemically important financial institutions tend to be low. Amongst the few such cases in recent years, the evidence seems to suggest an even lower recovery rate than 50 percent and thus provides an argument for an even higher absolute value for k. However, the move from 40 percent to 50 percent sheds light on the sensitivity of the results to the parameter and shows that the level of subsidies is significantly higher in both calm and volatile times. The higher k results in an average subsidy of 62 bps, even with the value for λ remaining at the very low level of 1 percent.

Furthermore, moving k back to the initial level of 40 percent but increasing λ to 3 percent raises the subsidy estimate even further to an average level of 110 bps. The higher level of λ also leads to a flatter level of subsidies over time, as the highest value, reached in 2009, is 22 percent over the average compared to 45 percent for the higher k scenario. Whether the true probability of a crisis event is closer to the baseline calibration or the scenario just outlined is unknowable, but we note that even in the conservative baseline scenario the subsidies remain considerable and certainly not higher than in other similar studies.[28]

[28] Note that λ here reflects the actual probability of a credit event. It is thus the conditional probability of a decision not to intervene by public bodies given that the institution experiences insolvency. A true measure of insolvency probability would thus be higher if there is a non-zero probability of government support.

Figure 5 - Changing parameters



One last example serves to illustrate the importance of introducing non-normal asset price assumptions. Setting $k = \lambda = 0$ reduces the results to a standard Black Scholes environment. Doing so all but reduces the subsidies to zero in all years expect 2008 and 2009. Despite differences in opinion in the progress achieved in reducing the subsidies post-crisis, there is widespread agreement that the subsidies were substantial in the pre-crisis era. Thus the results from the Black Scholes equivalent show that the assumptions are inadequate and support the approach of introducing the more empirically-valid negative jumps as per above.

5 Conclusions

In this paper we have tried to shed light on the extent of progress in addressing the threat caused by systemic financial institutions following the GFC. We employed a jump diffusion option pricing model in an attempt to capture the extent and development of implicit subsidies from governments to banks that arise due to their systemic nature. Overall, our estimates suggest that these subsidies have indeed declined following the crisis, as volatility has declined and equity levels improved. As such, our conservative baseline estimate is that the weighted average subsidy for eleven G-SIBs peaked at 70 bps during the crisis and has declined to approximately 35 bps in the post-crisis era, which is in line with the literature although towards the lower end of the range. However, this remains a sizable amount and is furthermore achieved by using conservative numbers for the probability and cost of crises. To achieve a reduction in the subsidies that renders them trivial, a significant decline in volatility or increase in capital levels would be required.

Looking at counterfactuals, we found that keeping capital at pre-crisis levels would have increased the subsidies considerably, as would a return to a high-volatility environment, as per 2008 and 2009. Furthermore, a significant rise in capital requirements would dramatically reduce the implicit subsidies, as losses would be borne by equity holders. A further conclusion, in line with the previous literature, was the sensitivity of the estimates to the parameterization of the model. Depending on several factors, most notably the subjective likelihood of a crisis and the potential shortfall in the event of such a crisis, the estimates fluctuate considerably, rendering point estimates of the subsidies questionable. However, as mentioned above, within plausible parameter values for the aforementioned variables the subsidies remain non-trivial.

A particularly important parameter is the jump intensity, or loss given default. Changing the baseline loss parameters to coincide with recovery estimates from the Lehman Brothers estate increases the weighted average to 75 bps - or roughly double the baseline. An even greater effect can be seen when increasing the probability of a crisis event. A move from a 1 percent implied probability to 3 percent increased the average subsidy level to 110 bps. It is important to keep in mind that given the size of G-SIBs in relation to their host economies, an annual value of 25 bps can give rise to substantial subsidies, in addition to an intangible, but large, misallocation of resources. For example, economies with large financial centers may have G-SIB liabilities within their borders that amount to several hundred percent of GDP. A subsidy of 25 bps, coupled with G-SIB liabilities amounting to 300 percent of GDP, for example, gives rise to an annual implicit cost of 0.75 percent of GDP. If the implied probability of default is considered to be higher these subsidies can quickly become a large issue for economies that are responsible for G-SIB health and resolution. These costs are also separate to any fundamental economic costs that arrive from misallocation of credit.

Finally, in addition to the effect of the various parameters on the estimates of the subsidies, there remain some underappreciated aspects of the contingent claims framework. These include the long recovery time for creditors in the event of default, particularly for systemic institutions. This exacerbates the real loss given default, thus enhancing the value of implicit subsidies. Another factor that would serve to downplay estimates of the subsidies is the endogeneity of government involvement in realized volatility calculations. As such, the rise in volatility seen in 2008 and 2009 is dramatic and leads to higher estimates of the value of implicit subsidies to creditors but it is fair to say that the volatility would have been higher still in the market solution, whereby central banks and other public institutions had not stepped in. Non-calibrated parameters, such as k and λ are thus a necessary evil despite inevitable disagreement regarding their precise value. As highlighted above, however, such estimates can still be informative as initial conservative values and subsequent sensitivity analysis points to a certain range of possible outcomes.

A Appendix - G-SIB Banks and Selected Statistics

Name	*Country of listing*	*Required level of additional loss absorbency*	*Total debt 2005 (USDmn)*	*Total debt now (USDmn)*	*Debt as % of host-country GDP*	*Simple leverage ratio 2005 (total equity to debt)*	*Simple leverage ratio 2015 (total equity to debt)*	*Interest expenses to total debt*
HSBC	United Kingdom	2.5%	1,403,744	2,212,138	77%	6.5%	8.2%	0.66%
JP Morgan Chase	United States	2.5%	1,091,731	2,104,125	12%	8.9%	10.5%	0.35%
Barclays	United Kingdom	2.0%	1,638,407	1,597,719	56%	2.6%	5.9%	0.44%
BNP Paribas	France	2.0%	1,539,531	2,174,445	90%	3.7%	5.0%	0.99%
Citigroup	United States	2.0%	1,381,500	1,508,118	8%	7.5%	12.9%	0.79%
Deutsche Bank	Germany	2.0%	1,222,170	1,792,609	53%	3.0%	4.2%	0.65%
Bank of America	United States	1.5%	1,190,270	1,888,111	10%	7.9%	11.9%	0.56%
Credit Suisse	Switzerland	1.5%	1,289,087	775,787	117%	3.7%	5.5%	1.29%
Goldman Sachs	United States	1.5%	675,638	774,208	4%	4.4%	10.1%	0.70%
Mitsubishi UFJ FG	Japan	1.5%	1,616,073	2,341,576	57%	5.3%	5.8%	0.23%
Morgan Stanley	United States	1.5%	869,275	711,281	4%	3.3%	9.7%	0.39%

Note: Selection of G-SIBs as per the FSB's 2015 classification. 19 banks defined as G-SIBs with a required level of additional loss absorbency of 1% were excluded. Financial figures are for full-year or end-year 2015, unless otherwise stated. Source: FSB, Bloomberg and authors' calculations.

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