Contingent Convertible Bonds:

Payoff Structures and Incentive Effects*

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Abstract

This paper analyses two aspects of contingent convertible (Coco) bonds. First, we establish and compare in detail the payoffs to equity and bond holders in different bail-out/in schemes, namely no bail-out/in, government bail-out, equity-conversion Coco bail-in and write-off Coco bail-in. This reveals that the equityholders progressively gain extra incremental option positions at each step of the bail-out/in schemes in the order listed. Second, we investigate two types of agency costs: the wealth-transfer problem and the value destruction problem. We show that these are aggravated under equity-conversion Coco bail-ins, and are even higher under write-off Coco bail-in for larger asset values, suggesting inherent structural incentive issues associated with these bonds.

JEL Classification: D82; G21; G28; G32

Keywords: Coco bond; bail-in; agency cost; incentives

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1. Introduction

Basel III financial regulation has had a strong impact on the nature of the banking business, and in particular on the capital structure of banks. Amongst its features, the new style of subordinate debt, the contingent convertible, or the Coco bonds, have been much in focus in recent years. This is an intricate product that either converts to equity, or is written-down/off, when a bank's capital ratio hits a trigger ratio. The product has become very popular in a low yielding environment, as investors rush into such high yield instruments and banks take advantage of it by issuing a "cheap" (relative to the cost of equity of the banks) equity-like instruments that helps bolster the capital and leverage ratios.[1] Its market was tested in February 2016 with the news of a possible default (strictly, coupon cancellation) by Deutsche Bank, where its AT1 bond[2] saw a near 20% fall. Yet by September of that year, $6 billion of issuance by three banks attracted more than $50 billion in demand from investors.[3] The first (and so far only) Coco trigger occurred in June 2017 when Banco Popular, a Spanish Bank, failed and its Coco debts were converted into equity, before Santander purchased them for €1.[4] However, the lack of standardisation in its characteristics, such as the equity conversion ratio, permanent or temporary write-downs/offs, high or low trigger and the embedded equity option (for equity-conversion Cocos), and its complex nature means that its impact on banks' behaviour is still not well understood.[5]

The aim of this paper is to scrutinise in detail the characteristics of Coco bond bail-in. Coco bonds, initially termed "reverse convertible debentures" (RCDs), were first recommended by Flannery (2002). The idea was to counter a firm's incentive to use tax-advantaged debt rather

[1] See for example, "Coco bond feeding frenzy sends yields tumbling", *The Financial Times*, March 26, 2014.

[2] The European Banking Authority's (EBA) Buffer Convertible Capital Securities Common Term Sheet (8 December 2011) defines "additional tier 1" (AT1) instruments as perpetual Coco bonds with cancellable coupons.

[3] "Investors grab cocos while the sun shines", The Financial Times, September 1, 2016.

[4] On 7 June 2017, "Banco Popular's €500m 11.5% AT1 bond has collapsed 50 points to a bid value of just 5 cents on the euro, while another fell 45 points to 2 cents". ("Banco Popular CoCo bonds wiped out after Santander takeover", *The Financial Times*, June 7, 2017.

[5] See for example, "Regulators must act on coco bond risks", *The Financial Times*, May 7, 2014.

than equity, that also reduces the firm's ability to take losses. Flannery argued that the issuance of RCDs would still maintain the tax advantage whilst reducing the latter risk. In more recent terminology the suggested structure was an equity-conversion Coco bond with a market value trigger. In terms of post-trigger treatments there are two types of Coco bonds: equity-conversion, and write-down or write-off bonds. In the former, upon trigger Coco bonds are converted into common equity,[6] whilst in the latter, bonds are either partially written down or wholly written off to cover the incurred loss. In this paper we investigate and compare both of these. For the trigger mechanism, broadly two types are suggested in the literature: an accounting ratio trigger and a market value trigger. Himmelberg and Tsyplakov (2011), Berg and Kaserer (2011) and Hilscher and Raviv (2014) are examples of the former. However Flannery (2014), amongst others, argues that "accounting measures trail economic developments when a firm encounters difficulties, and managers can manipulate accounting statements" (p235). Pennacchi (2010), Prescott (2011), Glasserman and Nouri (2012), Koziol and Lawrenz (2012) and Albul, Jaffee and Tchistyi (2013) are examples that adopt the latter. In this case Sundaresan and Wang (2014) point out that a market trigger bail-in does not lead to a unique competitive equilibrium. This problem arises from the fact that the share price reflects both the current value of the firm (say below the Coco trigger value) and the post-bail-in value of shares (which would then be above the trigger value). Many have sought solutions to this: Pennacchi (2010) by including Coco bond values in the capital ratio's numerator; Prescott (2011) by introducing a "sliding conversion rule"; Glasserman and Nouri (2012) argue that the multiple equilibria problem is a feature of discrete-time models; Albul, Jaffee and Tchistyi (2013) achieve unique equilibrium by placing the trigger directly on the asset value. However market value trigger also suffers from the possibility of price manipulation; as suggested by Pennacchi, Vermaelen and Wolff (2014), "the financial industry justifies its objection to Cocos

[6] Coffee (2010) suggests a conversion into preference shares with cumulative dividends and voting rights, for risk incentive reasons.

with market based triggers on the basis of... manipulation/death spiral fears." (p550-1).[7] In this paper we follow the common market practice and focus on accounting capital ratio trigger Cocos.[8]

The analysis in this paper is twofold. First, the payoffs to equityholders, vanilla bondholders and Coco bondholders at the maturity of the bonds are investigated in detail and compared in the following bail-out/in scenarios: (i) no bail-out/in, (ii) government bail-out using common equity, (iii) equity-conversion Coco bail-in and (iv) write-off Coco bail-in.[9] There is a minimum capital ratio that is set by the regulator, and in each case (except (i)), where possible the bail-out/in results in the common equity capital ratio being boosted up to a minimum ratio. We derive at a neat result that each step of the schemes in the listed order can be represented by a sale of an incremental "put-spread" or "condor-like" option structure[10] from the bail-out/in providers to the equityholders. As such, the original equityholders are unambiguously better off in the order of the schemes listed. Evaluation before bond maturity, and government bail-out by preference shares are also investigated as extensions. Berg and Kaserer (2011) undertake a similar exercise, but they consider extreme and stylised Coco structures with immediate full conversion. Here we allow partial conversion, and additionally take into account the different scenarios for what happens when Coco bonds are exhausted, i.e. when the losses are larger than the face value of the Coco bonds.

Second, we investigate the incentive problems inherent in these bail-out/in structures. Agency costs in banking was pointed out as far back as Jensen and Meckling (1976), who argued that the call option held by the equityholders would lead to asset substitution problem, resulting in excessive risk-taking and a "gambling-for-resurrection" in times of a financial crisis.

[7] See for example, "'Coco' trigger plan draws wary response", *The Financial Times*, April 4, 2011. Duffie (2010) suggests using multiday average as a solution to this.

[8] McDonald (2011) suggests a dual price trigger that depends on both the bank's share price and the value of a market stock index.

[9] Though not formally analysed, the results for write-down Coco bail-in are also included in the paper.

[10] These structures are described in the text.

Here we distinguish two types of agency costs. The first is the *wealth-transfer problem*, where the equityholders have an incentive to take on riskier projects because of their positive *vega*[11] of their long option positions[12] (call option plus any incremental "put-spread" or "condor-like" options). A choice of a higher volatility of the projects' outcomes means higher option value, leading to wealth being transferred from the sellers of the options (Coco bondholders or the government) to the buyers (the equityholders).[13] We compare the level of this agency cost by comparing the vega curves of each bail-out/in scheme. The second is the *value destruction problem*, where in a falling solvency scenario, the equityholders are tempted to "gamble-for-ressurection", i.e. sacrifice value for higher volatility. The temptation is higher, the more the potential gain from higher gamble offsets the firm value sacrificed. Therefore the level of this agency cost can be gauged by the ratio of *delta*[14] to vega, where the smaller the ratio, the higher the temptation. Three main results are obtained: (i) in no bail-out/in or government bail-out scenarios, both types of agency costs are worse the further the firm value falls towards insolvency; (ii) for asset values above the bail-in trigger point, the agency costs are unambiguously higher under equity-conversion Coco bail-in than under no bail-out/in or government bail-out; and (iii) for higher asset values, the agency costs are still higher under write-off Coco bail-in than under equity-conversion Coco bail-in. The latter two are the unintended consequences of the deviation from absolute priority rules (DAPR), where under the absolute priority rule (APR) bondholders do not bear losses until equityholders have been wiped out.

There are much related work in the literature. In a pre-Coco set-up, Eberhart and Senbet (1993) investigates the role of APR violation. They assume the wealth-transfer to be a con-

[11] *Vega* is the sensitivity of the option value to an increase in the volatility of the underlying asset price. Thus where V is the value of the option and σ is the volatility, $Vega = \frac{\partial V}{\partial \sigma}$.

[12] When one buys a security, such as a share or an option, he is said to hold a *long* position in the security. Similarly, when one borrows and sells a share, or writes (i.e. creates and sells) an option, then he is said to hold a *short* position.

[13] Basically, here the holder of an option is able to determine the volatility of the underlying asset. If this was possible in financial markets, then it would be an illegal market manipulation.

[14] *Delta* is the sensitivity of the option value to an increase in the underlying asset price. Thus where V is the value of the option and S is the underlying asset price, $Delta = \frac{\partial V}{\partial S}$.

stant proportion of the firm value, and argue that DAPR can reduce agency costs. In Flannery (2002) no DAPR is assumed, i.e. the equityholders continue to bear losses while the converted RCDs replenish the capital base. Pennacchi (2010) builds a model of a jump-diffusion process for asset return using Monte Carlo simulations. They investigate the bank's risk-taking incentives, and find that "moral hazard is usually less than if it had issued an equivalent amount of subordinated debt" (p3). Himmelberg and Tsyplakov (2011) consider the dilution effect of a trigger and argue that the bank would have "strong incentives to avoid triggering conversion by preemptively de-leveraging and raising equity capital well before it becomes financially distressed" (p3), while for non-dilutive (write-off) Cocos it is incentivised to "burn" money. Calomiris and Herring (2013) also conclude that the threat of dilution gives the bank an incentive to reduce risk. Berg and Kaserer (2011) is perhaps the closest to our work here where they too investigate the vega. They consider "Convert-to-Steal (CoSt)" (write-off) and "Convert-to-Surrender (CoSu)" (immediate expropriation of equityholders) bonds and advocate the latter as a vega-reducing scheme. This is extended to a first-passage time framework in Berg and Kaserer (2015) to explore trigger before bond maturity. Hilscher and Raviv (2011) derive at a similar result under a different set-up (they price bonds as a set of *barrier options*[15]), that for Coco bonds with zero conversion ratio ("CoSt" in Berg and Kaserer) the equityholders have an incentive to increase risk, while for Coco with conversion ratio equal to one ("CoSu") they have an incentive to decrease risk. Then there is always an intermediate level of conversion ratio for which the incentives for equityholders to change asset risk are eliminated. Glasserman and Nouri (2012) and Albul, Jaffe and Tchistyi (2013) both price coupon-paying Coco bonds, former using Black and Cox (1976) and the latter extending Leland (1994), but they do not discuss incentive issues. Finally, Koziol and Lawrenz (2012) focus on risk-taking incentives. They argue that debt financing exerts a disciplining effect on the decision-makers of the firm

[15] *Barrier options* are options which can be "knocked-out" or "knocked-in" when the underlying asset price breaches a pre-determined barrier.

from the threat of losing control rights in bad states, and as "by construction, Coco bonds postpone the transfer of complete control rights,... [they] may distort decision-makers' incentives" (p91). In their model both default and trigger occur according to the level of cash flow, and a trigger results in "coupons default" that lowers the required level of cash flow before default (but there is no additional equity). Thus higher risk-taking is beneficial to the equityholders, as it increases the probability of a trigger that reduces the probability of default.[16]

The paper is organised as follows. In Section 2, we analyse comprehensively the payoff structure of different bail-out/in schemes. In Sections 3 and 4, we investigate respectively the wealth-transfer and value destruction problems of the agency costs associated with these structures. Then in Section 5, we give concluding remarks.

