Optimal Pay Regulation for Too-Big-To-Fail Banks*

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Abstract

This paper considers optimal executive pay regulations for banks that are *too-big-to-fail*. Theoretically, we map the consequences of a series of commonly-used pay schemes, describing their relative optimality and ultimate societal consequences. We argue that in a world of too-big-to-fail policy, simple equity-linked remuneration schemes maximise shareholder value by incentivising executives to choose excessively risky projects at the expense of the taxpayer. We find that paying the executive partly in debt fails to mitigate the project choice distortion when debt markets are informed. By contrast, both clawback rules and linking pay to interest rates can incentivise the executive to make socially optimal risk choices, but only if they are accompanied by appropriate restrictions on the curvature of pay with respect to the bank's market value. Pay curvature can be generated by tools such as equity options and promotion policy. The policy implication is that unless regulators can enforce restrictions on pay curvature, bank shareholders can undermine the effectiveness of these pay regulations.

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JEL Classification: G21, G28, G38.

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1 Introduction

In the recent global financial crisis, a number of banks accumulated large losses while their most senior employees were paid extraordinary bonuses up to that point. The fact that these losses in some cases led to bank failures requiring support from taxpayers prompted many to call for a review of bank executives' pay structure in order to reduce incentives for excessive risk-taking. Partly in response, the Financial Stability Board (FSB) (2009a,b) published the *Principles* and *Implementation Standards for Sound Compensation Practices* with the aim of aligning compensation with prudent risk-taking. Since then, a number of jurisdictions have introduced compensation regulations:[1] for example, the United States has instituted say-on-pay rules and is actively considering mandating clawback provisions; the European Union has imposed bonus caps of no more than 100% of base pay (200% with shareholder approval); and the United Kingdom has mandated that at least 40% of the variable remuneration is deferred for material risk takers for a period of three to seven years, and that their variable remuneration can be clawed back for a period of seven to ten years.[2]

This paper examines the optimal design of pay regulation for banks that are *too-big-to-fail* (TBTF), using a principal-agent framework. In the presence of explicit deposit insurance and the implicit possibility of government bailouts (the TBTF effect), a bank's shareholders ('the principal') have the incentive to design pay contracts to encourage the executive ('the agent') to take excessive risks at the expense of the taxpayers (risk-shifting). We first demonstrate that a standard equity-linked bonus contract, such that pay increases proportionally with share prices, is sufficient to incentivise the executive to select projects which maximise shareholder value; but this project choice represents excessive risk-taking for society in the presence of the TBTF distortion. Bank shareholders will have the incentive to exploit the TBTF distortion as long as the bank has some debt, implying capital regulation, by itself, cannot correct the project choice distortion.

We then examine how pay regulations might be used to mitigate this risk-shifting incentive. Previous research has found that, for corporations in general, including debt in executive pay can ameliorate the agency problem between shareholders and debt holders (Anantharaman, Fang and Gong (2014), Edmans and Liu (2011), Sundaram and Yermack (2007)). Our analysis shows that this policy will not curb the excessive risk-taking incentives created by the TBTF effect, if the debt market can observe and price the bank's risk. As the expected return on debt is invariant to the project choice in this case, paying the executives in debt will not deter them from exploiting the TBTF distortion for the

[1] For the US, see Dodd-Frank Act Section 951, and in addition see "U.S. Regulators Revive Work on Incentive-Pay Rules," Wall Street Journal, Feb 16, 2015. For the UK, see the Policy Statement PRA12/15 FCA PS15/16. For the EU bonus cap rules, see DIRECTIVE 2013/36/EU.

[2] For further details on the deferral and clawback periods in the UK, see the Policy Statement PRA12/15, FCA PS15/16. The final provisions on clawback and deferral will apply to variable remuneration awarded for performance periods beginning on or after 1 January 2016.

benefit of the shareholders.

We therefore consider the prominent alternative policy designed to mitigate such risk-shifting by bank executives: malus and clawback. Both malus and clawback are aimed at exposing senior bank executives to potential losses of pay, if they are found to be responsible for poor risk management, failure of managerial oversight, misconduct, etc., which may come to light several years later. Whereas malus refers to *ex post* adjustment of the unvested deferred pay, clawback can be applied on bonus pay which has already vested. As such hurdles for triggering clawbacks are typically higher than those for malus.

The Financial Stability Board report that, as of 2014, 80% of its reporting jurisdictions required malus mechanisms, while less than half of them mandated the adoption of clawback provisions, mainly due to local legal impediments.[3] By end 2014, malus had been exercised within the senior executive population in 8 jurisdictions out of 24 surveyed by the FSB, while no jurisdiction reported clawbacks actually exercised against senior bank executives.[4] But the frequency of their use is not necessarily a good measure of their effectiveness, given that the presence of these clauses itself could deter excessive risk-taking or malpractice *ex ante* and thus reduce the need to trigger malus or clawback *ex post*. Rather, their effectiveness hinges on whether they can be actually used when major incidences emerge. Indeed, FSB (2015) reports that major banks in the United Kingdom alone disclosed malus adjustments of £290 million in 2014 (equivalent to US$453 million based on the end-2014 exchange rate). It also notes that JP Morgan Chase recovered more than US$100 million of compensation through the firm's clawback mechanisms from individuals linked to the 2012 London Whale incident, in which its Chief Investment Office generated a trading loss initially estimated to be US$2 billion through derivative transactions.[5]

In the theoretical analysis below, we refer to all forms of *ex post* pay adjustment as 'clawback' as a shorthand. We first demonstrate that if banks are required by the regulator to implement a clawback mechanism, and they restrict themselves to using equity-based pay, then the clawback regulation will reduce the bank executive's risk-taking incentives. Because investing in risky projects makes clawback more likely, the bank executive is deterred from choosing risky projects unless they are expected to generate sufficient additional shareholder value over and above that available from low-risk alternatives. But the clawback regulation works imperfectly: it can incentivise the executive to avoid investing in high risk projects that generate a higher social surplus than the low risk alternatives. We then demonstrate that the effect of the clawback regulation can be entirely undone if shareholders make pay sufficiently convex in equity prices in a bid to restore the executive's risk-taking incentives, e.g. via use of equity options in pay. Our analysis reveals that

[3]See FSB (2014), section 2.

[4]See FSB (2015), page 13.

[5]The Financial Times report that the trading loss was subsequently revised up to US$6.2 billion. *UK financial watchdog wins London Whale identity case*, Financial Times, 22 March 2017.

this loophole can be closed: clawback can be made effective and deliver the societal first best project choice if it is implemented with an appropriate restriction on the curvature of pay.

Given the practical challenges associated with clawing back vested compensation in some jurisdictions, we also consider alternative approaches for curbing bank executives' risk-taking incentives. Our analysis demonstrates that linking pay to the bank's interest rate can achieve outcomes equivalent to those from clawback. The intuition for this result is simple: if the bank executive takes more risk, the bank will have to pay a higher interest rate on its debt, yet because of the TBTF policy the higher interest rate is insufficiently reflective of the total risks being taken by the bank. It is then socially valuable that the executive's incentive to take risks is reduced if pay is made decreasing in the bank's interest rate. Unfortunately, such a regulation will be subject to the same weakness as the clawback regulation: its impact could be entirely undermined if banks can make pay more convex with respect to equity prices in response to the regulation. So, to be effective such a pay regulation once again needs to be implemented with an appropriate restriction on pay curvature.

Our results therefore have important implications for policy, as discussed in detail in Section 5. In order to justify regulation of banks' compensation arrangements, a divergence in bank shareholders' and the wider society's interests needs to be established. The TBTF distortion is one reason why such a divergence may exist. But when such a divergence exists, the regulator representing the society's interests will need to be mindful of the possibility that bank shareholders will use tools at their disposal to undo the effect of compensation regulations. Regulations requiring banks to implement clawback or to link pay negatively to their own interest rates could produce the society's first best outcome, if regulators can also limit pay convexity. Granting equity options is one way of creating pay convexity, so restricting the use of equity options is one way of limiting pay convexity. But there may be other ways of generating pay convexity, for example making large bonus awards or promotions conditional on hitting an earnings target. Thus, if regulators cannot fully observe the structure of pay, or lack the tools to control the curvature of pay in practice, there is a reason to question the extent to which compensation regulations can effectively counter excessive risk-taking incentives created by the TBTF effect.

Our paper contributes to the recent literature exploring how pay regulations can be used to control bank executives' incentives to exploit the depositor guarantee and too-big-to-fail distortions.[6] Prominent in this field are Hakenes and Schnabel (2012) and Bolton, Mehran and Shapiro (2015). Hakenes and Schnabel study a model in which a bank can produce one of three possible return realisations, and such that an optimising

[6] An alternative approach pursued is to link pay regulations to capital regulations and the price of deposit insurance. Papers in this vein include John, Saunders and Senbet (2000), Freixas and Rochet (2013), Hilscher, Landskroner and Raviv (2016), and Eufinger and Gill (2016).

principal (the bank owner) would make a positive payment to the executive only if the highest possible outcome is realised. Absent regulation the executive is over-incentivised to choose risky projects which maximise the probability of the high outcome. The optimal regulatory response is to limit what can be paid in this high state. The insight of this work for policy is ambiguous, however, as bonus caps, pay which is flat enough in bank value, and a pay function which is not too curved would all be equivalent when mapped into a study in which pay has only two possible values. Our work studies a continuous distribution of returns and so allows us to demonstrate that pay which is 'flat enough' will not prevent exploitation of too-big-to-fail; while clawback plus a curvature restriction in pay can deliver society's first best. Bolton et al. (2015) propose instead that a linear adjustment to credit risk (specifically by linking pay to the premium on credit default swaps) is added to equity-based pay to mitigate the incentives a bank executive has to risk-shift on to the taxpayer. Our contribution is to demonstrate that, when the bank optimises against pay regulations, a simple interest-rate linkage can be circumvented by the bank. We demonstrate that appropriate restrictions on the curvature of pay must also be implemented to deliver the desired disincentive to selecting risky projects.

The paper is organised as follows. Section 2 outlines our principal-agent model. Section 3 pins down the regulator's and the bank owner's preferred project decision rules and demonstrate that, in the absence of any pay regulations, the bank owner will incentivise the bank executive to take excessive risks through equity-linked pay. Section 4 examines different types of pay regulations to correct for the executive's excessive risk-taking incentives, including debt in pay, clawbacks (and malus), bonus caps and linking pay to the interest rate on debt. Section 5 discusses the implications of our analysis for policy and empirical testing, and Section 6 concludes.

2 The Model

We propose a principal-agent model in which the bank owner ("she") is the principal and the bank executive ("he") is the agent. The agency problem here is that the bank executive makes a project choice from a list of available projects that only he can observe. The risk level of the bank will therefore be determined endogenously by the bank executive. The bank owner can influence the executive's risk choice via the compensation contract offered. We will study how possible rules on this contracting problem, created and enforced by a financial regulator, can affect the optimal contracting between the bank owner and executive and so the asset risk of the bank.

