The Economics of Deferral and Clawback Regulation: A Pigouvian Tax Approach*

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Abstract

This paper analyzes the effects of mandatory deferral and clawback requirements for managerial compensation contracts in the financial sector. Moderate deferral requirements for bonus payouts induce bank shareholders to incentivize more risk management effort from the manager (and, hence, lower bank failure rates), whereas stringent deferral requirements will lead to higher risk of bank failure. Additional clawback requirements may prevent such backfiring if and only if competition for managerial talent is sufficiently high. We provide conditions for when the optimal mix of capital and compensation regulation can achieve second-best welfare. Our analysis exploits the general idea that any (regulatory) restriction on compensation design can be understood as an indirect Pigouvian tax levied on the principal for incentivizing a given action.

Keywords: financial regulation, moral hazard, compensation design, clawbacks, bonus deferral, short-termism.

JEL Classification: D86 (Economics of Contract: Theory), G28 (Government Policy and Regulation), G21 (Banks, Depository Institutions, Mortgages).

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1 Introduction

> "Compensation schemes overvalued the present and heavily discounted the future, encouraging imprudent risk-taking and short-termism. In the UK, we have introduced a remuneration code prescribing that payment of bonuses must be deferred for a minimum of three years and, after payment, be exposed to clawback." **Mark Carney, Governor Bank of England, 2014**

Following the recent financial crisis, short-term oriented bonus schemes have been blamed to have contributed to excessive risk-taking and imprudent behavior in the financial sector (see introductory quote). This gave rise to various regulatory initiatives around the world aiming to intervene in the structure of compensation packages by imposing minimum deferral requirements and clawback/malus clauses for key employees in the financial sector.[1] While the implementation differs across countries (see Appendix B), the key feature of deferral constraints is that they put restrictions on the *timing* of bonus payouts, whereas clawback/malus[2] requirements pertain to the *contingency* of payouts by prohibiting payments to key risk-takers following severe underperformance including, in particular, bank failure within a given time period. One may paraphrase regulators' rationale for these interventions as follows: "Short-termist" compensation packages have *caused* short-termist actions of bank managers. If compensation packages paid out later in the future, so the heuristic argument goes, managers would take a more long-term perspective, reduce excessive risks, and, hence make banks, ultimately, safer.

What this "silver bullet" view of compensation regulation fails to account for, is that compensation packages are not exogenously given, but an endogenous outcome (a symptom rather than a cause). The heuristic argument above, hence, is subject to the Lucas-critique. In particular, adopting an optimal contracting view of compensation in the tradition of Grossman and Hart (1983), bank shareholders (the principal) effectively decide which action is implemented by designing the compensation package to incentivize the bank manager (the agent) accordingly. Hence, whichever distortion has led bank shareholders to design too "short-termist" compensation packages in the first place, it is still present when they face regulatory constraints in compensation design. For instance, access to public backstops distorts shareholders' incentives towards implement-

[1] For instance, in the EU, a new directive adopted in 2010 includes strict rules for bank executives' bonuses. Directive 2010/76/EU, amending the Capital Requirements Directives, which took effect in January 2011. It has already been fully implemented in a number of countries, including France, Germany, and the UK and has lead to mandatory deferral of bonuses for several years.

[2] A malus refers to a "clawback" of *non-vested* bonus payments from an escrow bonus account, such as, e.g., in the case of Wells Fargo's fraud scandal in 2017. "Real" clawbacks of already paid-out bonuses face enforcement problems in practice (see Arnold (2014)), and are, hence, less common.

ing levels of risk-taking that are higher than what is socially optimal. The real question, thus, is how bank shareholders choose to restructure compensation packages for its key employees in the presence of compensation regulation. Since the proposed/implemented regulation still leaves sufficient flexibility to adjust other (unregulated) dimensions of the compensation contract, it is a priori unclear whether this simple regulation works as intended or can even achieve optimal outcomes from the regulator's perspective.[3] As the financial sector is subject to intense regulatory scrutiny, a second major question then is how the considered compensation regulation interacts with other interventions such as, most prominently, capital regulation, which is motivated by similar concerns among policymakers and academics and received revived attention in the aftermath of the financial crisis (see, in particular, Admati, DeMarzo, Hellwig, and Pfleiderer (2011).

Our paper contributes to this policy debate by building a framework that allows to analyze the positive and normative effects of mandatory deferral and clawbacks requirements as well as their interaction with capital regulation. Our positive analysis shows that moderate deferral regulation, i.e., requirements exceeding the laissez-faire payout date by a small amount, typically increase bank stability in the sense of reducing excessive risk-taking, while sufficiently stringent deferral requirements always backfire. Additional clawback restrictions on compensation contracts only prevent backfiring if the bank manager's outside option is sufficiently high. In our normative analysis, we show that the restricted regulatory toolset of capital regulation and compensation regulation may achieve second-best welfare if and only if the employee's outside option is sufficiently high. The optimal policy mix then implies a substitutability between the degree of regulatory interference in form of capital regulation and compensation regulation — here in the form of mandatory deferral and clawback clauses. Beyond the concrete application to financial sector regulation, we conceptually contribute to the principal-agent literature by developing a Pigouvian tax approach that allows to determine the impact of any (regulatory) constraint on compensation design on the set of actions implemented in equilibrium.