2. Comparison of Structures

We investigate in detail the payoff structures of the following bail-out/in schemes:

1. No bail-out/in
2. Government bail-out
3. Equity-conversion Coco bail-in
4. Write-off Coco bail-in

In case 1, the firm follows the absolute priority rule (APR), where once the firm becomes insolvent the equityholders bear all the loss, before the bondholders become the residual claimant. In case 2 the APR is still followed, however the government injects capital to ensure that the minimum capital ratio is always attained, which results in the bondholders' position being guaranteed. With case 3, the bail-in is triggered when the capital ratio is below a trigger level, in which case a necessary amount of the Coco bond is converted into equity to attain a

[16] Various alternatives to Coco bonds have also been suggested, including Bolton and Samama (2012) (*Capital Access Bonds*), Bulow and Klemperer (2013) (*Equity Recourse Notes*) and Pennacchi, Vermaelen and Wolff (2014) (*Call Option Enhanced Reverse Convertibles*). Flannery (2014) gives a comprehensive review of the literature.

minimum capital ratio. This now represents a deviation from absolute priority rule (DAPR). Case 4 is the more extreme cases of DAPR, where the Coco bonds are wholly written off to cover the loss.

2.1. Set-up and Assumptions

Consider a simple firm financed by common equity capital and discount bonds (vanilla or Coco) with maturity T. The total face value of the bonds is F, which may include equity-conversion Coco bond (face value F_C) or write-off Coco bond (face value F_W). The face value of the plain vanilla bond is F_B. Therefore the firm can have either $F = F_B$ (no bail-out/in or government bail-out), $F = F_B + F_C$ (equity-conversion Coco bond bail-in) or $F = F_B + F_W$ (write-off bond bail-in). The equity value at time 0 is E_0. The total asset value at time T is V_T. All bail-outs / bail-ins trigger at the trigger capital ratio $\tau > 0$. There exists a minimum capital ratio $\underline{E}$ set by the regulator, where $\underline{E} > \tau$. In all cases, where possible, when bailed-out/in the equity is boosted to this minimum capital ratio $\underline{E}$. In the following analysis, for the numerical examples the following parameter values are used when relevant: $F = 90$, $F_C = 20$, $F_W = 20$, $\tau = 7\%$ and $\underline{E} = 10\%$. The initial book value of equity is $E_0 = 20$ and the initial asset value is $V_0 = 110$.

For the purpose of this analysis, we make following two assumptions:

1. For the main body of this section, we review the payoff structures and the solvency of the firm at the bond maturity T.

2. Where government bail-out is required, this will be done by common equity.

Both of these assumptions are relaxed in Section 2.7, where the firm is reviewed at $t \leq T$ and preference share bail-out is considered.

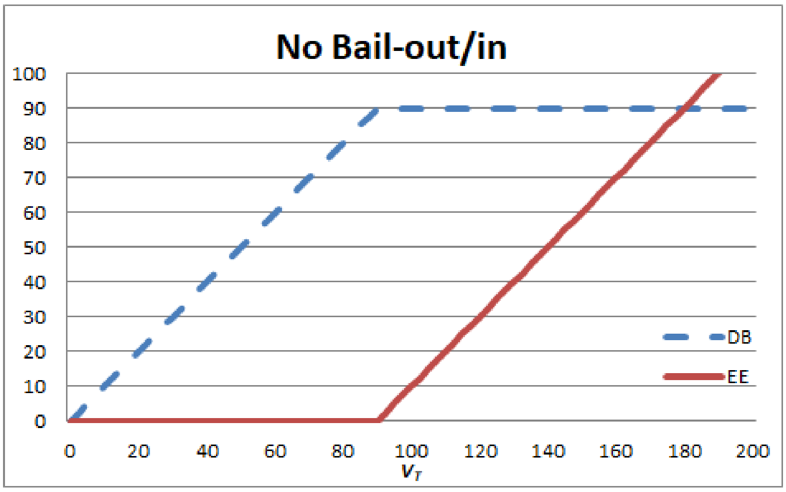

Figure 1: Payoffs for Equityholders (E_E) and Bondholders (D_B) with No Bail-out/in: $F = 90$

2.2. No Bail-out/in

This is the standard case of absolute priority rule (APR), where at the bond maturity T the initial losses are borne by the equityholders, and the bondholders become the residual claimant once the equityholders are wiped out. It is well established in the literature that the equityholders hold a call option at strike price F, while the bondholders' position is the bond minus a put option of the same strike price. The payoffs to bondholders (D_B^N) and equityholders (E_E^N) can be summarised as,

$$\begin{aligned} D_B^N &= \min\left[V_T, F\right] \\ E_E^N &= \max\left[V_T - F, 0\right]. \end{aligned} \tag{1}$$

These are depicted in Fig.1 when $F = 90$. The Black-Scholes-Merton (BSM) valuation of the debt and equity holdings at time $t = 0$ are,[17]

$$\begin{aligned} V_{D_B}^N &= Fe^{-rT} - P\left(F\right) \\ V_{E_E}^N &= C\left(F\right) \end{aligned} \tag{2}$$

[17] See for example Merton (1974).

where $C(K)$ and $P(K)$ are the prices of call and put European options with strike price K,

$$\begin{aligned} C(K) &= V_0 N(d_1(K)) - K e^{-rT} N(d_2(K)) \\ P(K) &= -V_0 N(-d_1(K)) + K e^{-rT} N(-d_2(K)) \\ \text{with } d_1(K) &= \frac{\ln\left(\frac{V_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right) T}{\sigma\sqrt{T}}, \; d_2(K) = d_1 - \sigma\sqrt{T}, \end{aligned} \tag{3}$$

and r is the risk-free rate, T is the option's time to maturity and σ is the asset volatility.

Note using the put-call parity[18] $V_{E_E}^N$ is equivalent to,

$$V_{E_E}^N = V_T - F e^{-rT} + P(F). \tag{4}$$

In other words, when $V_T < F$ the equityholders' position is protected by the put option $P(F)$ sold inherently by the bondholders. This is the consequence of the limited liability.

2.3. Government Bail-out

Next, consider the case of government bail-out. This is assumed to be triggered when the capital ratio $\frac{V_T - F}{V_T}$ falls below a threshold level τ. The bail-out occurs in the form of an injection of common shares,[19] the extent of which is such that the balance sheet is restored to the level where a minimum capital ratio $\underline{E}$ is reattained. With the bondholders fully protected at their face value F, this would be $V = \frac{F}{1-\underline{E}}$. For $V_T \leq F$, the original equityholders' position is wiped out while the government continues to bail out the bondholders, with the tax payers bearing the remaining loss. Fig.2 depicts the payoffs of the bondholders (D_B^{BO}) and the equityholders (E_E^{BO}), which are given by,

$$\begin{aligned} D_B^{BO} &= F \\ E_E^{BO} &= \max\left[V_T - F, 0\right], \end{aligned} \tag{5}$$

[18] See, for example, Hull (2017).

[19] The case for preference share injection is explored in Section 2.7.

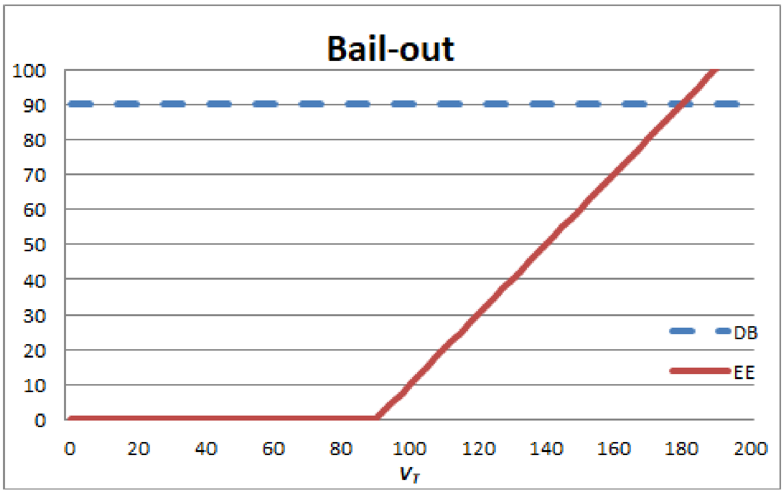

Figure 2: Payoffs for Equityholders (E_E) and Bondholders (D_B) with Government Bail-out: $F = 90$, $\underline{E} = 10\%$

the BSM valuation of which are,

$$
\begin{aligned}
V_{D_B}^{BO} &= Fe^{-rT} \\
V_{E_E}^{BO} &= C\left(F\right).
\end{aligned}
\tag{6}
$$

Comparing Eq.(6) with Eq.(2) suggests that the government bail-out provides a put option $P\left(F\right)$ to the bondholders, *but the equityholders gain no benefit from the bail-out.* This is only so as we are currently considering the payoffs at the bond maturity T. Section 2.7 relaxes this assumption and considers the case where the firm's solvency is reviewed at $t \leq T$, in which case the equityholders also benefit from the bail-out in cases where the firm is otherwise insolvent. Note also that compared to the no bail-out/in case, the government (i.e. the tax payers) replaces the bondholders as the provider of the hedge put $P\left(F\right)$ to the equityholders. As seen in the next sections, the Coco bail-in schemes are designed to replace back the hedge provider from the government to the bondholders.

2.4. Equity-conversion Coco Bail-in

Next, we consider bail-in by equity-conversion contingent convertible (Coco) bonds. As with the bail-out case, the bail-in is triggered when the capital ratio falls below τ to restore the ratio to the minimum capital ratio $\underline{E}$. However, in contrast to the government bail-out case, there is no external capital injection and therefore the balance sheet remains depleted.

Here we investigate in detail the stakeholders' payoffs for different outcomes of V_T. Firstly, for $V_T \geq F+E_0$, the balance sheet has expanded, while when $\frac{F}{1-\tau} \leq V_T < V_0$, the equityholders bear all of the loss according to the APR. In both cases, the bondholders receive their face value, $D_B = F$, and the equityholders receive the remainder, $E_E = V_T - F$.

For $V_T < \frac{F}{1-\tau}$, the Coco bail-in would be triggered. Then,

- The equityholders take the loss up to τV_T.
- With the minimum capital ratio requirement of $\underline{E}$, the Coco bond is partially or wholly converted to make up the remaining required capital of $E_C = (\underline{E} - \tau) V_T$.
- When there is enough Coco bond to cover the loss, then $D_C = (1 - \underline{E}) V_T - F_B$ (the total debt level minus the plain vanilla bond) of the Coco bond is left unconverted. As a result the Coco bondholders bear the loss equal to $F_C - (E_C + D_C) = F - (1 - \tau) V_T$.

This would be the case when there is enough Coco bond to cover the loss, i.e. $D_C \geq 0 \Leftrightarrow V_T \geq \frac{F_B}{1-\underline{E}}$. To demonstrate, take the example of $V_T = 80$ where the firm loses 30. Without the bail-in the equityholders are wiped out. Instead they bear a loss up to the trigger point, i.e. $E_E = \tau V_T = 80 \times 7\% = 5.6$, implying a loss of $E_0 - E_E = 20 - 5.6 = 14.4$. The Coco bond is partially converted to make up the shortfall for the minimum capital ratio, and therefore $E_C = (\underline{E} - \tau) V_T = (0.1 - 0.07) \times 80 = 2.4$. This leaves $D_C = (1 - \underline{E}) V_T - F_B = (1 - 0.1) \times 80 - 70 = 2$ of the Coco bond unconverted, so the Coco bondholders bear the loss of $F_C - (D_C + E_C) = 20 - (2 + 2.4) = 15.6$. The plain vanilla bondholders are unaffected.

For $V_T < \frac{F_B}{1-\underline{E}}$, even with the whole conversion of the Coco bond the minimum equity ratio cannot be attained. For example when $V_T = 76 < \frac{F_B}{1-\underline{E}} = \frac{70}{1-0.10} = 77.78$, the firm loses $V_0 - V_T = 110 - 76 = 34$. As before the equityholders bear the loss up to $E_E = \tau V_T = 76 \times 7\% = 5.32$, with a loss of $E_0 - E_E = 20 - 5.32 = 14.68$. The Coco bond is converted in its entirety into $E_C = V_T - (E_E + D_B) = 76 - (70 + 5.32) = 0.68$ of equity, and therefore they bear the loss of $F_C - E_C = 20 - 0.68 = 19.32$. The capital ratio $\frac{E_E + E_C}{V_T} = \frac{5.32+0.68}{96} = 7.89\%$ is now below the minimum capital ratio of 10%; however the firm is unable to attain this even with the full Coco conversion. This would be the case as long as $V_T \geq \frac{F_B}{1-\tau}$, when $E_C = (1-\tau) V_T - F_B \geq 0$.