The key parts of this model are therefore: the projects available to the bank executive; the capital structure of the bank and any implicit government guarantee; and the compensation contracting space including possible regulatory rules which might constrain it. We first present the order in which the players move, before detailing each individual

part of the model.

2.1 The Timeline

The timeline of the model is as follows:

- $t = -1$: The financial regulator announces any restrictions on the compensation function which the bank owner may design.
- $t = 0$: The bank owner designs a compensation contract for the bank executive which conforms to the regulations set by the financial regulator. The bank executive accepts or rejects the contract. If the contract is rejected, the game ends.
- $t = 1$: At the beginning of the period the bank executive privately observes the projects available and decides which project to pursue. This project choice is announced to the market. At the end of the period, the bank issues debt at an interest rate which reflects the selected project's risk given the too-big-to-fail implicit guarantee. The executive receives his compensation according to the pre-agreed compensation contract.
- $t = 2$: The project returns are realised, and the debt holders are repaid if the bank is solvent. If it is insolvent, the government bails out the debt holders with probability μ and compensates them in full. Without the government bailout, the debt holders receive the residual assets and shareholders are assumed to lose all their investment.

2.2 Bank capital structure

At $t = -1$, the bank owner contributes one unit of equity, and the bank has outstanding debt $(1 - \lambda) D$. We denote the interest rate payable on this debt by i_{-1}. We treat this interest rate as exogenous to the game. It can be thought of as the interest payable on the existing stock of debt. The bank owner then offers a compensation contract to the executive at $t = 0$. If the executive accepts the contract, he selects a project and publicly reveals the probabilistic distribution of returns of his chosen project at the start of $t = 1$. The bank then issues the remaining debt λD at the end of $t = 1$. We denote the interest rate payable on the $t = 1$ debt by i_1, which we assume fully incorporates the risks taken by the debt holders given the risk of the bank's project and the likelihood of the government bailout. Thus we capture the case that, after a project choice decision is taken, investors will have an opportunity to buy debt at a price commensurate with the risks they are taking. The parameter λ is a measure of the funding stability of the bank: a low λ captures long-term stable funding with unresponsive interest rates.

The regulator and the investors cannot learn the expected return of alternative projects which the executive did not choose. This information structure allows us to study a project choice decision in which the executive might choose a risky project when it actually has a lower net present value than some other less risky project, with neither the regulator nor the market participants able to discern whether or not this is the case.

Levels of debt and equity are assumed to be independent of the project chosen. This allows us to study distortions in the executive's project choice independently of the known distortions created by changes in leverage.[7]

We are interested in studying the possible interaction of an implicit government guarantee with endogenously chosen bank risk. We model the implicit government guarantee by assuming that all market participants believe that the government will bail out holders of the bank's debt in the event of bank failure with probability μ. We characterise this as a *too-big-to-fail* effect. This government guarantee will alter the interest required on the debt issued at $t = 1$, which we denote $i_1(\mu)$. We drop the argument μ for clarity when we believe it will not cause any confusion.

2.3 A Model of Project Choice

If the executive accepts to work for the bank owner, then at time $t = 1$ he must choose between two alternative projects: a high volatility project and a low volatility project. Only one project can be selected. The high volatility project is fully described by its expected return Z. The expected return Z is private information to the bank executive. Z is drawn from a publicly known probability density function $f_H(Z)$ with support on $[1, \infty)$. A high volatility project will succeed at $t = 2$ with probability χ and deliver a return equal to Z/χ. With probability $1 - \chi$ the project will fail and deliver a payoff of zero. This project is therefore 'risky'.

Alternatively, the bank executive may select the low volatility project. This project is fully described by its expected return r. The expected return r is again private information to the bank executive at $t = 1$. r is independently drawn from a publicly known probability distribution $f_L(r)$ with support $[1, \infty)$. A low volatility project with expected return r will succeed at $t = 2$ with certainty and deliver payoff r. This project is therefore 'safe'.

The draws of Z and r are independent and it is natural to assume that riskier projects generate higher expected returns on average:

$$E_H(Z) > E_L(r) \tag{1}$$

The *ex ante* distribution of returns for both high and low volatility projects are

[7] Invariance of the level of debt to project choice might arise naturally if: (i) the firm is fully leveraged given its pledgable or collateralizable assets; (ii) the owners decide on the levels of debt and equity they can contribute in advance of the executive's project choice; or (iii) regulatory capital requirements are not appropriately risk-sensitive.

bounded below by 1 to ensure that the executive always has at least one positive net present value project of each type. The assumption that the bank executive has only one high risk and one low risk project is without loss of generality; these should be interpreted as the best low risk and best high risk projects available. The structure of the returns has been simplified for tractability. This is not an essential assumption, but it allows us to simplify the exposition while retaining the key feature that a high volatility project yields a greater spread of possible payoff realisations, and has a greater probability of leading to bank default for any given level of debt.

2.4 Compensation contracting environment

The bank executive is assumed to be risk-neutral. The project choices available to the bank executive are private information. However, once a project is selected and announced at $t = 1$ all market participants observe the risk profile and expected return of the project undertaken. This allows the market to set the bank's market capitalisation (denoted K), and the interest rate payable on the $t = 1$ debt, i_1. We assume that the risk structure of the project is not explicitly contractible and so we focus our analysis on a compensation function for the bank executive which is a function of the market capitalisation K. This compensation function is denoted $s(K)$. The principal determines this compensation function at $t = 0$. The compensation function will create the incentives which will guide the bank executive's project choice at $t = 1$.

The bank executive is paid by the bank owner at the end of $t = 1$ after he selects and announces the project to the market, but before the payoffs from the project are realised. This is intended to capture the fact that banks often make long-term investments, particularly when compared to the typical tenure of executives. The analysis of clawback in Section 4 will require the executive to make intertemporal trade-offs. We denote the bank executive's discount factor for future pay as $\delta \leq 1$ while the bank's is normalised to 1. Thus, we allow for the executive to be more impatient than the bank.

We assume that the bank executive can always cause realised profits to shrink, and so we require the compensation contract to be weakly increasing in the bank market value: $s'(K) \geq 0$. We denote the outside option of the bank executive by u.

As the bank executive has private information in multiple dimensions (the payoff of the low risk project and the high risk project), the determination of the fully optimal contract is frequently intractable (Rochet and Stole (2003)). We make progress in our optimal contracting analysis by paying particular attention to the empirically realistic setting in which the outside option of the bank executive is orders of magnitude smaller than the size of the bank's balance sheet. That is, we will have particularly strong results in the limit of $u/(1 + D) \to 0$. In this setting, the maximum surplus available to the bank owner can be cleanly expressed. Hence, if a contract which delivers this surplus can

be found, then it must be optimal.

2.5 Bank owner and Financial regulator objective functions

The bank owner is risk neutral and seeks to maximise her profits. The bank owner selects the compensation function $s(K)$. We assume that there exists a financial regulator who can set rules as to the permitted structure of the compensation function $s(K)$. These rules may take the form of restrictions on the shape of the compensation function, or on restrictions in the securities in which the compensation can be paid. The financial regulator sets these rules in advance of the design of the compensation contract $s(K)$. We assume that the financial regulator is risk neutral and wishes the banking system to maximise the aggregate surplus created.

3 Contracting Without Regulations

The financial regulator's first best project choice rule is immediate from the objective that aggregate surplus should be maximised. It is that the bank should select the project with the highest net present value. That is the high risk project should be selected if and only if

$$Z > r \tag{2}$$

In equilibrium, the bank owner will design a compensation contract which maximises her profit given the interest rate on the existing stock of debt, i_{-1}. In order to pin down the optimal compensation contract, we first identify the bank owner's first best project choice rule, and then we demonstrate that the bank executive can be induced to deliver this project choice at the lowest possible cost.

If at $t = 1$ the executive chooses the low volatility project, the project yields $t = 2$ return $r \geq 1$ with certainty. We assume that the debt levels D and interest rate on outstanding debt (i_{-1}) are not so high that the bank is insolvent even with the low volatility project. It follows that at $t = 1$ the bank can issue debt λD at the risk free rate, normalised to equal to 1: $i_1 = 1$. The market value of the bank with a low volatility project at $t = 1$, denoted as $K_L(r)$, is therefore given by:

$$K_L(r) = (1 + D)\, r - \lambda D - (1 - \lambda)\, D i_{-1} \tag{3}$$

If the executive chooses the high volatility project, the interest rate on debt, i_1, will be a function of the probability of the bank being solvent, and the probability the government will nevertheless make good on the debt repayments if insolvent. The debt interest must

therefore satisfy:

$$\chi i_1 \lambda D + (1-\chi)\mu i_1 \lambda D = \lambda D \Leftrightarrow i_1 = \frac{1}{\chi + (1-\chi)\mu} \tag{4}$$

Thus, the $t = 1$ market value of the bank with a high volatility project, denoted as K_H, is given by:

$$K_H(Z) = \chi \left[(1+D)\frac{Z}{\chi} - \frac{\lambda D}{\chi + (1-\chi)\mu} - (1-\lambda) D i_{-1} \right] \tag{5}$$

The owner's first best project choice rule is to choose the risky project if and only if it maximises profits:

$$K_H > K_L \tag{Owner FB}$$

Comparing (3) to (5), we can determine the bank owner's first best project choice rule: that the risky project should be chosen if and only if

$$Z > r - \underbrace{\lambda \frac{D}{(1+D)} \frac{\mu(1-\chi)}{\chi + \mu(1-\chi)}}_{(a)} - \underbrace{(1-\lambda)\frac{D}{(1+D)} i_{-1}(1-\chi)}_{(b)} \tag{6}$$

Comparison of (2) to (6) demonstrates that the bank owner's optimal project choice rule induces riskier projects to be chosen more readily than the regulator's preferred rule. The reason for this separation of interests between the owner and the regulator arises from two different risk-shifting problems. The distortion labeled (a) in (6) is due to the possibility of risk-shifting onto government via the too-big-to-fail implicit bail-out guarantee. Under a too-big-to-fail guarantee, debt funding for risky projects receives an implicit subsidy. With no possibility of bailout, debt for a project with probability χ of success would require $1/\chi$ dollars to be repaid for each dollar lent. However, the too-big-to-fail distortion lowers the interest rate payable, (4), to below this level (though the interest rate remains above 1, the risk free rate). As a result, the payoff to the bank from the risky project is boosted, resulting in the bank preferring it even if it generates a slightly lower level of surplus relative to the safe project.

The distortion labelled (b) in (6) is due to the possibility of risk-shifting onto the existing private sector creditors. These creditors who supplied the stock of legacy debt have been promised an interest rate i_{-1}. However, if the risky project is chosen, the bank will default in the event the project fails; that is with probability $(1-\chi)$. This provides an additional incentive to the bank to choose the risky project, resulting in the bank preferring it even if it generates a slightly lower level of surplus.