Since our Pigouvian tax idea applies broadly, it can be understood within a generic principal-agent model. So, consider the implications of an arbitrary set of constraints on compensation design. For concreteness, suppose that these restrictions have a regulatory motivation, e.g., as externalities (on tax payer, environment, etc.) drive a wedge between the gross benefit of an action to the principal and value to society. As is imme-

[3] This is also echoed by regulators, e.g.: "The effectiveness of these mechanisms remains largely untested and more analysis is needed to assess whether tools such as malus and clawbacks are sufficiently developed and effectively used to deter risks." Financial Stability Board, 2015.

diate, regulatory constraints on the set of permissible contracts do not directly address these externalities, but instead affect the equilibrium action choice by (weakly) raising implementation costs for any action. For example, if, absent regulation, a given action is optimally implemented with an up-front bonus, shareholders must restructure the compensation contract along other dimensions to be able to incentivize the same action when facing a mandatory deferral constraint. The difference in compensation costs associated with the respective optimal compensation contracts (post vs. pre regulation) operates as an *indirect Pigouvian tax* on incentivizing a given action. The resulting Pigouvian tax function across actions then is a *sufficient statistic* for the effects of contracting constraints on the equilibrium action choice. In general, a *necessary* condition for compensation regulation to raise welfare is that it effectively taxes the actions that society prefers, say prudent actions, relatively less, than the laissez-faire action, say risk-taking.

This conceptual approach to compensation regulation guides the subsequent analysis of our concrete application. In particular, we consider a parsimonious principal-agent setting that is supposed to capture basic frictions present in the financial sector. The model has three central features. First, the bank manager (the agent) is a "relevant" employee, as targeted by the regulation, in the sense that she is a "key risk-taker" able to affect the survival rate of the entire institution. Second, to capture the concern of regulators that "Bad bets by financial-services firms take longer than three years to show up." (WSJ, 2015), we assume that the bank manager's unobservable action, which we interpret as "risk management" effort, has *persistent* effects on the bank's failure rate, so that learning about the quality of risk-management occurs through the absence of "disasters." Third, scope for regulatory intervention arises as bailout expectations allow bank shareholders (the principal) to finance risky projects with effectively subsidized debt (see Atkeson, d'Avernas, Eisfeldt, and Weill (2018) and Duffie (2018) for evidence on this distortion), and, hence, they do not fully internalize the social cost of bank failure.[4]

In the absence of compensation regulation, shareholders choose maximum leverage and write compensation contracts that incentivize the manager to exert too little risk-management effort compared to the social optimum. By virtue of universal risk-neutrality and relative impatience of the manager, the corresponding unconstrained optimal compensation contracts take a simple form (cf., Hoffmann, Inderst, and Opp (2017)): The manager receives a bonus if and only if the bank has not failed by an optimally chosen payout date that reflects the "informativeness" of bank survival at that date.[5] Under

[4] In our concluding remarks, we show how our modeling approach can be extended to a corporate governance problem. Regardless of whether the board chooses what shareholders want, it is key that the contract designer does not choose what society wants.

[5] The exact characterization of this single payout date differs depending on whether the principal has

plausible conditions, this payout date is increasing in the risk-management effort that shareholders incentivize, in which case they indeed offer equilibrium compensation packages with too short-termist payouts, as argued by the regulator.[6]

A key feature of our analysis of deferral regulation is that the associated Pigouvian tax is a hump-shaped function of the implemented effort level. This non-monotonicity, in turn, is responsible for our main positive result that moderate deferral regulation raises equilibrium effort while it is unambiguously lower under stringent deferral regulation (without clawbacks). The non-monotonicity results from the interaction of two opposing forces, which reflect "timing inefficiency" and "size-of-pay" effects. On the one hand, the timing inefficiency effect implies that deferral regulation taxes actions with short-term payout dates more. This is good news for deferral regulation, since unconstrained optimal contracts induce low "risk-management" effort typically with early payout dates. Since shareholders, thus, have to deviate more from their optimal choice when implementing low effort, they face c.p. a lower tax for higher risk-management. In particular, sufficiently high effort levels — with optimal endogenous payout dates exceeding the regulatory constraint — are not taxed at all. This force is the only one relevant under moderate mandatory deferral regulation which, thus, raises equilibrium effort. On the other hand, higher effort requires higher pay and, due to the manager's relative impatience, it is c.p. more costly for the principal to defer a larger compensation package. In fact, if no effort is incentivized (and, thus, no incentive pay is required), the Pigouvian tax on incentive pay is again zero, as deferring zero pay is costless for shareholders. This force is responsible for why shareholders eventually lower effort in response to "large" deferral periods. These qualitative effects of pure deferral regulation hold regardless of the agent's outside option. However, with a binding participation constraint, an additional regulatory clawback requirement has bite in that it reduces such backfiring for large deferral periods and allows the regulator to induce large improvements in risk-management quality.

To understand the effect of the clawback clause on the level of risk management bank shareholders wish to implement, we first need to understand how shareholders restructure compensation contracts — holding the level of risk management constant. One naïve perturbation of an unconstrained optimal contract with a payout date of say 3 years in response to a minimum deferral period of 4 years would be to simple defer the

a rent-extraction motive or not, i.e., whether the agent's participation is slack or binds.