For $V_T < \frac{F_B}{1-\tau}$, the Coco bond is wiped out, i.e. $D_C = E_C = 0$. There are now at least three different scenarios that can be considered. We could insist on the APR to be reinstated and write-down the equityholders' capital E_E. This would be analogous to the no bail-out/in case in Section 2.2. Alternatively, as with the bail-out case in Section 2.3, we could assume that the government would step in to inject common equity. Finally, we could assume that the regulator will exercise its bail-in power to force conversion of necessary amount of plain vanilla debt, such that the minimum capital ratio is again reattained. This would correspond to a repeat of the equity conversion bail-in just described in this section. Note in this case, any unsecured bond is inherently an equity-conversion Coco bond. In this paper we consider the first case in detail, which we refer to as Bail-in-No-bail-out/in, and comment on the latter two, which we refer to as Bail-in-Bail-out and Bail-in-Bail-in.

In the case of Bail-in-No-Bail-in/out then, for $F_B \leq V_T < \frac{F_B}{1-\tau}$ the equity E_E is written-down, while for $V_T < F_B$, the bondholders become the residual claimants. In summary,

<table>
<tr><td>V_T</td><td>$[0, F_B)$</td><td>$\left[F_B, \frac{F_B}{1-\tau}\right)$</td><td>$\left[\frac{F_B}{1-\tau}, \frac{F_B}{1-\underline{E}}\right]$</td><td>$\left(\frac{F_B}{1-\underline{E}}, \frac{F}{1-\tau}\right]$</td><td>$\left(\frac{F}{1-\tau}, F+E_0\right)$</td><td>$[F+E_0, \infty]$</td></tr>
<tr><td>D_B</td><td>V_T</td><td>F_B</td><td>F_B</td><td>F_B</td><td colspan="2">F_B</td></tr>
<tr><td>D_C</td><td>0</td><td>0</td><td>0</td><td>$(1-\underline{E})V_T - F_B$</td><td colspan="2">$F_C$</td></tr>
<tr><td>E_E</td><td>0</td><td>$V_T - F_B$</td><td>τV_T</td><td>τV_T</td><td colspan="2">$V_T - F$</td></tr>
<tr><td>E_C</td><td>0</td><td>0</td><td>$(1-\tau)V_T - F_B$</td><td>$(\underline{E}-\tau)V_T$</td><td colspan="2">0</td></tr>
<tr><td>Capital ratio</td><td>0</td><td>$[0,\tau]$</td><td>$[\tau, \underline{E}]$</td><td>$\underline{E}$</td><td>$\left[\tau, \frac{E_0}{F+E_0}\right)$</td><td>$\left[\frac{E_0}{F+E_0}, 1\right)$</td></tr>
<tr><td>Notes</td><td>E_E wiped out, debt-holders residual claimants</td><td>E_E written down</td><td>Coco wholly triggered, $\underline{E}$ unattainable</td><td>Coco partially triggered</td><td>E_E written down. Capital ratio $\geq \tau$.</td><td>Growth</td></tr>
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(7)

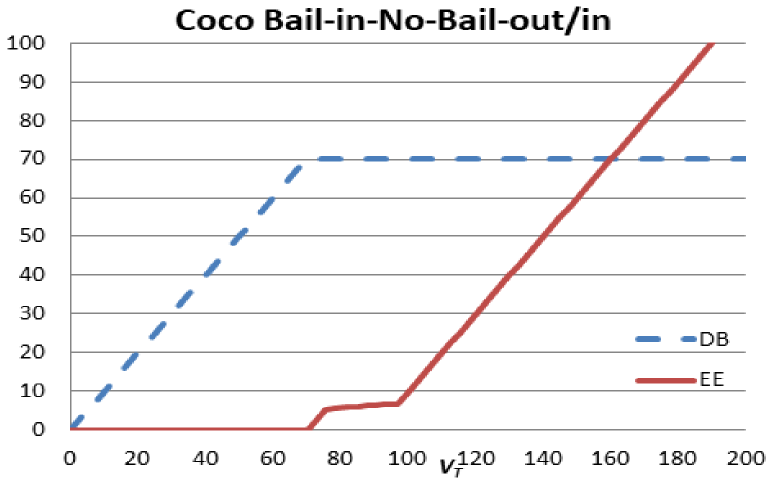

Figure 3: Payoffs for Equityholders (E_E) and Bondholders (D_B) with Equity-conversion Bail-in-No-Bail-out/in: $\tau = 7\%$, $\underline{E} = 10\%$, $F_B = 90$ and $F_C = 20$

The payoffs for bondholders, the original equityholders and the Coco bondholders are, where the Coco bondholders' payoff is the total of their bond and equity positions,

$$\begin{aligned}
D_B^{CN} &= \min\left[V_T, F_B\right] \\
E_E^{CN} &= \max\left[V_T - F, 0\right] + \left\{(1-\tau)\max\left[\tfrac{F}{1-\tau} - V_T, 0\right] - \max\left[F - V_T, 0\right]\right\} \\
&\qquad - \left\{(1-\tau)\max\left[\tfrac{F_B}{1-\tau} - V_T, 0\right] - \max\left[F_B - V_T, 0\right]\right\} \\
D_C^{CN} + E_C^{CN} &= F_C - (1-\tau)\left(\max\left[\tfrac{F}{1-\tau} - V_T, 0\right] - \max\left[\tfrac{F_B}{1-\tau} - V_T, 0\right]\right).
\end{aligned} \tag{8}$$

Fig.3 shows the bondholders' and equityholders' payoffs. The BSM valuation of these are,

$$\begin{aligned}
V_{D_B}^{CN} &= F_B e^{-rT} - P\left(F_B\right) \\
V_{E_E}^{CN} &= C\left(F\right) + \left[(1-\tau)P\left(\tfrac{F}{1-\tau}\right) - P\left(F\right)\right] - \left[(1-\tau)P\left(\tfrac{F_B}{1-\tau}\right) - P\left(F_B\right)\right] \\
V_{E_C}^{CN} + V_{D_C}^{CN} &= F_C e^{-rT} - (1-\tau)\left[P\left(\tfrac{F}{1-\tau}\right) - P\left(\tfrac{F_B}{1-\tau}\right)\right].
\end{aligned} \tag{9}$$

Note, we recover $V_{D_B}^{N}$ and $V_{E_B}^{N}$ when $\tau = F_C = 0$. $V_{E_E}^{CN}$ derived in Eq.(9) differs from the expression for "Convert-to-surrender Coco" in Berg and Kaserer (2011) in two ways. First, they assume 100% conversion of the Coco bond when triggered. Here we allow partial conversion.

Second, they assume the whole liability to be Coco bonds, i.e. $F = F_C$, and therefore the equityholders are never wiped out for $V_T > 0$. Here our assumption of $F_C < F$ means that, once the Coco bond is wiped out, the normal practice of APR resumes where the equityholders' holdings are written down ahead of the vanilla bonds.

One way of viewing the Coco bail-in effect is to regard the difference between $V_{E_E}^{CN}$ in Eq.(9) and $V_{E_E}^{N}$ in Eq.(2) as the wealth-transfer induced by the introduction of deviation from absolute priority rule (DAPR). Diagrammatically, this is the area between the E_E payoff in Fig.3 and the normal call option payoff in Fig.1. Eberhart and Senbet (1993) also investigate the role of APR violations in reducing agency conflicts between bondholders and shareholders. However they assume the wealth-transfer to be a constant proportion of the firm value, and argue that when the firm is in distress the negative vega of the assumed wealth-transfer partly offsets the positive vega of the equityholders' position, hence mitigating the agency cost incentive. Here we are able to explicitly derive the amount of DAPR-induced wealth-transfer as $V_{E_E}^{CN} - V_{E_E}^{N}$:

$$V_{E_E}^{CN} - V_{E_E}^{N} = \left[(1-\tau)\, P\left(\frac{F}{1-\tau}\right) - P\left(F\right)\right] - \left[(1-\tau)\, P\left(\frac{F_B}{1-\tau}\right) - P\left(F_B\right)\right]. \tag{10}$$

Intuitively, the equityholders' payoff is improved by a *bear spread*-like protection $(1-\tau)\, P\left(\frac{F}{1-\tau}\right) - P\left(F\right)$ (a combination of a long put and a short put, where the long put has the higher strike), which represents the DAPR induced by the introduction of the Coco bond. The *bull spread*-like structure $-(1-\tau)\, P\left(\frac{F_B}{1-\tau}\right) + P\left(F_B\right)$ (the short put has the higher strike) reinstates the APR once the Coco bond is wiped out. Together they create a "condor-like" structure, which we will call the "*Coco condor*". The payoff of this structure for different values of V_T are depicted in Fig.4.[20]

In the case of Bail-in-Bail-out, the government bail-out is triggered when the capital ratio

[20] A *condor* is created by a combination of either a bull call spread with a bear call spread, or a bull put spread with a bear put spread. A *bull call spread* is formed by combining a long call option with a short call option of a higher strike price, such that the holder of the structure gains from a rise in the underlying asset price. In a *bear call spread*, the short call option has the lower strike price. Similarly for *bull* and *bear put spreads*.

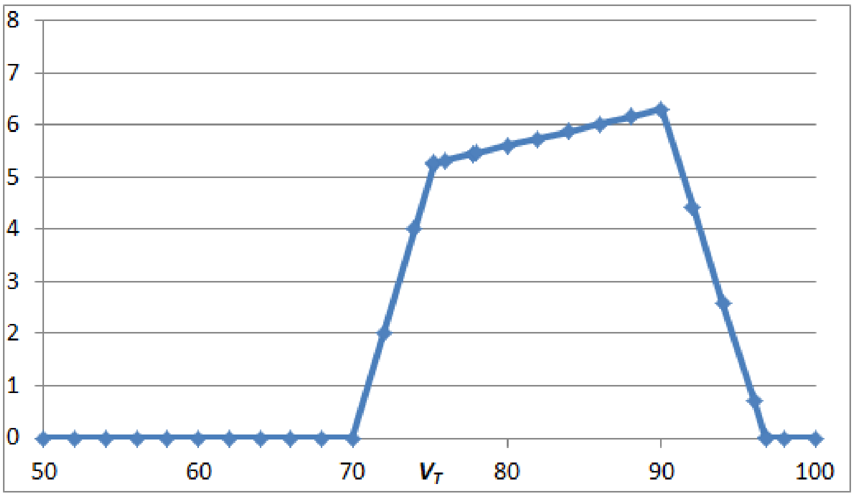

Figure 4: Coco Condor Payoffs for Different Values of V_T

hits below τ (i.e. $V_T < \frac{F_B}{1-\tau}$), with an injection of common equity E_G. Analogous to before, this boosts the balance sheet to $\frac{F_B}{1-\underline{E}}$ and the capital ratio to $\underline{E}$. The equityholders are wiped out for $V_T < F_B$, at which point the tax payers are required to bear any remaining loss. As seen in equations (2) and (6), the effect of this is to transfer the provider of the hedge put $P(F_B)$ from the bondholders to the government, thus guaranteeing the vanilla bondholders' position at F, while the equityholders gain no benefit from the bail-out, at least when we are only considering the payoffs at T. This is seen in Fig.5. The valuations of the payoffs for bondholders, equityholders and Coco bondholders are,

$$\begin{aligned} V_{D_B}^{CBO} &= F_B e^{-rT} \\ V_{E_E}^{CBO} &= C(F) + \left[(1-\tau)P\left(\tfrac{F}{1-\tau}\right) - P(F)\right] - \left[(1-\tau)P\left(\tfrac{F_B}{1-\tau}\right) - P(F_B)\right] \\ V_{E_C}^{CBO} + V_{D_C}^{CBO} &= F_C e^{-rT} - (1-\tau)\left[P\left(\tfrac{F}{1-\tau}\right) - P\left(\tfrac{F_B}{1-\tau}\right)\right]. \end{aligned} \tag{11}$$

Therefore the equityholders again benefit from the Coco condor defined in Eq.(10).