By inspection of (6), we can see that the difference in the owner's and regulator's preferred project choice rule grows the greater is the probability of government bailout, μ, or the more leveraged the bank is. Further, we note that a capital adequacy requirement,

which requires banks to keep D below a pre-determined level, will reduce the distortion, but cannot eliminate it as long as banks are partially funded by debt. This implies that appropriately designed compensation regulation can potentially complement capital adequacy requirements in mitigating excessive risk taking caused by the too-big-to-fail effect.

Proposition 1 *The bank owner can maximise her profits by offering a linear equity-linked compensation contract, $s(K) = bK$, which gives the executive a proportion b of the bank's equity at $t = 1$. The project choice rule will be given by the owner's first best (6).*

Proof. See Technical Appendix. ■

Proposition 1 demonstrates that, absent any regulation, a simple equity-linked pay scheme is sufficient to align the interests of the bank owner and the bank executive and so deliver the decision rule (6). Thus, the bank executive can be incentivised with equity to choose riskier projects than the regulator's preferred rule (2) would demand. The simple equity-linked pay scheme causes the bank executive to take excessive risk from society's point of view: the executive is rewarded for risk-shifting onto the wider public via the too-big-to-fail guarantee. The more levered the bank, or the more probable the too-big-to-fail guarantee, the greater is the distortion.

4 Compensation Regulation

Having established that the privately optimal remuneration contract induces socially excessive risk-taking in the presence of an implicit government guarantee on debt, we now examine what form of compensation regulation could help induce socially optimal risk-taking incentives. This analysis is complicated by the fact that the bank owner can optimally adjust compensation contracts in response to regulation. We will focus on three prominent types of compensation regulation: (i) a requirement to pay part of the executive's compensation in debt securities; (ii) a requirement for some pay to be subject to clawback provisions; and (iii) a requirement for the executive's compensation to be a function of the interest rate payable by the bank.

When discussing the bank's choices, it will be helpful to change variables and work with the $t = 1$ market capitalisation of the bank conditional on project choice, $\{K_H, K_L\}$, rather than the underlying expected return of the individual projects. The bank owner's first best project choice rule is given by (Owner FB). In these variables, (2) can be rewritten using (3) and (5) to give the regulator's first best project choice rule: the high risk project only being selected if the resultant market capitalisation satisfies:

$$K_H > K_L + \underbrace{\lambda D \frac{\mu(1-\chi)}{\chi + \mu(1-\chi)}}_{(a')} + \underbrace{(1-\lambda)(1-\chi) D i_{-1}}_{(b')} \equiv K_L + \omega. \qquad \text{(Reg'r FB)}$$

Condition (Reg'r FB) demonstrates that the regulator only wishes the bank executive to select the high risk project if the resultant market capitalisation is sufficiently larger than the market capitalisation with the low risk project. We label the wedge in capital values required by the regulator as $\omega > 0$. In other words, if the bank would have only a slightly higher market capitalisation with the risky project, the regulator would rather the bank chose the lower market capitalisation by selecting the low risk project. The reason for this wedge is that some of the gains to the shareholders are not real surplus creation, but are rather drawn from risk-shifting on to either the taxpayer via the too-big-to-fail guarantee (denoted (a') in (Reg'r FB)), or risk-shifting onto the private creditors who supplied the original stock of bank debt (denoted (b') in (Reg'r FB)).

Using (3) and (5), we can define the probability density function of the possible market capitalisations, K_L and K_H, as $g_L(K)$ and $g_H(K)$, respectively, where:

$$g_L(K) \triangleq \begin{cases} f_L\left(\frac{K+\lambda D+(1-\lambda)Di_{-1}}{1+D}\right) & \text{if } K \geq 1+(1-\lambda)(1-i_{-1})D \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

and

$$g_H(K) \triangleq \begin{cases} f_H\left(\begin{array}{c} \frac{K}{1+D}+\lambda\frac{D}{1+D}\frac{\chi}{\chi+\mu(1-\chi)} \\ +(1-\lambda)\chi\frac{D}{1+D}i_{-1} \end{array}\right) & \text{if } K \geq 1+\left(\begin{array}{c} 1-\lambda\frac{\chi}{\chi+\mu(1-\chi)} \\ -(1-\lambda)\chi i_{-1} \end{array}\right)D \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

We now analyse different possible regulatory interventions into compensation.

4.1 Remuneration partly paid in debt

It has been proposed that excessive managerial risk-taking can be mitigated by remunerating the executive in part through debt. The Federal Reserve Bank of New York has offered its support for increasing the proportion of debt in pay.[8] As an example, AIG declared in its 2010 SEC filing that, for some of its executives, 80% of their bonus will be based on the value of the bank's junior debt, and 20% on its stock.[9] We explore whether the excessive risk-taking implied by the gap between (Owner FB) and (Reg'r FB) can be alleviated if the regulator forces the bank to remunerate the executive partly in debt. The following regulatory pay rule is a typical approach:

Mandatory Debt-in-Pay Rule: If the bank owner offers compensation contract $s(K)$ to the bank executive, then the regulator allows only the fraction $(1-c)s(K)$ to be

[8] See Dudley (2014).

[9] Reported in Fortune magazine:
http://archive.fortune.com/2010/07/02/news/companies/aig_executives_compensation_debt.fortune/index.htm

paid out (in cash) at $t = 1$; the remainder has to be paid in debt which matures at $t = 2$.

Thus, at $t = 1$, the executive should receive debt with face value $cs(K)$. At $t = 1$ the bank's debt has interest rate $i_1(\mu)$ and so the debt component of pay will pay out $i_1(\mu) \cdot cs(K)$ if debt holders are repaid at $t = 2$ and zero otherwise.

We are considering the case in which the executive's debt is not singled out for special treatment in the case of default – it is *pari passu* with the other $t = 1$ creditors. It might seem more appropriate that the executive's debt should not be bailed out, or that the executive should be especially punished in the case of default. This would be to create a penalty regime specifically for the executive. This would be similar to a clawback regime which we analyse below (Section 4.2). Here, we are exploring the benefits of using standard debt in pay.

Proposition 2 *Under a mandatory debt-in-pay rule:*

1. *Any remuneration contract in which the executive's pay is strictly increasing in shareholder value K will deliver the owner's first best project choice rule, given by (Owner FB).*

2. *If the ratio of the executive's outside option u to the bank's balance sheet value $(1 + D)$ tends to zero, then the bank owner can secure profit arbitrarily close to the maximum. The owner's preferred project choice rule (Owner FB) is implemented.*

Proof. See Technical Appendix. ■

Proposition 2 demonstrates that including debt which is *pari passu* with other uninsured debt in the executive's compensation contract does not correct the project choice distortion caused by the fact that uninsured debt is subject to some bailout probability. When the executive announces his choice of project, the informed debt market observes the risk of repayment. The expected return on debt is then given by the return required by investors on loans made and so is independent of project choice. Thus, even allowing for the executive's impatience, the presence of debt in the executive's compensation does not alter the project selection incentives. It remains the case that the executive wishes to maximise the bank value, and this is achieved by exploiting the too-big-to-fail subsidy.

The literature has shown that in some models payment in debt can move the interests of the executive (i.e. agent) towards those of the private sector creditors and so partially reduce the incentives to risk-shift (e.g. Edmans and Liu (2011)). This mechanism does not operate in our model. The key assumption distinguishing our approach from this literature is whether the debt markets are less informed than the executive about the risks being taken at the moment when compensation is paid. In our model, creditors are permitted to research the projects selected by the bank executive and so debt markets

are as informed as the bank executive when he is paid in debt; thus the executive cannot risk-shift to creditors. As debt prices adjust to the executive's project choice, the net present value of his compensation in debt is invariant to his project choice. It follows that paying the executive in debt will not influence his project choice when the debt market is informed. By contrast, if debt markets are less informed than the executive, then the executive can choose a high risk project without reducing the market value of the bank's debt. In such a setting, in which the executive can risk-shift to uninformed creditors, debt in pay can deter the executive from selecting excessively risky projects at the expense of creditors.

These insights show that, for payment partly in debt to mitigate the effects of too-big-to-fail, the executive would need to be *more* exposed to losses than private creditors are, or think they are, in the event of a bank failure triggering the too-big-to-fail bailout. One way to achieve this is to require special treatment of the executive in the event of bank failure; akin to a clawback regime. We turn to this now.

4.2 Malus and Clawback

We now consider an alternative method of exposing the executive's compensation to risks that may crystallise only in the long-run: malus and clawback. Malus is an arrangement that permits the institution to prevent the vesting of all or part of the amount of deferred remuneration awarded to its employees in relation to risk outcomes or performance. Clawback is a contractual agreement whereby employees agree to return ownership of an amount of remuneration that has already been paid by the institution under certain circumstances. The intended aim of these policies is to discourage excessive risk-taking and encourage more effective risk management. In the United Kingdom, for example, the variable remuneration of material risk takers will be subject to clawback for a period of seven to ten years, and firms are required to set criteria for the application of malus and clawback to cover situations where the employee "participated in, or was responsible for, conduct which resulted in significant losses to the firm; or failed to meet appropriate standards of fitness and propriety".[10] The primary aim of this policy is to mitigate excessive risk-taking by extending individuals' risk horizon and internalizing the cost of potential losses associated with risk taking, rather than to cover the cost of misconduct, such as fraud and market abuse. The effectiveness of malus and clawback need not be limited to the period during which an individual is employed with the firm, if a contract between the new employer and employee provide for the possibility of malus and clawback to be applied on the basis of a determination notified by the old employer.[11]

[10]For further details on the deferral and clawback periods in the UK, see the Policy Statement PRA12/15, FCA PS15/16.

[11]For further details on the proposal for making malus and clawback work after the employee leaves the firm in the UK, see Prudential Regulation Authority Consultation Paper CP2/16.

The following regulatory pay rule is in the spirit of the clawback implementation:

Clawback Pay Regulation: If the bank owner offers compensation contract $s(K)$ to the bank executive then the regulator permits this amount to be paid at $t = 1$. However, in the event of bank insolvency at $t = 2$, the bank executive must pay back a proportion $p \leq 1$ of his prior earnings.

The parameter p can be interpreted as the probability that the clawback is enforced in the event of a bank failure, or alternatively, the proportion of pay which is liable to clawback, or the product of both. For simplicity, we assume that, in the case of a bank failure, any pay returned (or cancelled) does not accrue to the debt holders.[12]

As equity-linked pay is so prominent, we first analyse the effect of clawback on banks which do not optimise their compensation structure and offer simple equity-linked pay packages. Subsequently, we study how a profit maximising bank will optimally alter the structure of the compensation she offers.

4.2.1 Clawback with equity-linked pay

Suppose that the bank owner uses an equity-linked compensation structure given by $s(K) = bK$. We will see below that this contract is no longer an optimal compensation contract given the clawback regulation.