[6] Of course, when the conditions ensuring a positive relationship between risk management effort and unconstrained optimal payout dates are not satisfied, minimum deferral regulation unambiguously backfires. Interestingly, as we show, this case can only arise when the bank manager's participation constraint is slack.

payout of the bonus for an additional year using an escrow account that yields an interest rate equal to the manager's rate of time preference.[7] While such naïve restructuring is indeed the optimal response when the manager's participation constraint binds (e.g., if competition for managerial talent is sufficiently high), shareholders can do strictly better when it is slack. Intuitively, then, since shareholders are forced by regulation to defer up to year 4 anyway, they might as well exploit the additional information arriving between year 3 and year 4 to provide incentives by conditioning the payout on survival after year 4 (rather than year 3). Thereby, shareholders can reduce the manager's agency rent and partially offset the costs of mandatory deferral due to the manager's relative impatience. This logic unveils that the clawback requirement to only pay out conditional on survival is *automatically* satisfied when shareholders have a rent-extraction motive. However, as is clear, this mechanism does not apply when a binding participation constraint prevents shareholders from extracting any further rent from the manager. Then, the optimal response to a deferral clause is to make some pay unconditionally, i.e., to also pay following failure. An additional clawback requirement would then have a bite by preventing this adjustment.[8]

We now turn to the normative analysis. To address the underprovision of risk-management in our framework, regulators choose, next to the considered compensation regulation, the optimal amount of capital regulation. We are, therefore, able to analyze the interaction of these prominent policy tools, and when this restricted set of tools is sufficient to achieve second-best welfare. Of course, if equity financing were costless, sufficiently high capital regulation alone achieves the second-best outcome in our setup. Intuitively, stringent capital regulation simply eliminates the bailout distortion in shareholders' preferences such that shareholders, in turn, choose to implement the socially optimal action. It thus, operates, very differently compared to compensation regulation which targets not the source but a symptom of distortions, the compensation contract. Still, whenever capital regulation is restricted, e.g., as there are costs to raising capital (or political economy constraints), it is, under plausible conditions, optimal to augment capital regulation with compensation regulation. However, whether the second-best outcome can be achieved depends on whether competition for managerial talent in the banking sector is sufficiently strong, so that the respective participation constraint binds. The resulting policy mix achieving second-best welfare then features a form of substitutabil-

[7] The present value adjustment ensures that the manger receives the same present value of compensation while incentive compatibility is maintained. The role of the escrow account is to ensure that the institution can always deliver on its promises.

[8] Formally, the action is, then, not implementable, since it is impossible to satisfy both the regulatory constraints as well as the manager's participation constraint.

ity: Laxer capital requirements must be optimally compensated by stricter interventions (more deferral) in the compensation package. In particular, if regulators need to induce large changes via compensation regulation, not only do they need to require long deferral periods, but this also requires imposing a clawback requirement.

Literature Our paper contributes to the literature on regulation of incentive contracts, in particular, within the context of financial sector regulation. Within this branch, one can distinguish between structural constraints on compensation contracts, like the timing and contingency of pay, as is the focus of our paper, or constraints on the size of pay (see, e.g., Thanassoulis (2012)).[9] Our key conceptual contribution to this literature is that our Pigouvian tax approach can be applied to any type of compensation regulation, independently of the distortion that motivates regulatory intervention in the first place.

For firms outside the financial sector, regulatory intervention in executive compensation contracts is typically motivated by a perceived corporate governance problem (see e.g., Bebchuk and Fried (2010) or Kuhnen and Zwiebel (2009)). According to this view, compensation regulation should, thus, benefit shareholders and trigger positive market valuation responses (taking a narrow view of corporate governance as maximizing "shareholder" value).[10] An alternative view is that the board may indeed pursue the maximization of shareholder value, which, however, may not be fully aligned with societal goals, justifying regulatory intervention. This view is particularly relevant in the financial sector, and, hence, adopted in our concrete financial sector application. In particular, as is standard in the literature on banking regulation (Dewatripont, Tirole, et al. (1994), Hellmann, Murdock, and Stiglitz (2000), Matutes and Vives (2000), Repullo and Suarez (2004)), we assume that shareholders can externalize part of the default risk to society via bail-outs/deposit insurance.[11]

Direct taxation of the resulting negative externalities upon default is naturally restricted by banks' limited resources in this "disaster-event" and the limited liability embedded in the financial structure that they use to finance their business. A large

[9] Jewitt, Kadan, and Swinkels (2008) analyze the consequences of payment bounds in the standard static moral hazard problem. Another approach in the literature is to restrict the set of available contracts by only allowing the manager to be paid using standard financial instruments, such as stock, see, e.g., Benmelech, Kandel, and Veronesi (2010).

[10] With respect to the financial sector, there seems to be little empirical evidence that those banks where interests of top management were better aligned with those of shareholders performed better. (For some evidence to the contrary, see, for instance, Fahlenbrach and Stulz (2011)).

[11] Alternatively, in a multi-bank setting, shareholders of individual banks may choose the privately optimal compensation packages for their employees, but, facing competition, they are jointly hurt by their behavior in equilibrium. Such a mechanism is at play in Thanassoulis (2012), Bénabou and Tirole (2016), and, Albuquerque, Cabral, and Correia Guedes (2016).

literature in banking regulation (Dewatripont, Tirole, et al. (1994), Admati, DeMarzo, Hellwig, and Pfleiderer (2011)) has, thus, pointed out that a key role of capital requirements is to increase the loss-absorbing capacity ex post and reduce risk-taking incentives ex ante.[12] Our paper contributes to this literature by providing a novel analysis of the interaction between capital regulation and compensation regulation, in particular the role of deferral periods and clawbacks.[13] We find that such compensation regulation can work as a substitute to direct taxation of the externality.