For the case of Bail-in-Bail-in, once the Coco bonds are wiped out the regulator forces conversion of plain vanilla debt to assure that the minimum capital ratio is achieved. This means that the APR is not reinstated when $V_T < \frac{F_B}{1-\tau}$ in Table (7), and therefore effectively the plain vanilla bondholders provide a second bear spread-like protection (the negative of the

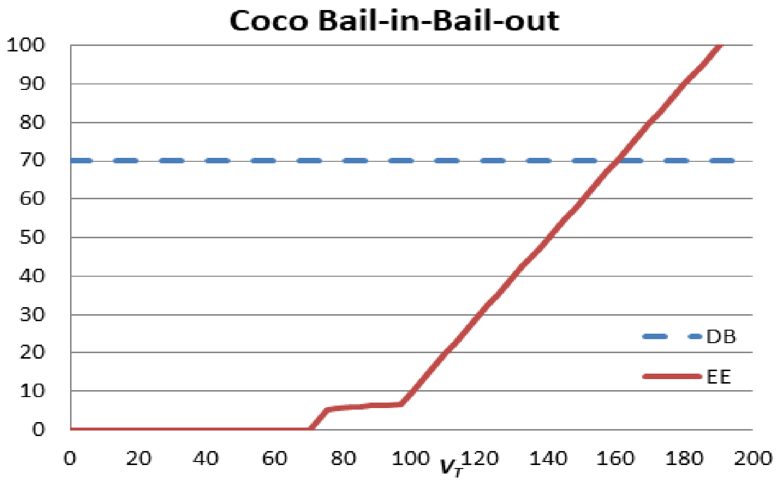

Figure 5: Payoffs for Equityholders (E_E) and Bondholders (D_B) with Equity-conversion Bail-in-Bail-out: $\tau = 7\%$, $\underline{E} = 10\%$, $F_B = 90$ and $F_C = 20$

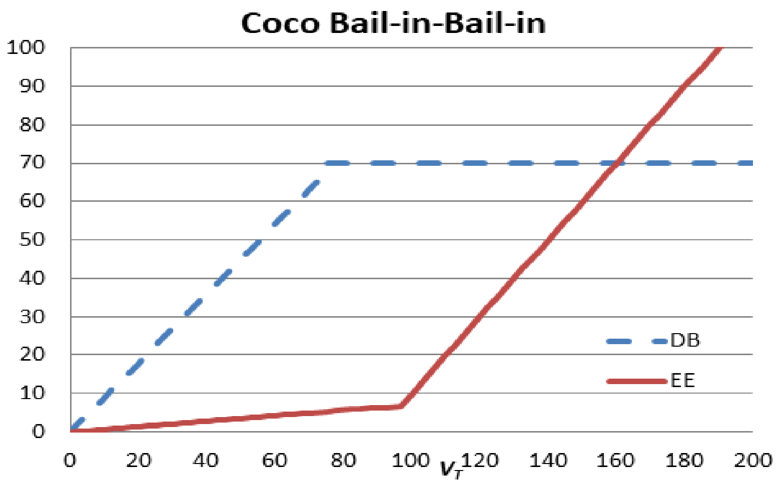

Figure 6: Payoffs for Equityholders (E_E) and Bondholders (D_B) with Equity-conversion Bail-in-Bail-in: $\tau = 7\%$, $\underline{E} = 10\%$, $F_B = 90$ and $F_C = 20$

second term in Eq.(10)). Adjusting for this term in Eq.(9) the valuations of the payoffs for plain vanilla bondholders, equityholders and Coco bondholders are,

$$
\begin{aligned}
V_{D_B}^{CBI} + V_{E_B}^{CBI} &= F_B e^{-rT} - (1-\tau) P\left(\tfrac{F_B}{1-\tau}\right) \\
V_{E_E}^{CBI} &= C(F) + \left[(1-\tau) P\left(\tfrac{F}{1-\tau}\right) - P(F)\right] \\
V_{E_C}^{CBI} + V_{D_C}^{CBI} &= F_C e^{-rT} - (1-\tau)\left[P\left(\tfrac{F}{1-\tau}\right) - P\left(\tfrac{F_B}{1-\tau}\right)\right].
\end{aligned}
\tag{12}
$$

Fig.6 shows the plain vanilla bondholders' and equityholders' payoffs.

2.5. Write-off Coco Bail-in

Next, we consider bail-in by write-off Coco bonds. In contrast to equity-conversion bail-in, here the entire bond is written-off at once for values of $V_T < \frac{F}{1-\tau}$. Then upon trigger, immediately the Coco bondholders' position goes to zero: $D_W = 0$. Now, it is unclear as to what happens to the remainder of the written-off bond when the write-off more than covers the firm's loss. Here we assume that the net amount becomes a contingent capital reserve (CCR). So consider again the example $V_T = 80$ when the firm loses 30. As before $E_E = \tau V_T = 80 \times 7\% = 5.6$ and so the equityholders bear the loss of $E_0 - E_E = 20 - 5.6 = 14.4$, and the write-off bond is triggered to cover the rest of the loss. Of $F_W = 20$, $30 - 14.4 = 15.6$ is required to write-off this loss, while the remaining $20 - 15.6 = 4.4$ is added to the equity capital as E_{CCR}. The capital ratio $\frac{E_E + E_{CCR}}{V_T} = \frac{V_T - F_B}{V_T} = \frac{80-70}{80} = 12.5\%$ is now above the minimum ratio $\underline{E}$. This would be true for values of V_T for which $\frac{V_T - F_B}{V_T} \geq \underline{E} \Leftrightarrow V_T \geq \frac{F_B}{1-\underline{E}}$. For V_T below this level, we in this case assume forced bail-in by the vanilla bondholders. As such, we denote this case as Write-off-Bail-in. In summary then,

V_T	$\left[0, \frac{F_B}{1-\tau}\right)$	$\left[\frac{F_B}{1-\tau}, \frac{F_B}{1-\underline{E}}\right)$	$\left[\frac{F_B}{1-\underline{E}}, \frac{F}{1-\tau}\right)$	$\left[\frac{F}{1-\tau}, V_0\right)$	$[V_0, \infty]$
D_B	$(1-\underline{E})V_T$	F_B	F_B	F_B	
D_W	0	0	0	F_W	
E_E	τV_T	τV_T	τV_T	V_T-F	
E_{CCR}	0	$(1-\tau)V_T - F_B$	$(1-\tau)V_T - F_B$	0	
E_B	$(\underline{E}-\tau)V_T$	0	0	0	
Capital ratio	$\underline{E}$	$[\tau, \underline{E}]$	$\underline{E}$	$\left[\tau, \frac{E_0}{F+E_0}\right)$	$\left[\frac{E_0}{F+E_0}, 1\right)$
Notes	Forced bail-in by vanilla bondholders	$\underline{E}$ unattainable even with the CCR.	WO bond triggered. Remainder net of loss added as CCR. $\underline{E}$ not breached.	E_E written down. Capital ratio $\geq \tau$.	Growth

(13)

In an actual trigger event, it is unclear who would own the contingent capital reserve. Assuming here that it is transferred to the equityholders, the payoffs can be summarised as,

$$
\begin{aligned}
D_B^{WOBI} + E_B^{WOBI} &= \min\left[(1-\tau)V_T, F_B\right] \\
E_E^{WOBI} + E_{CCR}^{WOBI} &= V_T - F + F_W \chi_{V_T \leq \frac{F}{1-\tau}} + (1-\tau)\max\left[\frac{F_B}{1-\tau} - V_T, 0\right] \\
D_W^{WOBI} &= F_W \chi_{V_T > \frac{F}{1-\tau}},
\end{aligned}
\tag{14}
$$

where $\chi_{V_T > \frac{F}{1-\tau}} = \begin{cases} 1 & \text{if} \quad V_T > \frac{F}{1-\tau} \\ 0 & \text{if} \quad V_T \leq \frac{F}{1-\tau} \end{cases}$ is an indicator function. Fig.7 shows the bondholders' and equityholders' payoffs. The BSM valuation of the debt and equity holdings at time $t = 0$ are,

$$
\begin{aligned}
V_{D_B}^{WOBI} + V_{E_B}^{WOBI} &= F_B e^{-rT} - (1-\tau) P\left(\frac{F_B}{1-\tau}\right) \\
V_{E_E}^{WOBI} + V_{E_{CCR}}^{WOBI} &= C(F) + F_W B_P\left(\frac{F}{1-\tau}\right) - \left[P(F) - P\left(\frac{F_B}{1-\tau}\right)\right] \\
V_{D_W}^{WOBI} &= F_w B_C\left(\frac{F}{1-\tau}\right).
\end{aligned}
\tag{15}
$$

where $B_C(K)$ and $B_P(K)$ are the price of *binary call* and *put* options with unit payout at

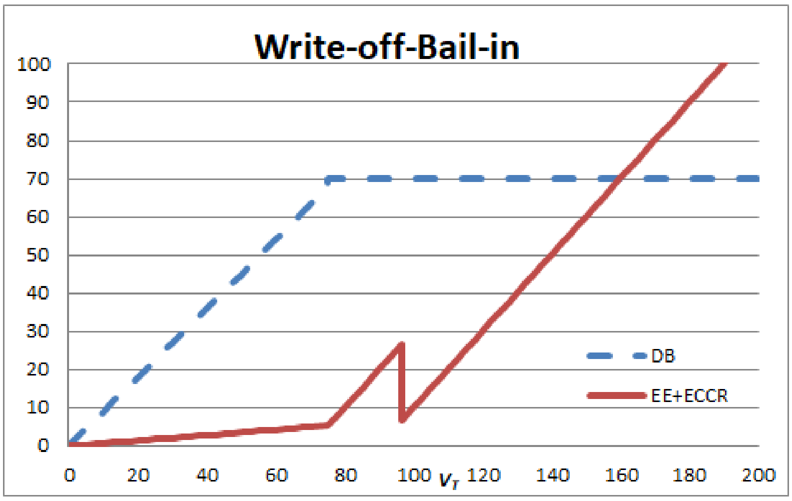

Figure 7: Payoffs for Equityholders ($E_E + E_{CCR}$) and Bondholders (D_B) with Write-down-Bail-in: $\tau = 7\%$, $\underline{E} = 10\%$, $F_B = 90$ and $F_W = 20$

strike K,[21]

$$\begin{aligned} B_C(K) &= e^{-rT} N(d_2(K)) \\ B_P(K) &= e^{-rT} N(-d_2(K)). \end{aligned} \tag{16}$$

The equityholders' position $V_{E_E}^{WOBI} + V_{E_{CCR}}^{WOBI}$ in Eq.(15) differs from the expression for "Convert-to-steal Coco" in Berg and Kaserer (2011), in that here the trigger point is at $\frac{F}{1-\tau}$ and that there is a forced bail-in by the vanilla bondholders at $\frac{F_B}{1-\tau}$.

Analogous to the Coco bail-in analysis, the difference between $V_{E_E}^{WOBI} + V_{E_{CCR}}^{WOBI}$ in Eq.(15) and $V_{E_E}^{N}$ in Eq.(2) represents the wealth-transfer induced by the introduction of DAPR:

$$\left(V_{E_E}^{WOBI} + V_{E_{CCR}}^{WOBI}\right) - V_{E_E}^{N} = F_W B_P\left(\frac{F}{1-\tau}\right) - \left[P(F) - P\left(\frac{F_B}{1-\tau}\right)\right]. \tag{17}$$

This we call a *Write-off condor*, the payoff of which for different values of V_T are depicted in Fig.8.

[21] A *binary option* (call and put) pays out 1 if the option is in-the-money and 0 if it is not.