Clawback in combination with equity-linked pay moves the bank executive's project choice rule – but not perfectly. The proof of Proposition 3 below demonstrates that the executive's project choice under clawback is to select the risky project if the resultant market value satisfies:

$$(1 - \delta(1 - \chi)p) K_H > K_L.$$

Studying this rule allows us to demonstrate:

Proposition 3 *Suppose that the executive receives equity-linked compensation $s(K) = bK$ and is subject to clawback. For any clawback parameter p:*

1. *There exist project alternatives which deliver market capitalisation (K_L, K_H) such that the executive will select the safe project even though $K_H > K_L + \omega$: that is, he chooses the safe project even though it delivers lower total expected surplus and lower market capitalisation than the risky alternative.*

2. *If the bank is sufficiently levered and funding costs are sufficiently unstable $(\lambda \to 1)$, there exist project alternatives which deliver market capitalisation (K_L, K_H) such that the executive will select the risky project even though $K_L < K_H < K_L + \omega$:*

[12] This assumption is made to simplify analysis, and can be justified on the ground that the bonus withheld or clawed back will be small relative to the debt outstanding. However, it is not an essential assumption as the intuitions do not hinge upon it.

that is, he chooses the risky project even though it delivers lower total expected surplus than the safe alternative, although the risky project delivers a higher market capitalisation than the safe alternative.

Proof. See Technical Appendix. ■

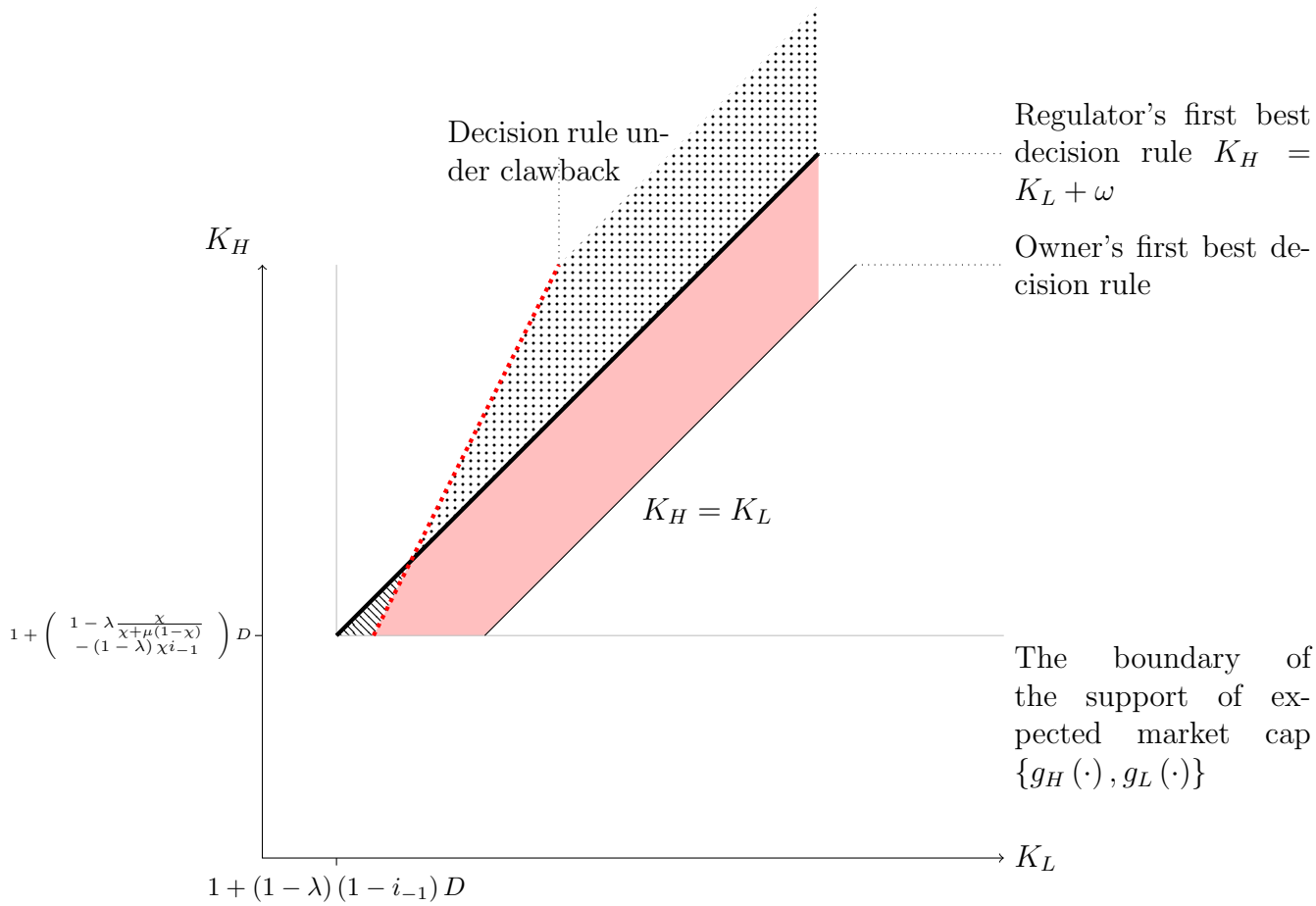

Figure 1: Bank executive's project selection regions under linear equity based pay. Notes: The project choice rules are depicted and labeled in the graph. The solid shaded region depicts project pairs for which the owner would rather the high volatility project is chosen, the regulator prefers the low volatility project to be chosen, and under the clawback regime the bank executive makes the regulator's prefered choice. The dotted area is the region in which the bank executive chooses the safe project which sacrifices both aggregate surplus and market value due to the clawback distortion (Proposition 3, part 1). The striped area is the region in which the bank executive is willing to sacrifice surplus in return for a higher bank market capitalisation by choosing the risky project (Proposition 3, part 2).

Figure 1 summarises these results graphically. The owner's first best project choice rule is to select the risky project if it generates a higher market capitalisation than is possible with the low volatility project. However, some of these gains are made through risk-shifting to taxpayers and to existing debt holders. Hence, the regulator requires a wedge in the decision rule: the high volatility project should only be selected if the resulting market capitalisation exceeds that generated from choosing the low volatility project by

a sufficient amount such that the project generates more surplus even in the absence of any risk-shifting. Under a clawback regime, the executive allows for the possibility that payment will be reduced in the case of a bank failure; and this can only arise if the high risk project is selected. The larger is the expected project value, the greater is pay, and so the greater the cash sum that is potentially exposed to clawback in the case of a subsequent bank default. Hence, the clawback intervention is increasingly distortive at higher project values, making the executive excessively incentivised to select the safe project. This is why the clawback regime rotates, rather than shifts, the project choice rule in Figure 1.

Proposition 3 and Figure 1 demonstrate that introducing a clawback regime yields both improvements and distortions in the executive's project choice rule. The executive's project choice rule (the heavy dotted line) is rotated towards the surplus maximising rule (the regulator's preferred rule given by the heavy solid line). However, this rotation implies that at high project expected values the executive chooses safe projects which sacrifice both aggregate surplus and owner surplus so as to avoid the threat of clawback. Thus, in general, the welfare implications of clawback are ambiguous. However, one unambiguous surplus result is available:

Proposition 4 *There always exist clawback parameters such that the introduction of a clawback regime increases the total expected surplus if the bank restricts itself to using equity based pay.*

Proof. See Technical Appendix. ■

From Figure 1 it is apparent that clawback causes the decision rule to move from (Owner FB) towards the regulator's preferred decision rule for all except choices between projects of high expected returns. The proof of the Proposition is driven by the fact that as the clawback parameter p shrinks, so that less pay is clawed back, the intersection between the clawback distorted boundary (heavy dotted line) and surplus maximising regulatory preferred rule (heavy solid line) is pushed out towards infinity. Hence, for small enough proportion of pay at risk of clawback, it must be the case that with arbitrarily high probability the project choice lies in the range where clawback is beneficial. This establishes that clawback parameters which increase surplus exist. There will be a whole range of such beneficial clawback parameters, and though the proof establishes the result for very mild clawback (p close to zero), the proof is silent on whether heavier clawback is beneficial or not.

4.2.2 Optimal contracting under clawback

We have seen that clawback can alter the project choice rule of the bank executive while the same does not follow for payment partly made in debt instruments. However, the

analysis of Section 4.2.1 assumes that the bank owner will continue to offer an equity-linked pay contract under which the executive's pay increases linearly with the bank's shareholder value. We now allow the bank owner to optimise the pay contract when facing a clawback rule. Our key result here is that the bank owner can unwind the effect of clawback; and under the realistic case in which the bank's balance sheet is greatly in excess of the bank executive's outside option, the bank owner can return the project choice rule to her first best (Owner FB). One way a bank can game the clawback regulation is by offering a pay schedule that is increasing and convex in the bank's shareholder value:

Proposition 5 *Suppose the regulator enforces the clawback regulation on compensation. If the ratio of the executive's outside option u to the bank's balance sheet $(1+D)$ tends to zero, then the bank owner can secure within ε of the maximum surplus even in the presence of clawback, through the use of a sufficiently curved compensation schedule. The owner's preferred project choice rule (Owner FB) is implemented.*

Proof. See Technical Appendix. ■

The proof of Proposition 5 is based on an analysis of remuneration schemes which are convex in shareholder value. To see why this works consider the following simplified example. Let us suppose the high volatility project has a 1/10 chance of failure (thus $\chi = 0.9$), and the regulator would prefer a low volatility project which creates $t = 1$ bank value of 90 to be selected over a high volatility project creating a $t = 1$ bank value of 100 (thus in (Reg'r FB) $\omega = 10$). Under an equity based compensation rule when the bank and executive are equally patient this can be achieved if the regulator sets $p = 1$. This follows as if the executive selects the low volatility project her pay is $s(K) = bK = 90b$, while the high volatility project yields a payment of the same value as $[(1-\delta(1-\chi)p)\,s(K)]_{\delta=p=1} = (9/10)\,100b = 90b$.

However, the bank owner can restructure the compensation schedule to undo these effects of the clawback rule. The proof of Proposition 5 identifies one way in which this can be done. Suppose the principal wishes the agent to select a low volatility project only if it is worth at least 95 against a high volatility project worth 100. To achieve this suppose that the principal changes the remuneration schedule to $s(K) = \tilde{b}K^{\beta}$ for some new constants $\tilde{b}$ and β. If the agent selects the high volatility project she now gets paid,

$$\tilde{b} \cdot 100^{\beta} \cdot \left(1 - \frac{1}{10}\right);$$

whereas selecting a low volatility project generating market value 95 yields

$$\tilde{b} \cdot 95^{\beta}.$$

Simple calculations yield that the high volatility project will be selected over the low volatility one if

$$\beta > \frac{\ln(10/9)}{\ln(100/95)} \approx 2.05. \tag{9}$$

By increasing the curvature (β) further, the decision rule can be pushed closer to (Owner FB). Finally note that the scaling parameter $\tilde{b}$ is free so the level of the payments can be adjusted to keep expected pay unchanged.