Finally, our paper builds on recently developed tools that permit a tractable characterization of optimal compensation design in principal-agent models with persistent effects (see Hoffmann, Inderst, and Opp (2017)). The particular modeling of a (potentially rare) negative event is shared with Biais, Mariotti, Rochet, and Villeneuve (2010) and notably Hartman-Glaser, Piskorski, and Tchistyi (2012) as well as Malamud, Rui, and Whinston (2013). All these papers focus purely on optimal compensation design absent regulation. They, thus, neither analyze optimal contracts under regulatory constraints, nor do they study the effect of regulation on the implemented action, nor the normative aspects of such regulatory intervention.

2 A Pigouvian tax approach

Our paper analyzes the positive and normative implications of deferral regulation and clawback requirements within a concrete agency model capturing basic frictions present in the financial sector. One key insight of our *positive* analysis is that these regulatory constraints on compensation contracts operate as an indirect Pigouvian tax on the principal. Since this idea applies more generally to any (regulatory) constraint on compensation contracts and, thus, also holds outside of the concrete agency model developed below, it is useful to, first, illustrate our Pigouvian tax approach to contract regulation within an abstract and general principal-agent setting. We then fill in the details specific to our applied setting, such as the effects of the agent's action and its institutional interpretation, when applying the Pigouvian tax approach to our concrete agency model.

We consider a standard principal-agent framework, in which the present value of

[12] To tame risk taking incentives, Bolton, Mehran, and Shapiro (2015) propose making CEO compensation a function of a bank's CDS spreads. In a setting not specific to the financial sector, Edmans and Liu (2010) advocate combining equity stakes with debt-like instruments such as uninsured pension schemes.

[13] A recent paper by Eufinger and Gill (2017) proposes to link banks' capital requirements to CEO compensation, but does neither analyze deferred incentive pay nor clawbacks. Outside the regulatory context, John and John (1993) analyze the link between optimal incentive contracts and the agency conflicts arising from capital structure choices.

revenue accruing to the principal, $\Pi(a)$, is affected by the agent's *unobservable* and possibly multidimensional action.[14] To induce a given action (vector) $a \in \mathscr{A}$, the principal commits to a cost-minimizing compensation contract $\gamma(a)$ stipulating the timing, contingency and size of pay such that the canonical incentive and participation constraints are satisfied. Let $W(a)$ denote the minimum wage cost resulting from this optimal compensation design. Then, following Grossman and Hart (1983), the principal optimally induces action

$$a^* = \arg\max_{a \in \mathscr{A}} \Pi(a) - W(a). \tag{1}$$

The positive part of our analysis is concerned with the generic effects of a given set of contracting constraints on this action choice. To illustrate our Pigouvian tax approach, it is irrelevant whether these constraints are exogenously given or the outcome of a planner's problem. Yet, in light of our subsequent concrete application to the financial sector, it is useful to view regulatory intervention as being motivated by divergent interests of shareholders and society, i.e., the principal's benefit from some action a, $\Pi(a)$, differs from the planner's benefit $V(a)$. For example, shareholders may not fully internalize all downside risk implications of managerial actions (pollution, safety, tax payer costs). As a result, the laissez-faire compensation contract associated with action a^*, $\gamma(a^*)$, does not induce the second-best action $a^{SB} = \arg\max_{a \in \mathscr{A}} V(a) - W(a)$.

Let Γ and Γ_R denote the space of permissible contracts in the absence and presence of compensation regulation, respectively. Then, since regulatory constraints restrict the set of permissible contracts (see examples in Introduction and Appendix B), i.e., $\Gamma_R \subset \Gamma$, the minimum wage cost required to implement action a under regulation must be weakly greater than in the absence of regulation, i.e., $W(a|\Gamma_R) \geq W(a) := W(a|\Gamma)$. In particular, if binding regulation restricts one dimension of the cost-minimizing compensation contract for some action a, say the associated contract $\gamma(a)$ violates a regulatory minimum deferral constraint of 3 years, the principal must adjust other features of the contract (e.g., size or contingency of pay) such as to still implement the same action. The cost to the principal resulting from optimal restructuring of compensation is the indirect "*Pigouvian tax.*"

Definition 1 *The indirect Pigouvian tax for any implementable action a, $\Delta W(a)$, is given by*

$$\Delta W(a) := W(a|\Gamma_R) - W(a|\Gamma) \geq 0. \tag{2}$$

If action a cannot be implemented with a contract $\gamma \in \Gamma_R$, then $\Delta W(a) := \infty$.

[14] While we frame the arguments in a static setting, actions may also be taken sequentially.

In the presence of regulation, the shareholders' optimal action choice, thus, satisfies

$$a_R^* = \arg\max_{a \in \mathscr{A}} \Pi(a) - W(a|\Gamma) - \Delta W(a). \tag{3}$$

This decomposition highlights that (potentially multi-dimensional) contracting constraints only affect the equilibrium action choice through their effect on the single-valued Pigouvian tax function. Hence, a necessary condition for compensation regulation to change the equilibrium action is that the Pigouvian tax, $\Delta W(a)$, varies across actions. Since a relevant incentive problem implies that different actions are optimally implemented with different compensation contracts, a given regulatory constraint typically affects the costs of implementation differentially across actions. More formally, we obtain