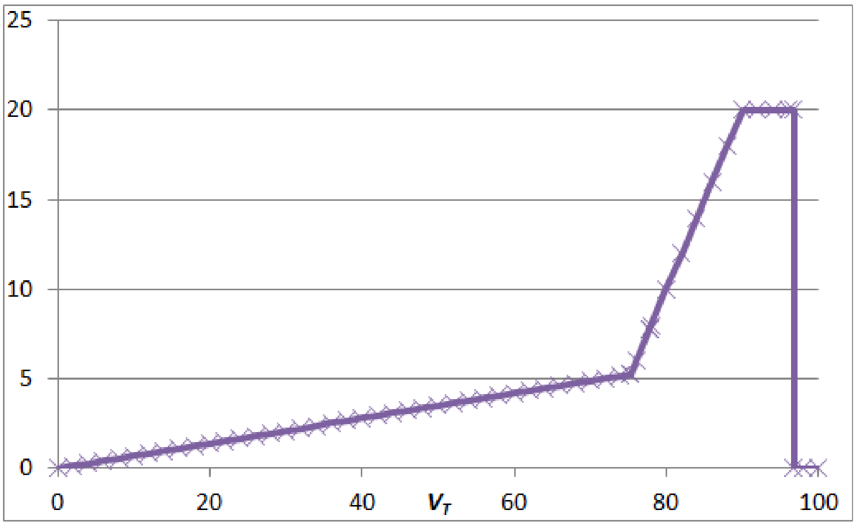

Figure 8: Write-off Condor Payoffs for Different Values of V_T

2.6. Analysis

The BSM valuations of the equityholders' positions in Eqs.(2), (6), (9), (11), (12) and (15) are summarised below, but with $C(F)$ replaced with $V_0 - Fe^{-rT} + P(F)$ using put-call parity:

$$
\begin{array}{cl}
\text{No Bail-out/in} & V_0 - Fe^{-rT} + P(F) \\
\text{Bail-out} & V_0 - Fe^{-rT} + P(F) \\
\text{Bail-in-No-bail-out/in} & V_0 - Fe^{-rT} + (1-\tau)\,P\left(\frac{F}{1-\tau}\right) - \left[(1-\tau)\,P\left(\frac{F_B}{1-\tau}\right) - P(F_B)\right] \\
\text{Bail-in-Bail-out} & V_0 - Fe^{-rT} + (1-\tau)\,P\left(\frac{F}{1-\tau}\right) - \left[(1-\tau)\,P\left(\frac{F_B}{1-\tau}\right) - P(F_B)\right] \\
\text{Bail-in-Bail-in} & V_0 - Fe^{-rT} + (1-\tau)\,P\left(\frac{F}{1-\tau}\right) \\
\text{Write-off-Bail-in} & V_0 - Fe^{-rT} + \left[F_W B_P\left(\frac{F}{1-\tau}\right) + (1-\tau)\,P\left(\frac{F_B}{1-\tau}\right)\right].
\end{array}
\tag{18}
$$

Writing these in this way clarifies the protection each scheme offers to the equityholders. For example, as discussed in Sections 2.2 and 2.3, in both the no-bail-out/in and bail-out cases the equityholders are protected by a put option with strike price F. On the other hand with equity-conversion bail-in-bail-in, the equityholders' protection is by $1-\tau$ unit of a put option with a higher strike price $\frac{F}{1-\tau}$. These protections are plotted respectively in Figs 9 and 10. For example in Fig.9, for no bail-out/in case, the familiar payoff curve for put option is shown with

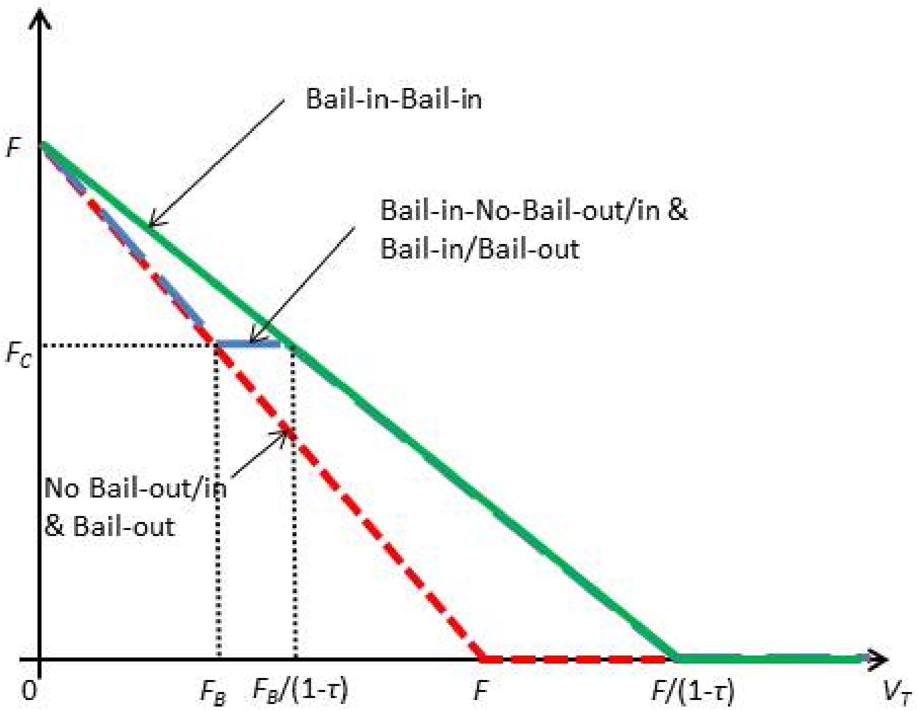

Figure 9: Equityholders' Protections for No Bail-out/in, Government Bail-out and Equity-conversion Bail-in

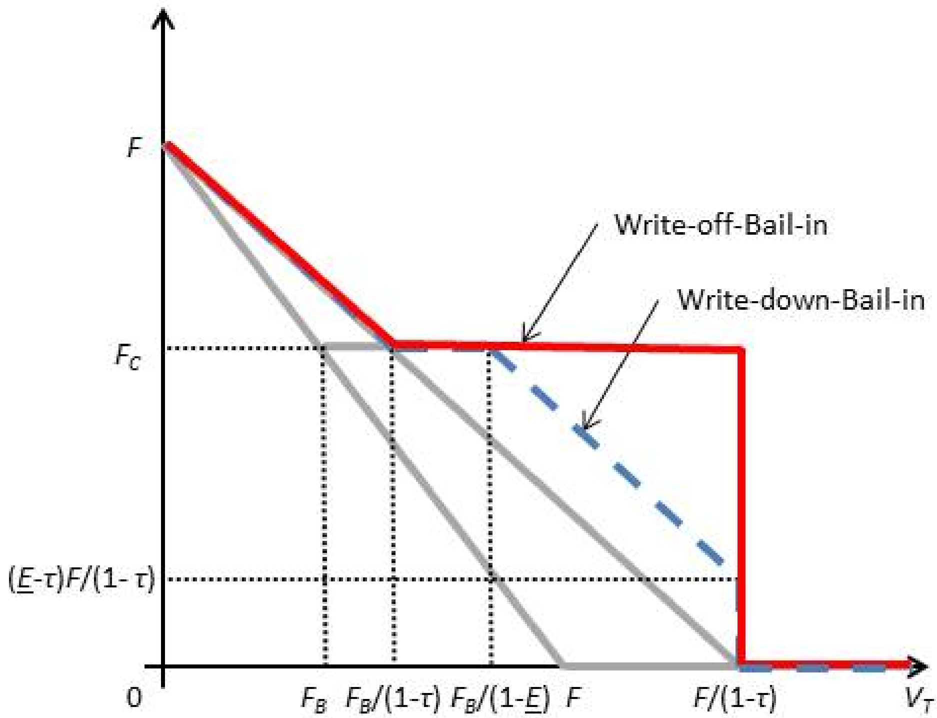

Figure 10: Equityholders' Protections for Write-down-Bail-in and Write-off-Bail-in

strike price F. For bail-in-bail-in, the strike price is higher at $\frac{F}{1-\tau}$, but the slope of the payoff curve is flatter. The figures clearly demonstrate the increasing protection for the equityholders in the order of (i) no bail-out/in and bail-out, (ii) bail-in-no-bail-out/in and bail-in-bail-out, (iii) bail-in-bail-in, (iv) write-down-bail-in[22] and (v) write-off-bail-in. In other words, at each step there is an extra incremental "put-spread" or "condor-like" option structure inherently sold by the bail-out / bail-in providers to the equityholders. These lead to increasing agency costs, as will be discussed in Sections 3 and 4.

2.7. Extensions

2.7.1. Valuation before Bond Maturity

As discussed in Section 2.3, the government bail-out provides no benefit to equityholders at bond maturity. This is not the case before maturity $t < T$, where the bail-out enables the firm to continue operating as going-concern in cases where the firm would otherwise become gone-concern. This provides the equityholders with a strictly positive time value of the continuing option, which is the benefit of the bail-out to the equityholders.

To demonstrate this, consider an inspection by the regulator at time $t < T$. Assume that in the case of no bail-out/in the firm is closed down if its capital ratio is below the minimum equity ratio $\underline{E}$, i.e. $V_t < \frac{F}{1-\underline{E}}$. In this case the value of the equityholders' position at t is,

$$V_{E_E}^N = \begin{cases} \max\left[V_t - F, 0\right] & \text{if} \quad V_t < \frac{F}{1-\underline{E}} \\ C\left(V_t, F, r, \sigma, T-t\right) & \text{if} \quad V_t \geq \frac{F}{1-\underline{E}} \end{cases}, \tag{19}$$

[22] Write-down Coco bail-in is not discussed in this paper. In contrast to write-off Coco bonds, these bonds are only partially written-down when the trigger occurs. The protection provided by these bonds can be shown to be,

$$V_0 - Fe^{-rT} + (1-\tau)\, P\left(\frac{F}{1-\tau}\right) + (\underline{E} - \tau)\left[\frac{F}{1-\tau} B_P\left(\frac{F}{1-\tau}\right) - P\left(\frac{F}{1-\tau}\right)\right]$$
$$- (1-\underline{E})\, P\left(\frac{F_B}{1-\underline{E}}\right) + (1-\tau)\, P\left(\frac{F_B}{1-\tau}\right).$$

where $C(S, K, r, \sigma, s)$ is the price of a call option given by (3), with the price of the underlying asset S, strike price K, continuously compounding interest rate r, volatility σ and the time to maturity s. The payoff reflects the fact that when the capital ratio is below $\underline{E}$ and the firm is forced to close, the value of the equityholders' call option equals its intrinsic value.[23] This is not the case when there is government bail-out:

$$V_{E_E}^{BO} = \begin{cases} \frac{\max[V_t - F, 0]}{\frac{\underline{E}}{1-\underline{E}}F} C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right) & \text{if} \quad V_t < \frac{F}{1-\underline{E}} \\ C(V_t, F, r, \sigma, T-t) & \text{if} \quad V_t \geq \frac{F}{1-\underline{E}} \end{cases}. \tag{20}$$

Upon inspection, if the capital ratio is less than $\underline{E}$, the government injects common equity E_G to boost the asset value to $\frac{F}{1-\underline{E}}$. The total equity $E_E + E_G$ is then $\frac{\underline{E}}{1-\underline{E}}F$. The market value of this total equity is $C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right)$, with the original equityholders holding a share $\frac{\max[V_t - F, 0]}{\frac{\underline{E}}{1-\underline{E}}F}$ of it. This represents the dilution resulting from the common equity capital injection. Now $V_E^{BO} > V_E^N$ unambiguously, as,

$$\begin{aligned} \frac{\max[V_t - F, 0]}{\frac{\underline{E}}{1-\underline{E}}F} C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right) &> \max[V_t - F, 0] \\ \Leftrightarrow C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right) &> \frac{\underline{E}}{1-\underline{E}}F, \end{aligned} \tag{21}$$

where $\frac{\underline{E}}{1-\underline{E}}F = \frac{F}{1-\underline{E}} - F$ is the intrinsic value of $C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right)$. This clearly illustrates the equityholders' benefit from the government bail-out, which is their share $\frac{\max[V_t - F, 0]}{\frac{\underline{E}}{1-\underline{E}}F}$ of the time value $C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right) - \frac{\underline{E}}{1-\underline{E}}F$ of the continuing call option.