Intuitively, we see that clawback is designed to create a wedge whereby the bank executive only selects the high risk project if it generates a market value sufficiently in excess of that available from the low risk project. The wedge is induced by threatening to claw back some pay from the bank executive with some probability, conditional on the high risk project being chosen. Thus, even if the high risk project would dominate the low risk one for the bank owner, it need not for the bank executive in the presence of a clawback rule. But the bank owner can counter this effect of the clawback rule by having the executive's pay rise sufficiently rapidly in the bank's market capitalisation. The faster this rate of increase, that is the more convex the remuneration scheme, the closer the bank executive's preferences move to the bank owner's despite clawback. Further, as what matters here is the comparison of one project choice to another, the absolute level of pay is not directly relevant. Thus, pay levels can be scaled down whilst increasing pay curvature to ensure that the convex remuneration scheme does not cost the bank owner any more (in expected terms) than the linear scheme.

Proposition 5 implies that, while the clawback rule has the effect of mitigating the executive's excessive risk-taking incentives if his pay remains linearly increasing in equity value, the efficacy of the rule will be diminished if the bank owner can re-optimise the pay contract to game the pay regulation. One way the bank owner can circumvent clawback is to make the executive's pay more convex in response. Convex pay arrangements are not difficult to create: stock options, which are widely used in practice, can deliver such structure to compensation. Thus, clawback implemented on its own is unlikely to be effective in dealing with the too-big-to-fail distortion.

4.2.3 Regulator Optimal Implementation of Clawback

It follows that, in order to ensure that clawback rules can mitigate excessive risk-taking incentives, the regulator has to at least control the curvature of the pay schedule. In fact, the following addendum to the clawback pay regulation can realign the bank executive's project choice rule with the regulator's preference (Reg'r FB).

Addendum to Clawback Pay Regulation In addition to the clawback pay regulation (page 15 above), the regulator requires a restriction on the executive's pay function

$s(K)$, such that:

$$\frac{s\left(K+\omega\right)}{s\left(K\right)} \leq \gamma \tag{10}$$

for given parameters ω and γ, at all market capitalisations K.

The addendum to the pay regulation is equivalent to a restriction on the curvature of the executive's pay function. We will discuss the policy implications and how this can be implemented in Section 5. This addition to the clawback rule can result in the bank owner offering a pay contract which induces the executive to implement society's first best project choice rule, (Reg'r FB). To achieve this, the regulator needs to set:

$$\begin{aligned} \text{From (Reg'r FB): } \omega &= \lambda D \frac{\mu\left(1-\chi\right)}{\chi+\mu\left(1-\chi\right)} + \left(1-\lambda\right) D \left(1-\chi\right) i_{-1} \\ \text{and } \gamma &= 1/\left(1-\delta\left(1-\chi\right)p\right) \end{aligned} \tag{11}$$

Proposition 6 *Suppose the curvature addendum to the clawback pay regulation (10) applies with the curvature parameters set by (11). In the limit of the ratio of the bank executive's outside option u to total bank balance sheet value $(1+D)$ tending to zero, the bank owner will incentivise society's first best project choice rule, (Reg'r FB).*

Proof. See Technical Appendix. ■

The intuition for Proposition 6 proceeds in two steps as follows. The first insight is that the curvature restriction applied by the regulator (10), combined with parameters γ and ω set according to (11), creates a lower bound on how far the bank executive's project choice boundary can be pushed towards the bank owner's preferred point, and this lower bound coincides with the regulator's preferred project choice rule (Reg'r FB). This is shown in the proof by contradiction. Let us suppose the bank owner seeks a compensation function which has the effect of incentivising the bank executive to choose a risky project which would deliver a market value of $\tilde{K}_H$ over a safe project which would deliver a market value of $\tilde{K}_L$, even though the regulator would rank these differently. One can show that any such compensation function must violate the curvature restriction for pay awarded given bank market capitalisations in the range $[\tilde{K}_L, \tilde{K}_L+\omega]$, and so fails to satisfy regulatory requirements.

The second step is to observe that the optimal contract for the bank owner is one which pushes the bank executive's project choice as close to the lower bound created by the curvature restriction as possible; and so incentivises a project choice rule which coincides with the regulator's preferred project choice rule (Reg'r FB). Such a remuneration function would maximise profit as it is not possible for the project choice boundary to move any further towards the owner's first best rule (Owner FB). There may be multiple ways this can be accomplished; the proof demonstrates that there exists at least one remuneration function which delivers the most profitable project choice rule permitted by the

curvature restriction. This is the most convex compensation contract which satisfies the regulator's constraints (10) and (11). Finally, once again the shape of the contract is key rather than the level of pay and so the expected remuneration can be kept in line with the outside option. Thus, in the limit of the bank balance sheet being larger than the outside option of the bank executive, the bank owner can get arbitrarily close to implementing the regulator's preferred project choice rule, and doing so maximises her profit.

Thus, any clawback level $p > 0$ can deliver society's first best project choice, if it is accompanied by an appropriate restriction on pay curvature. Inspection of the required parameters (11) demonstrates that the appropriate curvature restriction is specific to both the bank and the executive. The probability of default, probability of government bailout, interest rate on long-term funding and bank leverage are required to set the parameter ω optimally; the probability of clawback being applied and the discount factor of the bank executive are required to set the parameter γ optimally.

The relevance of the curvature restriction on pay adds an important insight into the current understanding of the optimal use of remuneration to control risk-shifting. An important reference here, noted above, is Hakenes and Schnabel (2014). Analogously to Hakenes and Schnabel (2014), we study a setting in which the bank owner wants to induce the executive to take more risks than socially optimal, in order to profit from the too-big-to-fail guarantee. The model of Hakenes and Schnabel (2014) has three possible bank value realisations, and the executive's pay is positive only if the highest of these occurs. Hakenes and Schnabel (2014) show that societal outcomes can be improved if the pay in this event is bounded above by the regulator. The policy inference one might make from this result could be that bankers' pay should be capped; or that it should not rise too fast in bank value; or that it should not be too curved in bank value. It is not possible to distinguish these conclusions in the Hakenes and Schnabel framework. Our work deepens analysis of the risk-shifting problem by studying a continuous setting in which projects of any real return may exist. In this setting, we have shown that a positive slope in pay will align the interests of the bank executive with those of the bank owner, but not with those of society (Proposition 1), thus a flatter pay policy proposal is not appropriate. A regulator might seek to counter the risk-shifting with clawback, but this effect can be undermined if bank owners can make the executive pay more convex in market capitalisation (Proposition 5). Our analysis implies that an appropriate way to understand the literature generated by Hakenes and Schnabel (2014) and our work is that a curvature restriction combined with clawback can be used to deter excessive risk shifting (Proposition 6). We turn to the efficacy of bonus caps, including the implications of stopping bonuses entirely, next.

4.2.4 Clawback and Bonus Caps

The European Union is the first major jurisdiction to introduce a mandatory bonus cap on all material risk takers of banks and investment banks as part of financial regulation. Material risk takers can normally only receive variable pay up to a limit of 100% of their fixed salary.[13] It is tempting, in the light of the insights underlying Propositions 5 and 6, to observe that bonus caps will also place a limit on the curvature of compensation as the pay must level off once the cap is reached. Hence, one might suspect that bonus caps can help clawback to be effective.

We don't dissent from this as after the cap is reached curvature of pay is clearly controlled; but we note that nonetheless the effect of bonus caps might be weak in preventing the circumvention of clawback. To see why, note that it is likely that the bank owner can anticipate a bounded range of possible project values the executive will likely have a choice over with a high degree of certainty. The bonus can then be concentrated around this range generating highly convex remuneration schedules over this bounded range. These would in turn deliver the owner's preferred project choice rule over this given bounded range of project values. Hence, in general, the bonus cap does not prevent the bank owner from significantly undermining the incentive effect of the clawback rule.

In the context of our model, the bank owners would be unable to incentivise the bank executive to choose particular projects if pay had to be a fixed amount; that is all financial reward was independent of the value of the bank and so bonuses were restricted to being zero. In this setting the bank executive would be indifferent as to which project he picked; and a socially minded executive might well pick projects which a regulator would prefer. It is equally possible, however, that a bank executive would resolve indifference by picking projects which would be preferred by the bank owners rather than the regulator. Hence a flat pay proposal would offer little certainty that the too-big-to-fail distortion is corrected.

4.3 Linking Compensation to Interest Rates

Clawback is one tool at a regulator's disposal which can have the effect of reducing the expected payoff of the bank executive from selecting the high risk project. Note that there is a second possible approach for curbing bank executives' risk-taking incentives within the context of our model, as the regulator observes the interest rate payable on debt. Hence, in principle, the regulator could seek to alter the bank executive's project choice by requiring the executive's pay to decline if the interest rate the bank pays rises. A higher interest rate signifies that the bank executive has selected the risky rather than the safe project. In reality of course, if this avenue were promising, other proxies for the interest rate, such as the premia on credit default swaps, could be used. This section will

[13] See DIRECTIVE 2013/36/EU Article 92(g)(i). If preceded by an authorising vote at an AGM, the bonus cap can be raised to 200% of the fixed pay.

show that using interest rates can indeed deliver the regulator's first best project choice, and a restriction on the curvature of pay is again required to prevent the bank owner from circumventing the regulatory intervention.

Consider first a simple regulatory pay rule which requires compensation to be linked to the bank's interest rate:

Interest Linkage Pay Regulation: The remuneration package must be decreasing in the interest rate i_1 such that if $i_1 > 1$,

$$s(K, i_1) \leq \eta \cdot s(K, 1) \tag{12}$$

for some $\eta < 1$ and for all K.

The rationale for a rule such as (12) is that a higher market interest rate i_1 signifies that private sector creditors are bearing more risk. As this risk is understated because of the too-big-to-fail guarantee, the regulator can discourage the executive from selecting such projects by forcing a reduction in the pay which can be received in this case. However, analogously to Proposition 5 we have an irrelevance result:

Proposition 7 *Suppose the regulator enforces the interest linkage regulation on compensation. If the ratio of the executive's outside option u to the bank's total balance sheet value $(1 + D)$ tends to zero, then the owner can secure within ε of the maximum surplus even in the presence of the regulation. The owner's preferred project choice rule (Owner FB) is implemented.*

Proof. See Technical Appendix. ■

The intuition underlying Proposition 7 can be explored using the simple example discussed in Section 4.2.2. In that example, we assumed that the high volatility project had a 1/10 chance of failure and that the regulator's preference was that a low volatility project delivering a $t = 1$ bank value of 90 should be chosen over a high volatility project creating a $t = 1$ bank value of 100. We noted that if the bank did not optimise and restricted itself to equity based pay, then this choice could be delivered by clawing back 100% of pay in the event of bank failure $(p = 1)$.