Proposition 1 *Consider two actions a and a' with associated optimal contracts $\gamma(a)$ and $\gamma(a')$ in the absence of regulation. Suppose that $\gamma(a) \in \Gamma_R$ whereas $\gamma(a') \notin \Gamma_R$, then*

$$\Delta W(a') > \Delta W(a) = 0.$$

The subsequent Corollary shows that this abstract result generates empirical content by linking regulatory constraints used in practice to comparative statics of unconstrained optimal contracts. Let $\gamma_i \in \mathbb{R}$ refer to a real-valued dimension i of a generic contract. For example, in practice, γ_i could refer to the fraction of the bonus vested until year 3, the ratio of variable-to-fixed pay, the maximum bonus size, the total compensation etc. Moreover, let $\gamma_i(a)$ denote the corresponding value of this contractual parameter in the cost-minimizing contract associated with action a. Then, we obtain

Corollary 1 *Consider two actions a and a' such that $\gamma_i(a) > \gamma_i(a')$. If the regulator imposes a constraint requiring that $\gamma_i \geq \kappa$ where $\kappa \in (\gamma_i(a'), \gamma_i(a)]$, then $\Delta W(a') > \Delta W(a) = 0$.*

The Corollary highlights that regulators can induce differential taxation across actions by exploiting comparative statics of unconstrained optimal contracts ($\gamma_i(a) > \gamma_i(a')$) in combination with the appropriate choice of regulatory constraint (here, a lower bound).[15] Differential taxation, in turn, can then induce a change in the implemented action as governed by (3).

This Pigouvian tax approach is valid for general action sets and any constraint on compensation contracts. In what follows we will now apply this approach to analyze

[15] Of course, if the regulator imposed an upper bound, he could increase compensation costs only for action a (but not for a').

the effects of minimum deferral regulation and clawback requirements within a concrete model in which the agent's action can be economically interpreted as risk-management effort. A concrete model specification is necessary to derive the three relevant functions V, Π and W, governing the effects and desirability of regulatory intervention, from primitives. Of particular interest is how the principal optimally restructure compensation contracts when facing deferral and clawback constraints (yielding $W(a|\Gamma_R)$), as this determines the size of the Pigouvian tax for different actions, the optimally implemented action choice and, ultimately, welfare. In addition, the concrete model allows to analyze when the "ad-hoc" tools of deferral and clawback regulation are sufficient for inducing the second-best outcome, and, when other regulatory tools (such as capital regulation) add social value.

3 Model setup

We consider an infinite-horizon continuous-time setting in which time is indexed by $t \in \mathbb{R}^+$. The economy is populated by three types of economic parties (1) bank shareholders, (2) a bank manager, and (3) "society." All parties are risk-neutral. However, while bank shareholders and society discount payoffs at the market interest rate r, the bank manager discounts payoffs at rate $r + \Delta r$, where $\Delta r > 0$ measures her rate of impatience (liquidity needs).[16]

At time 0, the bank has access to an investment technology that requires both a *one-time fixed-scale* initial capital investment of size 1 by the bank and an unobservable *one-time* action choice $a \in \mathscr{A} = \mathbb{R}^+$ by the bank manager at personal cost $c(a)$, where $c(a)$ is strictly increasing and strictly convex with $c(0) = c'(0) = 0$ as well as $\lim_{a\to\infty} c'(a) = \infty$. We assume that the action of the bank manager has persistent effects on bank failure, i.e., relevant outcomes are only observed over time (cf., motivating quote in introduction). Precisely, the manager's effort at time 0 reduces the bank's failure rate $\lambda(t|a)$ at each point in time:[17]

$$\frac{d}{da}\lambda(t|a) < 0 \ \forall t \in (0, \infty), a \in \mathscr{A}, \tag{4}$$

where λ is a twice continuously differentiable function. One may, thus, best interpret the managerial action as an investment in the unobservable quality of the risk-management model.[18]

[16] See, e.g., DeMarzo and Duffie (1999), DeMarzo and Sannikov (2006), or Opp and Zhu (2015).

[17] Formally, this assumption plays a similar role as the monotone likelihood ratio property (MLRP) in static principal-agent models with immediately observable signals, see, e.g., Rogerson (1985).

[18] Many of our insights, in particular the validity of the Pigouvian tax approach, also apply, when the manager can explicitly engage in risk-taking (rather than just exert effort to prevent risks) or if there

Let $X_t = 1$ denote that the bank has failed by date t, and $X_t = 0$ otherwise. Formally, X_t is a stopped counting process on the probability space $(\Omega, \mathcal{F}^X, \mathbb{P}^a)$ where $\mathbb{P}^a$ denotes the probability measure induced by action a. The associated bank survival function $S(t|a)$ is then given by:

$$S(t|a) := \Pr(X_t = 0|a) = e^{-\int_0^t \lambda(s|a)ds},$$

and it follows directly from (4) that the survival probability is increasing in a for each t. In our subsequent analysis, we will frequently consider for illustration the Generalized Gamma distribution as a parameterized family of survival functions.