2.7.2. Preference Shares

So far the government bail-out has been assumed to be conducted by an injection of common equity only. Here we extend this to include preference shares injection. We assume a minimum

[23] An option's value at $t \leq T$ consists of two elements: its *intrinsic value* (its payout if exercised today) and its *time value* (the value of continuing the option).

common equity floor $\underline{E}_C < \underline{E}$, where the government's preference shares E_P are utilised to attain the minimum capital ratio $\underline{E}$, while the government's common equity bail-out E_G is used to maintain $\underline{E}_C$. The former kicks in if the common equity ratio is below τ, with E_P boosting the asset value to $\frac{F}{1-\underline{E}}$ and the total equity to $\frac{\underline{E}}{1-\underline{E}}F$, as before. Then $E_P = \frac{\underline{E}}{1-\underline{E}}F - (V_t - F) = \frac{1}{1-\underline{E}}F - V_t$. The latter kicks in if the common equity ratio, even after the preference share injection, is below the minimum common equity ratio $\underline{E}_C$, which occurs when $\frac{V_t - F}{\frac{F}{1-\underline{E}}} < \underline{E}_C \Leftrightarrow V_t < \frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F$. Then the equityholders' values at $t < T$ are,

$$V_{E_E}^{BO} = \begin{cases} \frac{\max[V_t-F,0]}{\frac{\underline{E}_C}{1-\underline{E}}F} C\left(\frac{F}{1-\underline{E}}, \frac{1-\underline{E}_C}{1-\underline{E}}F, r, \sigma, T-t\right) & \text{if} \quad V_t < \frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F \\ C\left(\frac{F}{1-\underline{E}}, \frac{2-\underline{E}}{1-\underline{E}}F - V_t, r, \sigma, T-t\right) & \text{if} \quad \frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F \le V_t < \frac{F}{1-\tau} \\ C\left(V_t, F, r, \sigma, T-t\right) & \text{if} \quad V_t \ge \frac{F}{1-\tau} \end{cases} . \tag{22}$$

When there is no trigger ($V_t \ge \frac{F}{1-\tau}$), the equityholders' value is the same as under no bail-out/in. When there is just the preference shares injection ($\frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F \le V_t < \frac{F}{1-\tau}$), then the equityholders' position remains undiluted, but their claim at bond maturity T is now on the asset value V_T minus the sum of the bond face value F and the preference shares principal $\frac{F}{1-\underline{E}} - V_t$. The strike price of the call option is therefore $F + \frac{F}{1-\underline{E}} - V_t = \frac{2-\underline{E}}{1-\underline{E}}F - V_t$. Finally, when there is also common equity injection ($V_t < \frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F$), then the equityholders' share of equity is diluted to $\frac{\max[V_t-F,0]}{\frac{\underline{E}_C}{1-\underline{E}}F}$, where $\frac{\underline{E}_C}{1-\underline{E}}F$ is the total common equity after bail-out. Their claim at T is on $V_T - F$ minus the maximum preference share injection of $\frac{\underline{E}-\underline{E}_C}{1-\underline{E}}F$, and therefore the strike price of the call option is $F + \frac{\underline{E}-\underline{E}_C}{1-\underline{E}}F = \frac{1-\underline{E}_C}{1-\underline{E}}F$.

Using preference shares instead of common shares in order to attain the minimum equity ratio $\underline{E}$ has two opposing effects on the equityholders' position. The positive effect is that of smaller (or no) dilution. Specifically, compared to Eq.(20), in Eq.(22) when $\frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F \le V_t < \frac{F}{1-\tau}$ there is no dilution (only preference shares are injected), while when $V_t < \frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F$ the dilution is smaller (there is less common equity injected). The negative effect is that of reduced

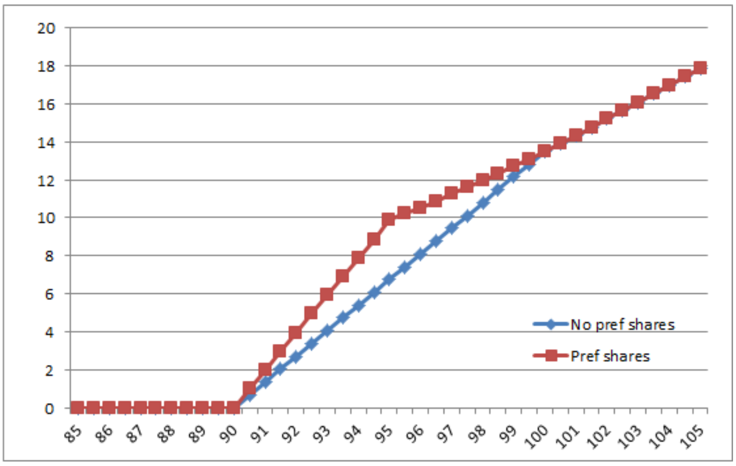

Figure 11: Value of equityholders' position $V_{E_E}^{BO}$ for different values of V_t with and without preference shares

claim on the asset due to higher ranking of the preference shares. This is reflected in the higher strike price of the call options in Eq.(22) (note, $\frac{2-\underline{E}}{1-\underline{E}}F - V_t > F$ for $V_t < \frac{F}{1-\underline{E}}$), which reduces the option value. Fig.11 shows that, when $F = 90$, $\underline{E} = 10\%$, $\underline{E}_C = 5\%$, $r = 5\%$, $\sigma = 20\%$ and $T - t = 0.5$, the positive effect of smaller dilution outweighs the negative effect of smaller claim. Indeed, it can be shown that this is always the case:

Proposition 1 *$V_{E_E}^{BO}$ is unambiguously higher with preference shares than without.*

Proof. Note when $\underline{E}_C = \underline{E}$, the curves coincide in Fig.11. Therefore it suffices to show that the gap between the two curves at $V_t = \frac{1-\underline{E}+\underline{E}_C}{1-\underline{E}}F$ (the kink of the preference shares curve) increases as $\underline{E}_C$ decreases, or

$$\frac{\partial}{\partial \underline{E}_C}\left[C\left(\frac{F}{1-\underline{E}}, \frac{1-\underline{E}_C}{1-\underline{E}}F, r, \sigma, T-t\right) - \frac{\underline{E}_C}{\underline{E}}C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right)\right] < 0$$
$$\Leftrightarrow \frac{F}{1-\underline{E}}e^{-r(T-t)}N\left(d_2\left(\frac{F}{1-\underline{E}}, \frac{1-\underline{E}_C}{1-\underline{E}}F, r, \sigma, T-t\right)\right) < \frac{1}{\underline{E}}C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right). \tag{23}$$

But $N\left(d_2\left(\frac{F}{1-\underline{E}}, \frac{1-\underline{E}_C}{1-\underline{E}}F, ...\right)\right) < N\left(d_2\left(\frac{F}{1-\underline{E}}, F, ...\right)\right)$, and so it suffices to show that,

$$\frac{\underline{E}}{1-\underline{E}}Fe^{-r(T-t)}N\left(d_2\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right)\right) < C\left(\frac{F}{1-\underline{E}}, F, r, \sigma, T-t\right)$$
$$\Leftrightarrow \frac{\underline{E}}{1-\underline{E}}Fe^{-r(T-t)}N\left(d_2\left(.\right)\right) < \frac{F}{1-\underline{E}}N\left(d_1\left(.\right)\right) - Fe^{-r(T-t)}N\left(d_2\left(.\right)\right) \tag{24}$$
$$\Leftrightarrow e^{-r(T-t)}N\left(d_2\left(.\right)\right) < N\left(d_1\left(.\right)\right).$$

This is true as $N\left(d_2\left(.\right)\right) < N\left(d_1\left(.\right)\right)$, since $d_1 = d_2 + \sigma\sqrt{T-t}$. Therefore as $\underline{E}_C$ decreases below $\underline{E}$, the equityholders are unambiguously better off with preference shares bail-out. ■

3. Agency Cost: Wealth-Transfer Problem

Having established the details of the different bail-out/in structures, we now investigate the agency costs associated with the over-investment problems in these structures. We distinguish two types of such agency costs:

1. *Wealth-transfer problem.* This is when the equityholders have an incentive for higher risk-taking, represented by the vega of their option position.

2. *Value-destruction.* Eberhart and Senbet (1993) state, "Risk-shifting can enhance equity value even when higher risk projects are of lower value, implying that investment decisions can be distorted away from firm value maximisation." When negative NPV projects are still beneficial to the equityholders (due to their convex payoff and the project's higher volatility), the reduction in the firm's total value represents this type of agency cost.

We investigate these in turn in this section and the next. For the purpose of the technical analyses, we assume $r > \frac{\sigma^2}{2}$ for the remainder of the paper.

As common in the literature (e.g. Eberhart and Senbet (1993); Berg and Kaserer (2011)), we investigate the vega of the equityholder position as a measure of their incentive to take on

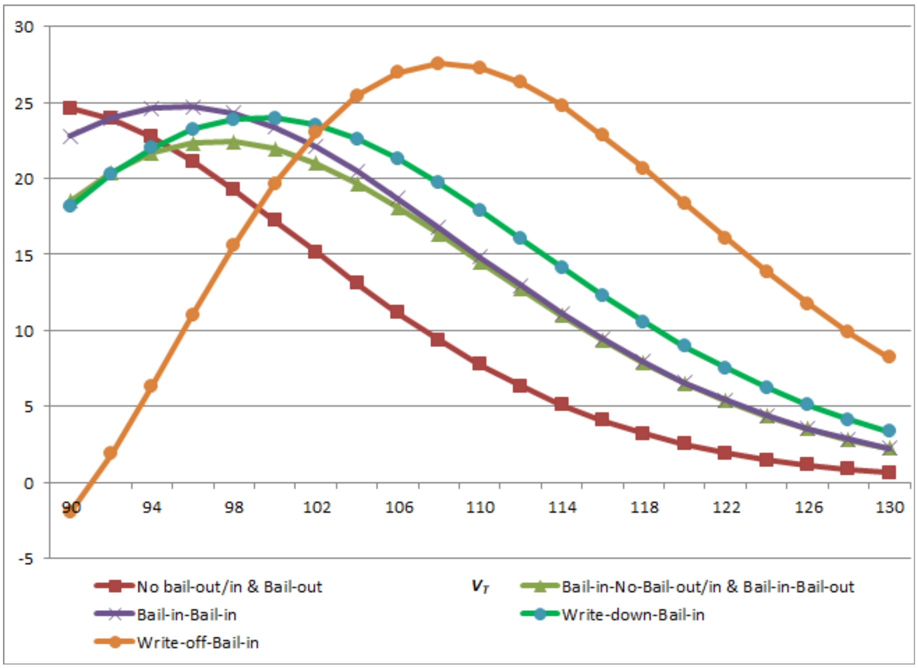

Figure 12: Equityholders' vega for different values of V_0 when $F = 90$, $F_C = F_W = 20$, $\tau = 7\%$ and $\underline{E} = 10\%$

riskier projects. The vega for each of the above cases are,

$$
\begin{aligned}
&Vega_{E_E}^{N} = Vega_{E_E}^{BO} = V_0\sqrt{T}N'\left(d_1\left(F\right)\right) \\
&Vega_{E_E}^{CN} = Vega_{E_E}^{CBO} = V_0\sqrt{T}\left[\left(1-\tau\right)N'\left(d_1\left(\tfrac{F}{1-\tau}\right)\right) - \left(1-\tau\right)N'\left(d_1\left(\tfrac{F_B}{1-\tau}\right)\right) + N'\left(d_1\left(F_B\right)\right)\right] \\
&Vega_{E_E}^{CBI} = \left(1-\tau\right)V_0\sqrt{T}N'\left(d_1\left(\tfrac{F}{1-\tau}\right)\right) \\
&Vega_{E_E}^{WOBI} = \tfrac{1}{\sigma}d_1\left(\tfrac{F}{1-\tau}\right)F_W e^{-rT}N'\left(d_2\left(\tfrac{F}{1-\tau}\right)\right) + \left(1-\tau\right)V_0\sqrt{T}N'\left(d_1\left(\tfrac{F_B}{1-\tau}\right)\right),
\end{aligned}
\tag{25}
$$

where $N'\left(d_1\left(K\right)\right) = \frac{1}{\sqrt{2\pi}}e^{-\frac{\left[d_1(K)\right]^2}{2}}$ for strike price K. These are depicted in Fig.12.[24] The graph compares the incentives for the equityholders to take on riskier projects at different values of V_0 above F between the five structures. We make the following observations:

[24] Write-down Coco bond is not discussed in the paper (see footnote 22). The vega of the equityholders' position in the case of write-down-bail-in is given by,

$$
\begin{aligned}
Vega_{E_E}^{WDBI} &= V_0\sqrt{T}\left[\left(1-\underline{E}\right)N'\left(d_1\left(\frac{F}{1-\tau}\right)\right) - \left(1-\underline{E}\right)N'\left(d_1\left(\frac{F_B}{1-\underline{E}}\right)\right) + \left(1-\tau\right)N'\left(d_1\left(\frac{F_B}{1-\tau}\right)\right)\right] \\
&\quad + \frac{1}{\sigma}d_1\left(\frac{F}{1-\tau}\right)\left(\underline{E}-\tau\right)\frac{F}{1-\tau}e^{-rT}N'\left(d_2\left(\frac{F}{1-\tau}\right)\right).
\end{aligned}
$$

Proposition 2 *With no bail-out/in or government bail-out, the incentive for higher risk taking increases as the firm's asset value falls towards the critical value F.*

In Fig.12 the critical value for no bail-out/in is $F = 90$. This is a restatement of a well-established fact in option theory that the vega of a call option increases as the option approaches at-the-money (i.e. $V_0 = F$). As such the proof is omitted.