The interest linkage regulation on compensation offers a second approach: should $t = 1$ interest rates be at the level consistent with the high risk project $(i_1 > 1)$, the pay formula should be reduced to 90% of what it otherwise would be: that is $\eta := 0.9$. Thus, if the bank restricted itself to the equity based formula, $s(K) = bK$, then a low volatility project delivering value 90 would yield pay $s(90) = 90b$; while the high volatility project delivering value 100 would also raise interest rates so that pay would be bounded above by $\eta s(100) = 0.9 \times 100b = 90b$. Thus the regulator's preference for the low volatility project would seemingly be delivered.

However, once again suppose the bank decided to optimise by altering the remuneration schedule to $s(K) = \tilde{b}K^{\beta}$ for some $\beta > 2.05$ (using equation (9)) and some constant $\tilde{b}$. Now the low volatility project delivering value 90 would yield pay $s(90) = \tilde{b} \times 90^{\beta}$; the high volatility project would be bounded above by $\eta s(100) = 0.9 \times \tilde{b} \times 100^{\beta}$ which is more attractive to the bank executive. Hence the regulator's preference is thwarted within the interest rate linkage rule.

To deliver the regulator's preferred project choice (Reg'r FB), a curvature restriction on pay is required, analogously to the clawback case.

Addendum to Interest Linkage Pay Regulation: The regulator adds to the pay regulation (12) the requirement that the curvature of the bank executive's pay function must satisfy

$$\frac{s(K+\omega, 1)}{s(K, 1)} \leq \frac{1}{\eta}. \tag{13}$$

for given parameter ω and at all market capitalisations K.

This regulation can result in the bank owner implementing society's first best project choice rule. To achieve this the regulator must use η from the regulatory rule (12) and set ω as in (Reg'r FB):

$$\omega = \lambda D \frac{\mu(1-\chi)}{\chi + \mu(1-\chi)} + (1-\lambda) D (1-\chi) i_{-1}. \tag{14}$$

Proposition 8 *Suppose the curvature addendum to the interest linkage regulation on compensation applies. In the limit of the ratio of the bank executive's outside option u to total bank balance sheet value $(1+D)$ tending to zero, the bank owner will incentivise society's first best project choice rule, (Reg'r FB).*

The intuition behind Proposition 8 follows that of Proposition 6. Using curvature in pay, the bank owner can ensure that increases in the market value of the bank achieved through risk-taking remain sufficiently valuable to the bank executive that they outweigh the reduction in pay mandated by the interest linkage pay regulation. Without a pay curvature restriction the bank could entirely undo the effect of the interest linkage pay regulation. The curvature restriction places a bound on how far the bank executive's decision rule can be pushed back towards the bank owner's preferred point by any remuneration function. By choosing the parameters of the curvature restriction according to (14) the best that the bank owner can hope to do from any remuneration function satisfying the pay curvature restriction is to deliver the regulator's optimal project choice. Analogously to the proof of Proposition 6 there is at least one remuneration function which allows the bank owner to achieve this bound.

We can extend our simple worked example to illustrate this effect. Continue to assume that the high volatility project has a 1/10 chance of failure and that the regulator's

preference is that a low volatility project delivering a $t = 1$ bank value of 90 should be chosen over a high volatility project creating a $t = 1$ bank value of 100. Thus $\omega = 10$, as the regulator's preference is that the high volatility project should be chosen only if $K_H > K_L + 10$. To deliver this decision rule with equity linked pay, a regulator would set the pay regulation and curvature restriction, (12) and (13), to have $\eta = 9/10$.

Satisfying the curvature restriction is not trivial, a linear scheme $s(K) = bK$ fails for small market values K. This is not a surprise given Proposition 3 and Figure 1 as it was for small values of K that the executive's decision rule was below (Reg'r FB), implying that the executive remained too incentivised to select risky projects. Given the regulatory restriction, suppose that the bank owner designs the compensation function:

$$s\left(K,1\right) = b_n \left(1 - \frac{(K/10)\ln 0.9}{n}\right)^n \text{ for } n > 1 \text{ and constant } b_n. \tag{15}$$

This family of pay schedules becomes more curved as n increases. Algebraic manipulation confirms that this remuneration function satisfies the curvature restriction (13) at all $n > 1$ and all $K > 0$.[14] When incentivised with this remuneration function plus the reduction in pay when $i_1 > 1$, the bank executive would select the high volatility project if:

$$\begin{aligned} 0.9s\left(K_H\right) &> s\left(K_L\right) \\ &\iff K_H > \frac{1}{0.9^{1/n}}K_L + \frac{10n}{-\ln 0.9}\left(\frac{1}{0.9^{1/n}} - 1\right) \end{aligned}$$

We plot this decision rule in Figure 2 for $n \in \{1, 2, 5\}$ along with (Reg'r FB) and (Owner FB). It is clear from the figure that as n grows the decision rule approaches the regulatory first best, and allows the project choice rule to move in the direction the bank owner would prefer. In the limit as $n \to \infty$ the pay function tends to the one demonstrated to be optimal in the proof of Proposition 8; namely:

$$\lim_{n\to\infty} b_n \left(1 - \frac{(K/10)\ln 0.9}{n}\right)^n = b_\infty \frac{1}{0.9^{K/10}}. \tag{16}$$

Thus, both clawback and linking pay to the bank's interest rate can be used to deliver society's first best project choice if accompanied by appropriate restrictions on pay curvature. In the limit of the ratio of the bank executive's outside option u to total bank balance sheet value $(1 + D)$ tending to zero, these two interventions are equivalent. They both induce the same project selection rule, which coincides with society's first best. However, they are not equivalent in practice as they differ in their timing and informational requirements. We discuss these policy relevant issues next.

[14] Given (15) $\frac{s(K+\omega,1)}{s(K,1)} = \left(1 + \frac{(1/n)\ln 1/\eta}{1+(K/\omega)(1/n)\ln 1/\eta}\right)^n \leq \left(1 + (1/n)\ln 1/\eta\right)^n \leq 1/\eta$. The final inequality follows as we know $1 + \ln x \leq x$ for $x > 0$.

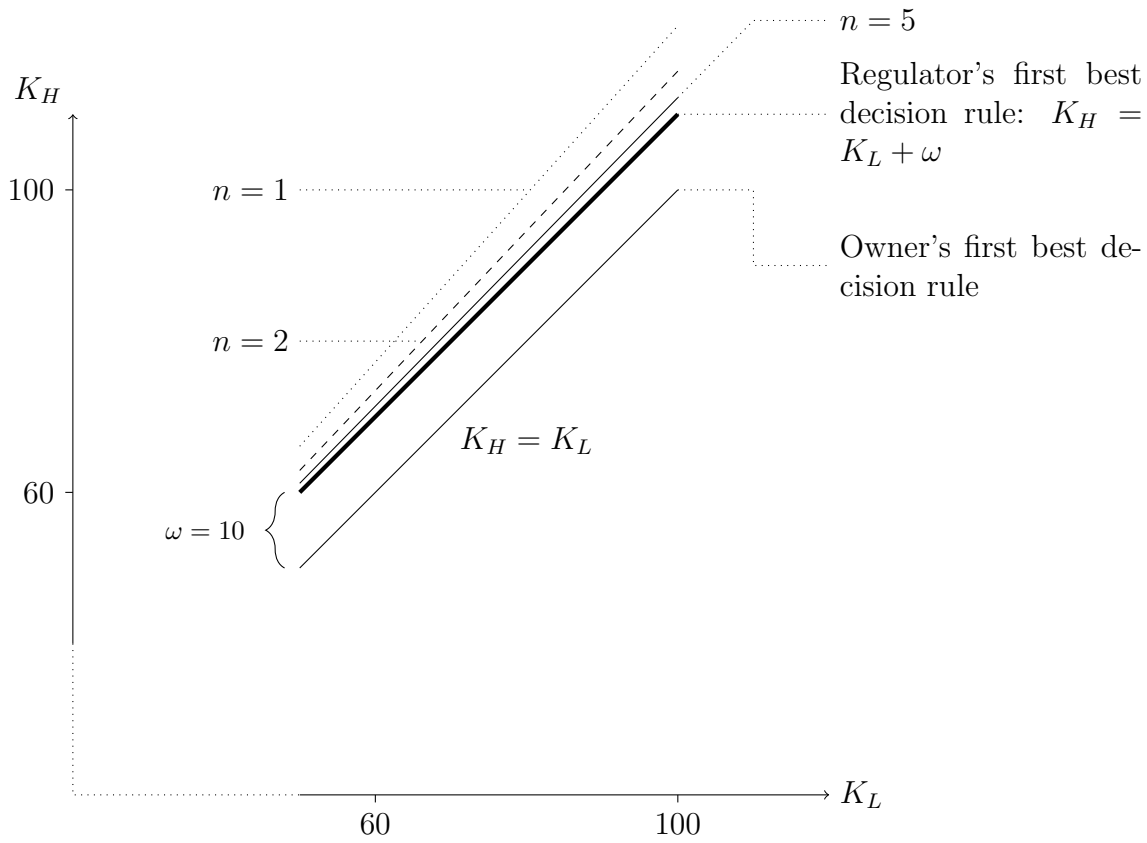

Figure 2: Bank executive's project selection boundary under interest linkage regulation on compensation with pay given by (15).

Notes: The compensation function (15) for given n would result in the bank executive choosing the high volatility project if it generates market value above the boundary line depicted. As the parameter n grows, the bank executive's choice approaches the regulator's preferred decision rule, but can never go below it due to the curvature restriction on pay. The optimising bank owner would select the most profitable remuneration schedule which results in society's first best decision rule being implemented (Proposition 8).

5 Model Implications

Our analysis has an important implication for remuneration regulations that, to our knowledge, has not been previously recognised: that is, the risk-mitigating effects of remuneration regulations could be undermined fairly easily if bank owners can make pay both increasing and convex in the bank's equity value in order to reward risk-taking. The pay schedule can be made convex most obviously through a schedule of equity-linked bonus payments and via stock options, but also through promotions which reward risk-takers by increasing their base pay. Our analysis above suggests that convex pay could be used to circumvent a range of pay regulations, including malus and clawback, and regulations linking pay to the interest rate on debt; and that convex pay can also limit the effectiveness of bonus caps.

We have demonstrated that, in theory, the regulator could close this 'loophole' by imposing restrictions on pay curvature. Implementing curvature restrictions in practice,

however, requires the regulator to observe the full pay schedule, i.e. how individual bank executives will be paid under different outcomes for market valuation. This is the function $s(K)$ in our model. In addition, the regulator has to be able to control the instruments used to generate the pay curvature. Restricting some methods of achieving pay convexity, such as schedules of bonus payouts and stock options, may be practicable. However, other methods of generating curvature, such as via a promotion policy designed to favour risk takers, might be difficult to regulate in practice. Without closing these loopholes, pay regulations are unlikely to be effective in achieving their stated aims of mitigating excessive risk-taking.