Example 1 *The Generalized Gamma distribution, $S(t|a) := \frac{\Gamma(\beta,(h(a)t)^p)}{\Gamma(\beta,0)}$,*[19] *with positive constant $p > 0$ satisfies Condition (4) if $h(a) > 0$ is a strictly decreasing function of a. It nests the exponential arrival time distribution, $S(t|a) = e^{-h(a)t}$, for $\beta = p = 1$.*

Since the key distortions in the bank shareholders' preferences result from the failure event (see below), we model project cash flows conditional on bank survival in the simplest possible way: The date-t cash flows, Y_t, are constant at $y > 0$ as long as the bank has not failed.

$$Y_t = \begin{cases} y & X_t = 0, \\ 0 & X_t = 1. \end{cases} \tag{5}$$

The cash flow process governed by (4) and (5) captures two features that have been considered relevant in the (regulation of the) financial sector in the simplest possible fashion. First, by construction, we focus on actions that affect the survival of the entire institution, which is in line with regulators targeting the compensation of material risk-takers (see Introduction). Second, information about their actions arrives gradually over time only through the absence of large, "rare" crisis events. This modeling captures environments in which prudent actions (high a) and imprudent actions often deliver similar performance in the short-run and can only be told apart better in the long run, e.g., as bank managers can replicate the costly generation of true alpha in good states by writing out-of-the money put options on rare bad states.

Let $\mathbb{E}^a$ denote the expectation under probability measure $\mathbb{P}^a$ induced by the manager's effort a, then the *net present value* of cash flows generated by the project, $V(a) := \mathbb{E}^a\left[\int_0^\infty e^{-rt} Y_t dt\right] - 1$, can be written as

$$V(a) = y \int_0^\infty e^{-rt} S(t|a)\, dt - 1. \tag{6}$$

are repeated actions (see the discussion in the Conclusion).

[19] Here, $\Gamma(\beta, x) := \int_x^\infty s^{\beta-1} e^{-s} ds$ denotes the upper incomplete Gamma function.

In the absence of an agency problem, first-best risk-management effort, thus, simply maximizes total surplus:

$$\Theta^{FB} := \max_a V(a) - c(a). \tag{7}$$

In our setting, the bank's objective function will differ from (7) for two reasons. First, as the bank manager's action a is unobservable, the bank needs to provide the appropriate incentives which results in wage costs, $W(a)$, that exceed the manager's cost of the action, $W(a) > c(a)$. Second, bailout expectations induce distortions in banks' capital structure, driving a wedge between the *social* value creation of the underlying real project, $V(a)$, and the *private* value creation for bank equity holders, $\Pi(a)$.

We now microfound both $W(a)$ and $\Pi(a)$ from optimal compensation design and (privately) optimal capital structure decisions, respectively. In the positive part of our analysis, we consider the existing regulatory environment as exogenously given. That is, the compensation design problem is subject to deferral and clawback regulation, and the optimal capital structure choice is subject to Basel-type bank capital regulation.

Bank shareholders' compensation cost function. Bank shareholders, the principal, design compensation contracts that induce the manager to exert effort a at lowest possible wage costs. Formally, a compensation contract is represented by a cumulative compensation process b_t progressively measurable with respect to the filtration generated by X_t (the information available at time t). In particular, db_t refers to the instantaneous bonus payout to the manager at date t. The formal compensation design problem of implementing action a at lowest expected discounted cost to bank shareholders – the first problem in the structure of Grossman and Hart (1983) – can be stated as

Problem 1 (Compensation design)

$$W(a|\Gamma_R) := \min_{b_t} \mathbb{E}^a \left[\int_0^\infty e^{-rt} db_t \right] \qquad s.t.$$

$$\mathbb{E}^a \left[\int_0^\infty e^{-(r+\Delta r)t} db_t \right] - c(a) \geq U, \tag{PC}$$

$$\frac{\partial}{\partial a} \mathbb{E}^a \left[\int_0^\infty e^{-(r+\Delta r)t} db_t \right] = c'(a), \tag{IC}$$

$$db_t \geq 0 \quad \forall t, \tag{LL}$$

$$b_t = 0 \quad \forall t < T_{\min}, \tag{DEF}$$

$$b_t = 0 \quad \forall t \ \mathit{if}\ X_t = 1. \tag{CLAW}$$

The first constraint is the bank manager's time-0 participation constraint (PC). The present value of compensation discounted at the manager's rate net of effort costs, must at least match the manager's outside option U.[20] Second, incentive compatibility (IC) requires that it is optimal for the manager to choose action a given the contract. As is common in the analysis of moral hazard problems with continuous actions (see, e.g., Holmstrom (1979) and Shavell (1979)) we have simplified the exposition by assuming that the first-order approach applies.[21] Limited liability of the manager (LL) imposes a lower bound on the transfer to the manager, i.e., $db_t \geq 0$.[22] The first regulatory constraint (DEF) puts a restriction purely on the timing of pay: Bank shareholders are prohibited to make a bonus payment to the manager before date $T_{\min}$. The second regulatory constraint (CLAW) imposes that no payout may be made at date t if the bank has failed by that date. We interpret this restriction on the contingency of payouts as a clawback requirement (formally, a malus).[23]

Excluding constraints (DEF) and (CLAW), or equivalently setting $T_{\min} = 0$,[24] yields compensation costs under the unconstrained optimal compensation contract, $W(a|\Gamma)$. Once we incorporate regulatory constraints, we obtain constrained optimal compensation costs, $W(a|\Gamma_R)$, reflecting bank shareholders' optimal restructuring of compensation contracts, which in turn yields the indirect Pigouvian tax for each action a, $W(a|\Gamma_R) - W(a|\Gamma)$.

Bank equity holders' gross profit function. To microfound $\Pi(a)$ and capture commonly noted distortions in the financial sector in the *simplest possible way*, we assume that banks' financing decisions are distorted by 1) tax-payer guarantees on their debt and 2) regulatory minimum capital requirements (see, e.g., Hellmann, Murdock, and Stiglitz (2000) or Repullo and Suarez (2013)). It is beyond the scope of this paper to microfound these distortions, in particular, since the results of our analysis of compensation regulation, which is the key focus of our paper, are *independent* of the source of the wedge between $\Pi(a)$ and $V(a)$ (see the Conclusion for a discussion of alternative distortions).