The wealth-transfer happens when the equityholders choose higher σ projects, due to their positive vega values, which results in an increase in the value of their call option $C(F)$. In the no bail-out/in case there is an equal fall in the value of the bondholders' position, due to the rise in the value of their short put option position $P(F)$. Thus the wealth is transferred from the bondholders to the equityholders by the equityholders' actions. For the government bail-out case the wealth-transfer is from the government (i.e. the tax payers) to the equityholders.

Proposition 3 *For asset values above trigger point, the risk-taking incentive is higher with equity-conversion Coco bail-in than under no bail-out/in or the government bail-out.*

Proof. We show this for the case of bail-in-bail-in, which would be true if $Vega_{E_E}^{CBI} > Vega_{E_E}^{BO}$ for $V_0 > \frac{F}{1-\tau}$, or

$$(1-\tau) V_0 \sqrt{T} N'\left(d_1\left(\frac{F}{1-\tau}\right)\right) > V_0 \sqrt{T} N'(d_1(F)) \text{ for } V_0 > \frac{F}{1-\tau}. \tag{26}$$

This is proved in Appendix A. Note Fig.12 also depicts that this is true for the bail-in-no-bail-in/out and bail-in-bail-out cases. ■

Proposition 4 *For higher asset values the risk-taking incentive is higher with the write-off Coco bond than with the equity-conversion Coco bond.*

Proof. For this we require $Vega_{E_E}^{WOBI} > Vega_{E_E}^{CBI}$ for sufficiently large V_0. It suffices to show that $\frac{1}{\sigma} d_1\left(\frac{F}{1-\tau}\right) F_W e^{-rT} N'\left(d_2\left(\frac{F}{1-\tau}\right)\right) > (1-\tau) V_0 \sqrt{T} N'\left(d_1\left(\frac{F}{1-\tau}\right)\right)$ for large V_0. Note from the property of Black-Scholes option pricing model that $V_0 N'(d_1(K)) = Ke^{-rT}N'(d_2(K))$ for strike price K. Then we require,

$$\frac{1}{\sigma}d_1\left(\frac{F}{1-\tau}\right)\frac{F_W}{F}(1-\tau)V_0 N'\left(d_1\left(\frac{F}{1-\tau}\right)\right) > (1-\tau)V_0\sqrt{T}N'\left(d_1\left(\frac{F}{1-\tau}\right)\right)$$
$$\Leftrightarrow d_1\left(\frac{F}{1-\tau}\right) > \frac{F}{F_W}\sigma\sqrt{T}$$
$$\Leftrightarrow V_0 > \frac{F}{1-\tau}e^{-\left[r-\left(\frac{F}{F_w}-\frac{1}{2}\right)\sigma^2\right]T}. \tag{27}$$

Thus $Vega_{E_E}^{WOBI}$ is unambiguously larger than $Vega_{E_E}^{CBI}$ for V_0 higher than $\frac{F}{1-\tau}e^{-\left[r-\left(\frac{F}{F_w}-\frac{1}{2}\right)\sigma^2\right]T}$.

■

For our numerical example, the expression on the right-hand side of Eq.(27) equals 102.25. The result of Proposition 4 can be checked in Fig.12. Note, in the diagram, that the vega for the write-off case is lower even than for no bail-out/in closer to the Coco trigger point ($\frac{F}{1-\tau} = 96.77$). This reflects the shape of the vega curve of the write-off condor structure in Fig.8, due to its right-angle kink at $V_0 = \frac{F}{1-\tau}$, where sufficiently to the left of $\frac{F}{1-\tau}$ the vega of the structure takes a negative value when the holders of the write-off condor (the equityholders) benefit from lower volatility (i.e. increasing the chance of remaining to the left of $\frac{F}{1-\tau}$).

To conclude, using the detailed analysis of the bail-out/in structures outlined in Section 2, in this section we have been able to establish that, in comparison to the no bail-out/in or government bail-out cases, the equity-conversion Coco bond exacerbates the wealth-transfer element of the agency cost for all firm values above the Coco trigger point, and that the effect is even larger for the write-off Coco bonds for larger values of V_0. In option trading terms, this is analogous to the holder of an option having the right to determine the volatility of the underlying asset price. In financial markets, this would be an illegal manipulation.

4. Value Destruction

Value destruction agency cost occurs when the equityholders do not follow value maximisation for the firm. This is a principal-agent problem where the interest of the decision makers (the equityholders) does not align with that of the firm.

To investigate this, let there be a discrete set of projects defined by their expected outcome $E\left[V_T^i\right]$ and the return volatility σ^i. Let the market price of risk be λ. Then the present value of each project is,

$$V_0^i = e^{-r^i T} E\left[V_T^i\right] \text{ , where } r^i = r^f + \lambda\sigma^i \tag{28}$$

where r^i is the required rate of return of project i and r^f is the risk-free rate. Under value maximisation the firm would choose project m such that,

$$V_0^m = \max_i \left\{V_0^i\right\}. \tag{29}$$

On the other hand, under no bail-out the equityholders choose project m^N such that,

$$V_0^{m^N} = \max_i \left\{V_{E_E}^N\left(V_0^i\right)\right\}, \text{ where } V_{E_E}^N\left(V_0^i\right) = C\left(V_0^i, F, \sigma^i\right) \tag{30}$$

with $C(.)$ as given in Eq.(2), where the arguments now specify the underlying asset value, the strike price and the volatility. When $m^N \neq m$, $V_0^{m^N} < V_0^m$, and hence there is value destruction.

The value destruction problem arises from the fact that the firm value is determined as the expected present value (Eq.(28)) and does not depend on the asset volatility beyond its effect on the required rate of return r^i, while for the equityholders their value increases with higher σ (positive vega of their call option position). Value destruction results when the reduction in the equityholders' value due to the lower choice of V_0^i (the delta effect) is more than offset by the increase in the value due to the higher volatility (the vega effect). The degree of this effect can therefore be represented by the relative size of the two, which we denote η:

$$\eta = \frac{Delta}{Vega}. \tag{31}$$

The smaller the η of the structure, the more likely that there will be value destruction.

The delta of the equityholders' positions for each bail-out/in structure are, respectively,

$$\begin{aligned}
&Delta^{N}_{E_E} = Delta^{BO}_{E_E} = N\left(d_1\left(F\right)\right)\\
&Delta^{CN}_{E_E} = Delta^{CBO}_{E_E} = \left(1-\tau\right)N\left(d_1\left(\tfrac{F}{1-\tau}\right)\right) - \left(1-\tau\right)N\left(d_1\left(\tfrac{F_B}{1-\tau}\right)\right) + N\left(d_1\left(F_B\right)\right)\\
&Delta^{CBI}_{E_E} = \tau + \left(1-\tau\right)N\left(d_1\left(\tfrac{F}{1-\tau}\right)\right)\\
&Delta^{WOBI}_{E_E} = \tau - \tfrac{F_W e^{-rT}}{V_0\sigma\sqrt{T}}N'\left(-d_2\left(\tfrac{F}{1-\tau}\right)\right) + \left(1-\tau\right)N\left(d_1\left(\tfrac{F_B}{1-\tau}\right)\right).
\end{aligned} \tag{32}$$

These are depicted on Fig.13.[25] We now make the following observations:

Proposition 5 *With no bail-out/in or government bail-out, the value destruction is more likely as the firm's asset value falls towards the critical value F.*

Proof. It is a well established fact in option theory that the delta of a long call option decreases as the underlying asset price decreases (in option theory, this is represented by a positive *gamma*[26]). Therefore $Delta^{N}_{E_E}$ and $Delta^{BO}_{E_E}$ decrease as V_0 decreases. From Proposition 2 we also know that $Vega^{N}_{E_E}$ and $Vega^{BO}_{E_E}$ increase as V_0 falls towards the critical value F. Therefore η is unambiguously decreasing for falling V_0 above F. ■

[25] Again write-down Coco bond is not discussed in the paper (see footnotes 22 and 24). The delta of the equityholders' position in the case of write-down-bail-in is given by,

$$\begin{aligned}
Delta^{WDBI}_{E_E} &= \tau - \left(\underline{E}-\tau\right)\frac{F}{1-\tau}\frac{e^{-rT}}{V_0\sigma\sqrt{T}}N'\left(-d_2\left(\frac{F}{1-\tau}\right)\right) + \left(1-\underline{E}\right)N\left(d_1\left(\frac{F}{1-\tau}\right)\right)\\
&\quad - \left(1-\underline{E}\right)N\left(d_1\left(\frac{F_B}{1-\underline{E}}\right)\right) + \left(1-\tau\right)N\left(d_1\left(\frac{F_B}{1-\tau}\right)\right).
\end{aligned}$$

[26] *Gamma* is the sensitivity of an option's delta to an increase in the underlying asset price. Thus where V is the value of the option, Δ is its delta and S is the underlying asset price, $Gamma = \frac{\partial\Delta}{\partial S} = \frac{\partial^2 V}{\partial S^2}$.

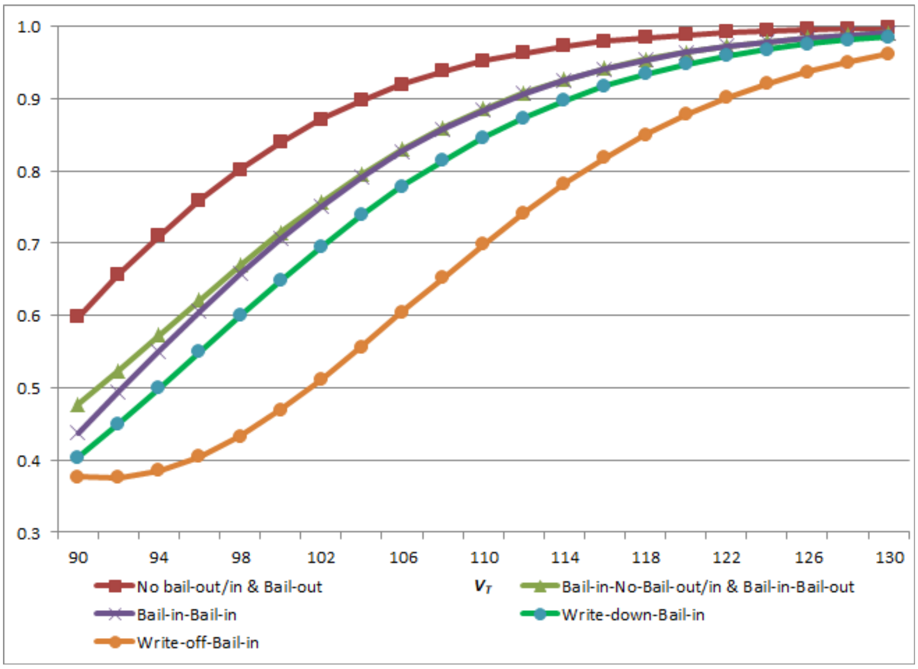

Figure 13: Equityholders' delta for different values of V_0 when $F = 90$, $F_C = F_W = 20$, $\tau = 7\%$ and $\underline{E} = 10\%$

Proposition 6 *For asset values above trigger point, the value destruction is more likely with equity-conversion Coco bail-in-bail-in than under no bail-out/in or the government bail-out.*

Proof. First we show that $Delta_{E_E}^{BO} < Delta_{E_E}^{CBI}$ for the required range of V_0, or

$$N\left(d_1\left(F\right)\right) > \tau + \left(1-\tau\right)N\left(d_1\left(\frac{F}{1-\tau}\right)\right) \Leftrightarrow N\left(-d_1\left(F\right)\right) < \left(1-\tau\right)N\left(-d_1\left(\frac{F}{1-\tau}\right)\right). \tag{33}$$

To show this, consider the following derivative:

$$\begin{aligned} &\frac{\partial}{\partial V_0}\left[N\left(-d_1\left(F\right)\right) - \left(1-\tau\right)N\left(-d_1\left(\frac{F}{1-\tau}\right)\right)\right] \\ = \;& -\frac{1}{V_0\sigma\sqrt{T}}\left[N'\left(-d_1\left(F\right)\right) - \left(1-\tau\right)N'\left(-d_1\left(\frac{F}{1-\tau}\right)\right)\right]. \end{aligned} \tag{34}$$

As $N'\left(-d_1\left(.\right)\right) = N'\left(d_1\left(.\right)\right)$, we know from Eq.(26) that this is positive for $V_0 > \frac{F}{1-\tau}$. Also,

$$\lim_{V_o\to\infty}\left[N\left(-d_1\left(F\right)\right) - \left(1-\tau\right)N\left(-d_1\left(\frac{F}{1-\tau}\right)\right)\right] = 0 \tag{35}$$

as the limit for both terms are zero. This means that $N\left(-d_1\left(F\right)\right)-\left(1-\tau\right)N\left(-d_1\left(\frac{F}{1-\tau}\right)\right)$ approaches 0 from below as V_0 increases from $\frac{F}{1-\tau}$, proving that $Delta_{E_E}^{CBI} < Delta_{E_E}^{BO}$ for $V_0 > \frac{F}{1-\tau}$. We also know from Proposition 3 that $Vega_{E_E}^{CBI} > Vega_{E_E}^{BO}$ for $V_0 > \frac{F}{1-\tau}$. Together this implies that η is unambiguously lower for equity-conversion bail-in-bail-in than for no bail-out/in or government bail-out. ■

Figs.12 and 13 suggest that this is also true for the remaining equity-conversion Coco bail-in cases, namely the bail-in-no-bail-out/in and the bail-in-bail-out.