As we noted above, clawing back money already paid to an individual may be problematic: he/she may have already spent it or may decline to return it. Pay could instead be held back by the bank for a specific period. Withdrawing deferred pay is referred to as malus, and is easier to implement. However, this may not be practical if the deferral period is long. Linking pay to interest rates avoids this problem as the interest rate provides a real-time signal of the risk being taken and so can be used to scale down the amount paid as a function of this risk. A disadvantage of this approach is that, in practice, a bank pays multiple interest rates, and these are volatile. In principle, the premia on credit default swaps may be used.[15] However, the credit default swap market can be illiquid and so the implied probabilities of default may not be accurate at critical times. Bank debt is traded in a liquid market, but if the interest rate is volatile then a risk-averse bank executive would discount the value of such pay arrangements and so some surplus will be lost in the implementation as pay levels are forced to rise.

There are other factors that undermine the effectiveness of pay regulations which we have not considered in our model. Most importantly, long-serving bank executives are likely to have a large exposure to the bank's shares through the existing holding of stock. If so, the incentive to maximise the share price by risk-shifting on to the taxpayer may be so great that reasonable restrictions on bonus pay have only a limited effect on behaviour. These considerations underscore the importance of minimising the too-big-to-fail distortion as much as possible directly, for example by establishing a credible resolution framework which enables banks to fail without causing a systemic crisis, and by making the deposit insurance premiums fully risk-sensitive.

There are a number of possible ways in which our theory could be tested. First, it may be possible to empirically exploit the fact that the application of clawback pay regulations differs across jurisdictions: with London invoking the practice and Hong Kong less so. One can compare trading desks based in these two jurisdictions which differ in the pay regulations but for whom the universe of investment projects is not materially different. In the short-run, before pay functions adapt to clawback, our analysis predicts that both risk and return should be reduced on average in the clawback-using jurisdiction.

[15] Others have identified these as promising: Bolton et al. (2015) for example.

In the longer-run our analysis predicts that the risk and return characteristics should re-converge across jurisdictions, but pay arrangements in the clawback-using jurisdiction should become more convex. Secondly, it may be possible to test the theory through a lab experiment in order to examine whether convex pay can indeed incentivise risk-taking even in the presence of clawbacks and bonus caps.

6 Conclusions

The interests of banks' shareholders and the regulator diverge in the presence of the too-big-to-fail effect. In this case, a compensation contract offered to the bank executive to maximise shareholder returns leads to socially excessive risk choices. Our anlaysis points to two main ways of correcting for the too-big-to-fail distortion. The first is to impose malus and clawback to ensure that the bank executives suffer a financial penalty when the bank fails, regardless of whether its creditors are bailed out or not. The second is to link the bank executive's pay to the interest rate on debt, whereby pay is reduced when the interest rate is high. Importantly, however, we demonstrate that neither of these will help curtail risk-taking incentives unless the regulator can also impose restrictions on pay curvature. Without restrictions on pay curvature, bank owners can undermine the impact of pay regulations by offering a pay package which is highly convex in equity value, and thus restore the executive's risk-taking incentives.

Our analysis suggests that passive remuneration regulation alone is unlikely to effectively mitigate bank managers' risk-taking incentives. To be effective, pay regulations would need to be complemented by active monitoring of gaming of remuneration regulation, for example through additional data collection on pay schedules. Regulators will therefore need to determine whether such restrictions are both feasible and cost-effective, in order to evaluate the desirability of pay regulations. Our analysis also underscores the importance of policy efforts to end the too-big-to-fail problem by, for example, establishing a credible resolution regime which can manage the impact of bank failure and so reduce the opportunity to risk-shift on to the taxpayer.

A Technical Appendix

Proof of Proposition 1. Suppose that the bank owner offers an equity-linked remuneration contract $s(K) = bK$, where K is the $t = 1$ market value of the bank. The agent secures remuneration of $b \cdot K_L(r)$ if he selects the low volatility project, and $b \cdot K_H(Z)$ if he selects the high volatility project. If $b > 0$, his decision rule is to choose the high volatility project if his pay is maximised, and this coincides with (Owner FB). This is therefore a Nash equilibrium of the $t = 0$ subgame. As the level of debt D is exogenous there is no strategic decision for the bank to make at $t = -1$ and so we have Nash equilibrium.

Calculating the executive's expected payment under the project choice rule (Owner FB) yields his participation constraint: $b\mathcal{S}^{FB}(\mu, i_{-1}) \geq u$, where $\mathcal{S}^{FB}(\mu, i_{-1})$ is the maximum expected profit which the bank owner can secure, gross of any payments to the bank executive. The bank owner can maximise her payoff by lowering b sufficiently to just satisfy the above participation constraint with equality:

$$b = \frac{u}{\mathcal{S}^{FB}(\mu, i_{-1})}. \tag{17}$$

The surplus accruing to the bank owner in this case is $(1-b)\,\mathcal{S}^{FB}(\mu, i_{-1}) = \mathcal{S}^{FB}(\mu, i_{-1}) - u$. As this coincides with the maximum available surplus, the contract is optimal. ■

Proof of Proposition 2. Consider a strictly increasing pay function $s(K)$, of which a fraction $(1-c)$ is paid out in cash at $t=1$ and the remaining fraction c is used to buy the bank's debt at $t=1$ and which pays out only at $t=2$. If the executive chooses the high volatility project, the expected return on the debt in his remuneration will be $(\chi + (1-\chi)\mu)i_1 = 1$. This follows from (4). Thus, the $t=1$ expected value of the bank executive's remuneration will be $(1-c)\,s(K_H) + \delta c s(K_H)(\chi + (1-\chi)\mu)i_1 = (1-c+c\delta)\,s(K_H)$. By contrast, if he chooses the low volatility project, the debt will pay a certain return equal to 1 at $t=2$, so his payoff will be $(1-c+c\delta)\,s(K_L)$. Hence, the high volatility project is chosen if and only if $(1-c+c\delta)\,s(K_H) > (1-c+c\delta)\,s(K_L) \Leftrightarrow s(K_H) > s(K_L) \Leftrightarrow K_H > K_L$.The first if and only if follows as $1-c+c\delta > 0$ and the second as $s'(K) > 0$. This proves Result 1.

To derive Result 2, we note that if $s(K) = bK$ which is strictly increasing, then the executive will follow the project decision rule (Owner FB). The bank executive is maximising the bank's value, gross of remuneration costs. The executive's participation requires $(1-c+c\delta)\,b\mathcal{S}^{FB}(\mu, i_{-1}) \geq u$, with $\mathcal{S}^{FB}(\mu, i_{-1})$ defined in the proof of Proposition 1. Profit maximisation requires the bank owner to lower the bonus such that

$$b = \frac{u}{(1-c+c\delta)\,\mathcal{S}^{FB}(\mu, i_{-1})} \tag{18}$$

Given the above contract, the owner's profit, net of the payment to the executive, is given by:

$$\Pi = (1-b)\,\mathcal{S}^{FB}(\mu, i_{-1}) = \mathcal{S}^{FB}(\mu, i_{-1}) - \frac{u}{(1-c+c\delta)}$$

Now $\lim_{u\to 0}\Pi = \mathcal{S}^{FB}(\mu, i_{-1})$. This proves Result 2. ■

Proof of Proposition 3. Suppose that the executive receives equity linked pay $s(K) = bK$ for some b. The executive's expected $t=1$ pay if he selects a high volatility project is $(1-\delta(1-\chi)p)\,bK_H$. It is bK_L if he selects the low volatility project. Thus, the executive's decision rule is to select the high volatility project if $(1-\delta(1-\chi)p)\,K_H >$

K_L. This rule is independent of b and so is invariant within the class of equity linked compensation schemes.

Recall that the regulator's first best project choice is given by (Reg'r FB). Note that (Reg'r FB) implies (6). It follows that if the regulator would rather the high risk project were chosen, then so would the bank owner. Part 1 therefore follows if there exists a pair (K_H, K_L) such that the regulator would rather the risky project be chosen, but under clawback the safe project is chosen. This is possible if

$$\frac{K_L}{1-\delta(1-\chi)p} > K_H > K_L + \lambda D \frac{\mu(1-\chi)}{\chi+\mu(1-\chi)} + (1-\lambda)(1-\chi) D i_{-1}.$$

This range is non-empty if K_L is sufficiently large, yielding the first result.

Part 2 follows if there exists a pair (K_H, K_L) such that the regulator would rather the safe project was chosen, but despite clawback the bank executive would choose the risky project. This is possible if

$$K_L + \lambda D \frac{\mu(1-\chi)}{\chi+\mu(1-\chi)} + (1-\lambda)(1-\chi) D i_{-1} > K_H > \frac{K_L}{1-\delta(1-\chi)p} \tag{19}$$

To show this range is non-empty set K_L and K_H equal to the lower bounds of their support using (7) and (8). At these values the first inequality is satisfied with equality. Suppose the second is satisfied with strict inequality, then by increasing K_L slightly and arguing by continuity we have that there exists a range of K_L values satisfying (19). It therefore remains to show that

$$\begin{aligned} K_H^{\min} &> \frac{K_L^{\min}}{1-\delta(1-\chi)p} \\ &\Leftrightarrow 1 + \left(1 - \lambda \frac{\chi}{\chi+\mu(1-\chi)} - (1-\lambda)\chi i_{-1}\right) D > \frac{1}{1-\delta(1-\chi)p}\left[1 + (1-\lambda)(1-i_{-1}) D\right] \end{aligned}$$

Letting $\lambda \to 1$ we require

$$1 + \left(1 - \frac{\chi}{\chi+\mu(1-\chi)}\right) D > \frac{1}{1-\delta(1-\chi)p}$$

which is true if D is large enough giving the result. ■

Proof of Proposition 4. Under a clawback regime with parameter p, if the bank restricts to equity based pay then Proposition 3 proved that the executive's decision rule becomes select the high volatility project if $(1-\delta(1-\chi)p) K_H > K_L$. Returning to (r, Z) space using (3) and (5), this decision rule to select the high volatility project is

$$(1-\delta(1-\chi)p)\left[(1+D)Z - \frac{\lambda D \chi}{\chi+\mu(1-\chi)} - (1-\lambda)\chi D i_{-1}\right] > (1+D) r - \lambda D - (1-\lambda) D i_{-1}$$

This is linear in (r, Z) space. This can be written as $r < \alpha(p) Z + \beta(p)$ with $\beta(p) > 0$. Explicitly we have

$$\begin{aligned}
\alpha(p) &= 1 - \delta(1-\chi) p \\
\beta(p) &= \lambda \frac{D}{(1+D)} \left[1 - \frac{\chi(1-\delta(1-\chi)p)}{\chi + \mu(1-\chi)} \right] + (1-\lambda) \frac{D}{(1+D)} i_{-1} \left[1 - \chi(1-\delta(1-\chi)p) \right]
\end{aligned}$$