[20] Since the manager in our model chooses an action only once at time 0 and is protected by limited liability, the participation constraint of the manager only needs to be satisfied at $t = 0$.

[21] Within our setting, validity of the first-order approach is ensured if the survival function S is concave for all (t, a). This condition is essentially the same (restrictive) sufficient condition as the convexity of the distribution function condition (CDFC) in static moral hazard environments (see Rogerson (1985)). See Bond and Gomes (2009) for an analysis when the first-order approach breaks down.

[22] For ease of exposition, we do not consider additional constraints such as upper bounds on transfers (see, e.g., Jewitt, Kadan, and Swinkels (2008) or Hoffmann, Inderst, and Opp (2017)).

[23] This follows standard terminology (see Footnote 2).

[24] As will be shown below, if $T_{\min} = 0$, (CLAW) does not constrain the principal's optimal compensation design.

The key advantage of taking a stance on the distortion embedded in Π is that it allows us to shed light on the fundamental difference between capital regulation and compensation regulation.

At date 0, the bank possesses K_0 units of capital in the form of cash and decides (once and for all) on its capital structure. We denote by $D \geq 0$ the amount of perpetual debt raised by the bank from competitive debtholders and by ΔK the net issuance of equity capital. Here, $\Delta K \leq 0$ can be interpreted as a dividend payout. Then, the bank faces the following (binding) budget constraint to finance the investment of size one: $K_0 + \Delta K + D = 1$. Given the – for now exogenous – regulatory constraint specifying the minimum capital ratio (and its level due to investment size of 1), $k_{\min}$, bank shareholders face the following financing constraint:

$$K_0 + \Delta K \geq k_{\min}. \tag{8}$$

Since taking on debt is effectively subsidized due to government (bailout) guarantees, shareholders find it optimal to choose as much leverage as possible, so that (8) binds and the (privately) optimal debt level (and ratio) is given by $D^* = 1 - k_{\min}$. Given these optimal financing decisions, bank shareholders' gross profits, i.e., the present value of project cash flows net of (risk-free) interest on issued debt and the co-investment by shareholders, $k_{\min}$, satisfies:

$$\Pi(a) = [y - rD^*] \int_0^\infty e^{-rt} S(t|a)\, dt - k_{\min}.$$

Then, the action a bank shareholders optimally induce is maximizing profits net of compensation costs. This problem represents the second problem in the structure of Grossman and Hart (1983).

Problem 2 *Bank shareholders implement action* $a_R^* = \arg\max_{a \in \mathscr{A}} \Pi(a) - W(a|\Gamma_R)$.

Welfare. We define welfare as the present value of cash flows generated by the project net of (wage) costs of incentivized the manager's action

$$\Omega(a) = V(a) - W(a|\Gamma_R).^{25} \tag{9}$$

This welfare definition implies that scope for regulation results entirely from externalities on the tax payer. The value of this externality can be interpreted as the effective debt financing subsidy accruing to bank equity holders (since debt is priced competitively):

[25] As in Plantin and Tirole (2018), this notion of welfare puts zero weight on the bank manager.

$$\Pi(a) - V(a) = (1 - k_{\min}) \left(1 - r \int_0^\infty e^{-rt} S(t|a)\, dt\right). \tag{10}$$

Intuitively, the financing subsidy, $\Pi(a) - V(a) > 0$, is lower the higher the survival probability $S(t|a)$ at each date t. As a result, bank shareholders do not fully internalize the benefits of improved risk-management, i.e., $\Pi'(a) < V'(a)$, which formally follows from condition (4). Also, the financing subsidy is greater the greater the amount of leverage (lower $k_{\min}$). Since our primary focus in the following section is the positive analysis of the (incremental) effects of compensation regulation, we initially treat $k_{\min}$ as an exogenous parameter (think of 8% as given by Basel I-II). In our normative analysis (Section 5), we will endogenize both compensation and capital regulation.[26]

4 Positive analysis

Our positive analysis of the effects of compensation regulation on equilibrium contract design follows the standard two-step structure of Grossman and Hart (1983). First, we analyze how the shareholders design cost-minimizing compensation contracts to implement any given action a (with and without deferral regulation). We then analyze the implemented action choice as a function of the deferral period. For ease of exposition, we initially consider the case where the manager does not have a relevant participation constraint, such that the shareholders' action and contract choice reflect a rent-extraction motive (see Section 4.1). This case applies for instance whenever the manager's outside option U equals zero or is at least sufficiently low, e.g., due to highly firm-specific human capital or little competition for managerial talent. In the subsequent Section 4.2, we then allow for $U > 0$ and show robustness of our main results as well as the additional implications of a binding participation constraint, such as a role for the clawback clause.