Proposition 7 *For higher asset values the value destruction is more likely with the write-off Coco bond than with the equity-conversion bail-in-bail-in case.*

Proof. Again compare the deltas. $Delta_{E_E}^{WOBI} < Delta_{E_E}^{CBI}$ if,

$$-\frac{F_W e^{-rT}}{V_0\sigma\sqrt{T}}N'\left(-d_2\left(\frac{F}{1-\tau}\right)\right)+\left(1-\tau\right)N\left(d_1\left(\frac{F_B}{1-\tau}\right)\right)-\left(1-\tau\right)N\left(d_1\left(\frac{F}{1-\tau}\right)\right)<0. \tag{36}$$

Appendix B proves that this is true for $V_0 > \frac{F}{1-\tau}$. We already know from Proposition 4 that $Vega_{E_E}^{WOBI} > Vega_{E}^{CBI}$ for sufficiently large V_0. Together this implies that η is lower for the write-off-bail-in for sufficiently large V_0 than for the equity-conversion bail-in-bail-in. ■

To conclude, not only do introduction of equity-conversion or write-off Coco bonds increase the incentive for wealth-transfer by increasing the vega of the equityholders' position, as shown in Section 3, in this section we have established that it also increases the incentive for value destruction by decreasing the delta, hence aggravating the delta-vega ratio η. Closer to the trigger point, this suggests a higher temptation to attempt "gamble-for-resurrection", where the equityholders sacrifice firm value for high risk strategies, in the hope for a positive outcome.

5. Concluding Remarks

The new financial regulation has been articulated to dampen moral hazard and to minimise the chances of another financial crisis that could jeopardise again the integrity of the banking system. However in reality, the regulator is “swapping” bail-out for bail-in, which is in essence a replacement of moral hazard, of banks relying on the inherent guarantee by the government, with agency costs described in detail in this paper. If the burden of an ailing bank fell to the tax payers in the past, it will now fall to the bondholders who will be required to be very mindful about the investments they own in a bank. Historically, apart from the very few cases where the bank was fully nationalised (e.g. Bankia in 2012; SNS in 2013), the equityholders would simply suffer dilution (e.g. Lloyds and ING, both in 2008), or, in many cases, were unaffected with the injection of new equity in the form of preference shares with CT1 qualification (Goldman Sachs, Morgan Stanley, etc.). Under the new bail-in regime, the equityholders take the first losses up to the Coco trigger point where bondholders get written-down/off or converted into equity whilst there is still at least 7.0% (the Coco trigger ratio) of assets in equity. This going-concern deviation from absolute priority rule (DAPR) accentuates the agency costs that the bail-in structure is introducing into the banking industry.

It is, moreover, possible that the new bail-in structure may even aggravate the moral hazard problem. Although not discussed in this paper, there is, in fact, a second moral hazard problem apart from that associated with the equityholders, which is that of the bondholders where they shirk on their monitoring effort when they know that their investments are guaranteed by the government bail-out. What the new bail-in structure does is to alleviate this second moral hazard problem, as it forces better monitoring by the bondholders that limits the risk taking of the banks. However the equityholders’ moral hazard remains, and one could argue that, in reality, the equityholders may have more incentives to “gamble for resurrection” when the wealth extraction comes from other investors (creditors) rather than tax payers, as the media scrutiny, and hence the reputational impact, would likely be lower. This factor is enhanced by the fact that no further shareholders' expropriation is allowed by the public fund until all possible bail-in is exhausted, as has been in the recent cases of Banco Espirito Santo, SNS Bank and Bankia bail-ins. Moreover, bail-in may not result in restrictions on dividends or bankers' compensations as there would be with tax payer bail-out. In summary, the bail-in structure solves the moral hazard problem of the stakeholder who cannot influence the bank performance rather than of those who can. These are issues not analysed in this paper but they enhance our case that the new financial regulation may not alleviate the incentive problems as aimed.

Traditional corporate finance literature has underscored the detrimental effects of agency costs on the relationships between bondholders and equityholders, especially due to the limited investment of the latter. Higher equity advocated by some (e.g. Admati *et al.* (2013)) does not attenuate the problem when the equityholders enjoy the put option implicit in the bail-in-able balance sheet. Higher capital costs on risky investments could potentially make banks safer. These are broader issues that would be explored in future research. In this paper we focussed on aspects that arise within the new bail-in world. Wealth-transfer and value destruction are two consequences of this new structure. To conclude, the new regulations do not solve the intrinsic moral hazard of the banking industry; instead they yield new unintended consequences.

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Appendix

A. Proof of $(1-\tau)\, N'\left(d_1\left(\frac{F}{1-\tau}\right)\right) > N'\left(d_1\left(F\right)\right)$ for $V_0 > \frac{F}{1-\tau}$

For this to be true we require,

$$(1-\tau)\, e^{-\frac{1}{2}d_1^2\left(\frac{F}{1-\tau}\right)} > e^{-\frac{1}{2}d_1^2(F)}. \tag{A.1}$$

Now,

$$d_1\left(F\right) = d_1\left(\frac{F}{1-\tau}\right) - \frac{1}{\sigma\sqrt{T}}\ln\left(1-\tau\right). \tag{A.2}$$

Hence,

$$e^{-\frac{1}{2}d_1^2(F)} = e^{-\frac{1}{2}d_1^2\left(\frac{F}{1-\tau}\right)} e^{-\frac{1}{2}\left\{-\frac{2}{\sigma\sqrt{T}}\ln(1-\tau)d_1\left(\frac{F}{1-\tau}\right)+\frac{1}{\sigma^2 T}[\ln(1-\tau)]^2\right\}}. \tag{A.3}$$

Thus for (A.1) to be true,

$$\begin{aligned}
1-\tau &> e^{-\frac{1}{2}\left\{-\frac{2}{\sigma\sqrt{T}}\ln(1-\tau)d_1\left(\frac{F}{1-\tau}\right)+\frac{1}{\sigma^2 T}[\ln(1-\tau)]^2\right\}} && \text{(A.4)}\\
\Leftrightarrow \ln\left(1-\tau\right) &> \frac{1}{\sigma\sqrt{T}}\ln\left(1-\tau\right) d_1\left(\frac{F}{1-\tau}\right) - \frac{1}{2\sigma^2 T}\left[\ln\left(1-\tau\right)\right]^2 \\
\Leftrightarrow 1 &< \frac{1}{\sigma\sqrt{T}} d_1\left(\frac{F}{1-\tau}\right) - \frac{1}{2\sigma^2 T}\ln\left(1-\tau\right) && (37)\\
\Leftrightarrow \frac{1}{2\sigma\sqrt{T}}\ln\left(1-\tau\right) &< d_1\left(\frac{F}{1-\tau}\right) - \sigma\sqrt{T} = d_2\left(\frac{F}{1-\tau}\right).
\end{aligned}$$

Noting that $\ln\left(1-\tau\right) < 0$ for $\tau > 1$, this is unambiguously satisfied when $d_2\left(\frac{F}{1-\tau}\right) > 0 \Leftrightarrow V_0 > \frac{F}{1-\tau}e^{-\left(r-\frac{\sigma^2}{2}\right)T}$, or definitely when V_0 is above the critical level $\frac{F}{1-\tau}$.

B. Proof of Eq.(36) being Negative

Consider the following derivative of Eq.(36) with respect to $F_W = F - F_B$ while keeping F constant:

$$\begin{aligned} & \frac{\partial}{\partial F_W}\left[-\frac{F_W e^{-rT}}{V_0\sigma\sqrt{T}}N'\left(-d_2\left(\frac{F}{1-\tau}\right)\right)+(1-\tau)\,N\left(d_1\left(\frac{F_B}{1-\tau}\right)\right)-(1-\tau)\,N\left(d_1\left(\frac{F}{1-\tau}\right)\right)\right] \\ = & -\frac{e^{-rT}}{V_0\sigma\sqrt{T}}N'\left(-d_2\left(\frac{F}{1-\tau}\right)\right)+\frac{1-\tau}{F_B\sigma\sqrt{T}}N'\left(d_1\left(\frac{F_B}{1-\tau}\right)\right) \\ = & -\left(\frac{1-\tau}{F}\right)\frac{1}{\sigma\sqrt{T}}N'\left(-d_1\left(\frac{F}{1-\tau}\right)\right)+\frac{1-\tau}{F_B\sigma\sqrt{T}}N'\left(d_1\left(\frac{F_B}{1-\tau}\right)\right). \end{aligned} \tag{B.1}$$

The second identity uses a property of the Black-Scholes put option pricing formula, $S_0 N'\left(-d_1\left(K\right)\right) = Ke^{-rT}N'\left(-d_2\left(K\right)\right)$. This is strictly negative if and only if,

$$\frac{1}{F}N'\left(-d_1\left(\frac{F}{1-\tau}\right)\right) > \frac{1}{F_B}N'\left(d_1\left(\frac{F_B}{1-\tau}\right)\right). \tag{B.2}$$

Analyse this:

$$\begin{aligned} \Leftrightarrow\ & \frac{1}{F}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d_1^2\left(\frac{F}{1-\tau}\right)} > \frac{1}{F_B}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d_1^2\left(\frac{F_B}{1-\tau}\right)} \\ \Leftrightarrow\ & -d_1^2\left(\frac{F}{1-\tau}\right)+d_1^2\left(\frac{F_B}{1-\tau}\right) > 2\ln\left(\frac{F}{F_B}\right) \\ \Leftrightarrow\ & \left[\ln\left(\frac{V_0\left(1-\tau\right)}{F_B}\right)\right]^2-\left[\ln\left(\frac{V_0\left(1-\tau\right)}{F}\right)\right]^2+2\left(r+\frac{\sigma^2}{2}\right)T\ln\left(\frac{F}{F_B}\right) > 2\sigma^2 T\ln\left(\frac{F}{F_B}\right) \\ \Leftrightarrow\ & \ln\left(\frac{V_0^2\left(1-\tau\right)^2}{FF_B}\right)+2\left(r+\frac{\sigma^2}{2}\right)T > 2\sigma^2 T \\ \Leftrightarrow\ & V_0 > \frac{\left(FF_B\right)^{\frac{1}{2}}}{1-\tau}e^{-\left(r-\frac{\sigma^2}{2}\right)T}. \end{aligned} \tag{B.3}$$

This is certainly satisfied for $V_0 > \frac{F}{1-\tau}$ when $r > \frac{\sigma^2}{2}$. Thus Eq.(36) is decreasing in F_W for this range of V_0. As Eq.(36) equals 0 for $F_W = 0$, this means that it is negative for all positive values of F_W when $V_0 > \frac{F}{1-\tau}$.