Note that if $r = Z = 1$ the high volatility project is selected for small p. The total expected surplus generated under a clawback rule for small p is therefore

$$W(p) = \int_{Z=1}^{\infty} \left(\int_{r=1}^{\alpha(p)Z+\beta(p)} Z f_L(r)\, dr + \int_{r=\alpha(p)Z+\beta(p)}^{\infty} r f_L(r)\, dr \right) f_H(Z)\, dZ$$

We can therefore establish what the impact is of a small amount of clawback on the total surplus created:

$$W'(0) = \int_{Z=1}^{\infty} (Z - \alpha(0) Z - \beta(0)) (\alpha'(0) Z + \beta'(0)) f_L(\alpha(0) Z + \beta(0)) f_H(Z)\, dZ$$

Now note that $\alpha(0) = 1$ implying that $Z - \alpha(0) Z - \beta(0) < 0$. Next note that $\alpha'(p) < 0 < \beta'(p)$ and so as $Z \geq 1$ we have

$$\begin{aligned}
\alpha'(0) Z + \beta'(0) \leq \alpha'(0) + \beta'(0) &= \delta(1-\chi) \left[\begin{array}{c} \lambda \left(-1 + \frac{D}{(1+D)} \frac{\chi}{\chi+\mu(1-\chi)} \right) \\ + (1-\lambda) \left(-1 + \frac{D}{(1+D)} i_{-1} \chi \right) \end{array} \right] \\
&< 0
\end{aligned}$$

The final inequality follows as $i_{-1} < i_1$ as the interest rate on legacy debt will take into account the possibility that the low volatility project may subsequently be selected. Hence $W'(0) > 0$ giving the required result. ■

Proof of Proposition 5. Consider a remuneration scheme of the form $s(K) = bK^{\beta}$ with $\beta \geq 1$ a constant. The executive's expected payoff if he selects a high volatility project is $(1 - \delta(1-\chi) p) bK_H^{\beta}$, and bK_L^{β} if he selects the low volatility project. Thus, the executive's decision rule, given the compensation scheme and the clawback rule, is to select the high volatility project if $(1 - \delta(1-\chi) p) bK_H^{\beta} > bK_L^{\beta}$, which can be reorganised as:

$$K_H > (1 - \delta(1-\chi) p)^{-1/\beta} K_L. \tag{20}$$

Using this remuneration scheme to incentivise the executive implies the bank's expected value gross of payments to the executive is given by:

$$\begin{aligned}
S^{\text{claw}} \triangleq \; & \int_{K=0}^{\infty} G_L \left((1 - \delta(1-\chi) p)^{1/\beta} K \right) K dG_H(K) \\
& + \int_{K=0}^{\infty} G_H \left((1 - \delta(1-\chi) p)^{-1/\beta} K \right) K dG_L(K)
\end{aligned}$$

Now note that the decision rule (20) tends to (Owner FB) as $\beta \to \infty$. Hence $\lim_{\beta\to\infty} S^{\text{claw}} = \mathcal{S}^{FB}(\mu, i_{-1})$, where $\mathcal{S}^{FB}(\mu, i_{-1})$ is the expected shareholder value under the bank owner's first best project choice rule (Owner FB).

To complete the proof we must show that in the limit of $\beta \to \infty$ the bank executive's remuneration does not become unbounded. The executive values the $t = 0$ expected wage under this decision rule as bT^{claw} where

$$T^{\text{claw}} \triangleq \begin{array}{l} \int_{K=0}^{\infty} G_L\left((1-\delta(1-\chi)p)^{1/\beta} K\right)(1-\delta(1-\chi)p) K^{\beta} dG_H(K) \\ \quad + \int_{K=0}^{\infty} G_H\left((1-\delta(1-\chi)p)^{-1/\beta} K\right) K^{\beta} dG_L(K) \end{array}$$

The executive's participation constraint, given the decision rule (20), is given by:

$$bT^{claw} \geq u \tag{21}$$

The bank owner optimally sets b to make the executive's participation constraint (21) binding, so that

$$b = \frac{u}{T^{\text{claw}}} \tag{22}$$

For the owner, the expected cost of compensating the executive is larger than bT^{claw} as the executive discounts funds which are clawed back, whilst these still represent a loss for the bank. Denoting the expected remuneration paid by the bank as $\mathcal{R}^{\text{claw}}$, we have:

$$\begin{aligned} \mathcal{R}^{\text{claw}} &= b \cdot \left[\begin{array}{c} \int_{K=0}^{\infty} G_L\left((1-\delta(1-\chi)p)^{1/\beta} K\right) K^{\beta} dG_H(K) \\ + \int_{K=0}^{\infty} G_H\left((1-\delta(1-\chi)p)^{-1/\beta} K\right) K^{\beta} dG_L(K) \end{array} \right] \\ &< b \cdot T^{\text{claw}} / (1-\delta(1-\chi)p) \\ &= u / (1-\delta(1-\chi)p) \end{aligned}$$

where we have used (22). We therefore have that remuneration is bounded above by a function proportional to u. Hence letting $u \to 0$ yields both results. ■

Proof of Proposition 6. Given a remuneration scheme, $s(K)$, the clawback rule leads to a project choice boundary function $K_H = K_L + d(K_L)$ where $d(\cdot)$ is given implicitly by $s(K + d(K))(1-\delta(1-\chi)p) = s(K)$. The executive will select the high volatility project only for $K_H > K_L + d(K_L)$.

Now we show that the boundary $K_H = K_L + d(K_L)$ cannot lie anywhere below the regulator's first best, (Reg'r FB) in (K_L, K_H) space. Suppose otherwise, then as $s'(K) \geq 0$ there exists a safe project K such that:

$$s\left(K + \lambda D \frac{\mu(1-\chi)}{\chi + \mu(1-\chi)} + (1-\lambda)(1-\chi) D i_{-1}\right)(1-\delta(1-\chi)p) > s(K)$$

This is a contradiction to the regulator's rule (10) given the parameters (11).

Next note that, ignoring the costs of incentivising the agent, the most profitable to the bank owner project boundary $d(K)$ above the regulator's preferred boundary (Reg'r FB) coincides with (Reg'r FB); any other boundary sacrifices high value projects for lower value projects. Hence, if the owner could incentivise (Reg'r FB) for cost u, she would have maximised her surplus given the regulatory pay restrictions.

Consider the remuneration contract:

$$s(K) := b \cdot \gamma^{K/\omega} \tag{23}$$

By inspection compensation is increasing in K as $\gamma > 1$, and the regulatory curvature restriction (10) is satisfied. The executive with this remuneration contract will implement a project choice boundary $K_H = K_L + d(K_L)$ with the function $d(K)$ given implicitly by:

$$\begin{aligned} & b \cdot \gamma^{(K+d(K))/\omega} (1 - \delta(1-\chi)p) = b \cdot \gamma^{K/\omega} \\ \Rightarrow \quad & \gamma^{d(K)/\omega} = \frac{1}{1 - \delta(1-\chi)p} \Rightarrow d(K) = \omega \end{aligned}$$

Thus the bank executive's project choice rule under compensation (23) coincides with (Reg'r FB). The coefficient b can be reduced to satisfy the participation constraint with equality. In the limit of $u \to 0$, we will have $b \to 0$. Hence the contract (23) delivers the most profitable possible decision rule under the regulatory curvature constraint: (Reg'r FB).

The result now follows. ■

Proof of Proposition 7. Consider the remuneration function $s(K, i_1) = s(K) \cdot [\eta \cdot \mathbf{1}_{i_1>1} + 1 \cdot \mathbf{1}_{i_1=1}]$ where $\mathbf{1}_A$ is the indicator function which takes a value 1 if the predicate A is true, and 0 otherwise. If the agent selects the high volatility project then she is paid $\eta s(K_H)$, if she selects the low volatility project she is paid $s(K_L)$. Hence the agent's decision is isomorphic to that under clawback by setting $\eta = 1 - \delta(1-\chi)p$. The result then follows from Proposition 5. ■

Proof of Proposition 8. Consider any remuneration scheme $s(K, i)$ which satisfies the regulator's constraints. We adapt the proof of Proposition 6 to confirm that the project choice boundary $K_H = K_L + d(K_L)$ cannot lie below the regulator's first best. Suppose otherwise, then there exists K such that from (Reg'r FB)

$$s\left(K + \lambda D \frac{\mu(1-\chi)}{\chi + \mu(1-\chi)} + (1-\lambda)(1-\chi) D i_{-1}, i_1\right) > s(K, 1). \tag{24}$$

The regulatory rule (12) implies that

$$\eta s\left(K+\lambda D\frac{\mu\left(1-\chi\right)}{\chi+\mu\left(1-\chi\right)}+\left(1-\lambda\right)\left(1-\chi\right)Di_{-1},1\right)\geq s\left(K+\lambda D\frac{\mu\left(1-\chi\right)}{\chi+\mu\left(1-\chi\right)}+\left(1-\lambda\right)D\left(1-\chi\right)i_{-1},i_{1}\right) \tag{25}$$

Combining (24) and (25) implies that

$$\eta s\left(K+\lambda D\frac{\mu\left(1-\chi\right)}{\chi+\mu\left(1-\chi\right)}+\left(1-\lambda\right)\left(1-\chi\right)Di_{-1},1\right)>s\left(K,1\right)$$

however this is a contradiction of the regulator's curvature rule (13) given (14).

Again we note that, ignoring the costs of incentivising the agent, the most profitable boundary north-west of the regulator's preferred boundary (Reg'r FB) in (K_L, K_H) space coincides with (Reg'r FB). Hence if the principal could incentivise (Reg'r FB) for cost proportional to u she would have maximised her surplus subject to the regulatory pay rule.

Consider the principal using the remuneration rule:

$$s\left(K\right):=b\cdot\left(\frac{1}{\eta^{K/\omega}}\right)\left[\eta\cdot\mathbf{1}_{i_1>1}+1\cdot\mathbf{1}_{i_1=1}\right]. \tag{26}$$

As $\eta<1$, pay is increasing in K. By inspection the regulatory rules (12) and (13) are satisfied. The agent facing such a remuneration schedule will implement a project choice rule boundary $K_H=K_L+d\left(K_L\right)$ such that

$$b\cdot\left(\frac{1}{\eta^{(K+d(K))/\omega}}\right)\eta=b\cdot\left(\frac{1}{\eta^{K/\omega}}\right)$$

simplifying we have $\eta^{d(K)/\omega}=\eta$ giving $d\left(K\right)=\omega$, which coincides with the regulator's first best project choice rule.

The coefficient b can be reduced to satisfy the participation constraint with equality. In the limit of $u\to 0$, we will have $b\to 0$. Hence the contract (26) delivers the most profitable possible decision rule under the regulatory curvature constraint: (Reg'r FB).

The result now follows. ■

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