4.1 Basic analysis: The rent-extraction case

4.1.1 Compensation design

Unregulated optimal rent-extraction contracts. A general insight from the optimal contracting literature in settings with bilateral risk-neutrality and limited liability of the agent is that optimal contracts only reward outcomes that are most indicative of

[26] To make the regulator's problem non-trivial, we consider both social costs of capital regulation in the form of costly equity issuances (or social benefits of money-like debt claims) as well as political economy constraints.

the recommended action (in a likelihood-ratio sense) and pay out zero otherwise.[27] In our concrete setting, it directly follows from the assumption that effort reduces the bank default rate, see condition (4), that the most informative outcome for any given date t is given by bank survival. Formally, among all possible date-t histories, the survival history is associated with the maximal likelihood ratio (score) for any recommended level of risk-management effort a. To track how much the principal has learned by time t, we record this maximal likelihood ratio in the informativeness function

$$\mathscr{I}(t|a) := \frac{d\log S(t|a)}{da} = -\frac{d\Lambda(t|a)}{da}, \tag{11}$$

where $\Lambda(t|a) := \int_0^t \lambda(s|a)\,ds$ denotes the cumulative hazard function. Intuitively, the informativeness of the date-t survival history is high if the derivative of the *cumulative* hazard at date t with respect to effort is high in absolute value. The function $\mathscr{I}(t|a)$ is a strictly increasing function of time and fully captures the informativeness benefit of deferral in our setting. The optimal timing of pay is then determined by trading-off the gain in informativeness with the costs of deferral arising from the manager's relative impatience. To ensure that the bank does not want to defer payments forever, we impose the technical condition that, for any given a,

$$\frac{\partial^2 \mathscr{I}/\partial t^2}{\partial \mathscr{I}/\partial t} = \frac{\partial^2 \lambda(t|a)/\partial a \partial t}{\partial \lambda(t|a)/\partial a} < \Delta r \tag{12}$$

holds for t large. Condition (12) requires that informativeness $\mathscr{I}(t|a)$ is (locally) less convex than impatience costs $e^{\Delta r t}$. Then, applying the characterization in Theorem B.1 of Hoffmann, Inderst, and Opp (2017) to our setting, we obtain the following result:

Lemma 1 *The unregulated cost-minimizing compensation contract can be implemented with a* ***single*** *payout date $T^*(a)$ that solves*

$$\frac{d\log \mathscr{I}(t|a)}{dt} = \frac{\partial\lambda(t|a)/\partial a}{\partial\Lambda(t|a)/\partial a} = \Delta r. \tag{13}$$

The manager receives a bonus of $db_{T^*}(a) = \frac{e^{(r+\Delta r)T^*(a)}}{S(T^*(a)|a)}\frac{c'(a)}{\mathscr{I}(T^*(a)|a)}$ if and only if $X_{T^*(a)} = 0$. The manager and the bank shareholders value the compensation package at $B(a)$ and $W(a)$, respectively, where

$$B(a) = \frac{c'(a)}{\mathscr{I}(T^*(a)|a)} < W(a) = B(a)\,e^{\Delta r T^*(a)}.$$

[27] See Innes (1990), and, in particular, the moral hazard environment with persistent effort in Hoffmann, Inderst, and Opp (2017).

The deferral period in a cost-minimizing contract trades off the gain in informativeness – which allows bank shareholders to reduce the manager's rent $B(a) - c(a)$ – with the deadweight costs resulting from the manager's impatience. The associated (necessary) first-order condition (13) implies that bank shareholders optimally defer until the (log) growth rate of impatience costs, Δr, equals the (log) growth rate of informativeness, $\frac{d \log \mathscr{I}}{dt}$, which from (11) is given by the sensitivity of the current default hazard rate with respect to effort relative to the respective cumulative sensitivity in all previous periods. One can use this characterization to obtain closed form expressions for many common survival distributions and perform comparative static analysis. By Corollary 1 of our general analysis, the ultimate effectiveness of *minimum* deferral regulation crucially depends on whether unconstrained optimal compensation contracts call for shorter or longer deferral periods to implement better risk-management (higher a). The optimality condition (13) reveals that the sign of the comparative statics depends on whether the growth rate of informativeness, $\frac{d \log \mathscr{I}(t|a)}{dt}$, is increasing or decreasing in the action.[28] Within Example 1 the sign of this comparative static is completely determined by the parameter β of the Gamma distribution (see Lemma 5 in Hoffmann, Inderst, and Opp (2017)).[29]

Result 1 *The payout date $T^*(a)$ of the unregulated compensation contract in Example 1 is strictly increasing in a for $\beta > 1$, strictly decreasing in a for $\beta < 1$, and independent of a for $\beta = 1$ where $T^*(a) = \frac{1}{\Delta r}$.*

Constrained optimal rent-extraction contracts. We will now analyze how shareholders optimally restructure compensation contracts for a given action a if compensation regulation prohibits the implementation of the unregulated compensation contract. To illustrate why the contingency requirement in (CLAW) is irrelevant when (PC) is slack, suppose that shareholders *only* face a deferral constraint of $T_{\min} > T^*(a)$. One possible (but suboptimal) perturbation of the original contract would be to still condition the bonus only on bank survival up to date $T^*(a)$ and simply defer the payout of the bonus until $T_{\min}$ in an escrow account that yields an interest rate equal to the manager's rate of time preference $r + \Delta r$. By construction, this contract restructuring both satisfies the regulatory deferral constraint (DEF) and incentive compatibility (IC). However, bank

[28] This follows from (13) and the implicit function theorem.

[29] These comparative statics are similarly easy to check for other commonly used survival time distributions. For instance for the log-normal $S(t|a) = \frac{1}{2} - \frac{1}{2} \operatorname{erf}\left[\frac{\log t - a}{\sqrt{2}\sigma}\right]$, with $a \geq 0$ and $\sigma > 0$, we obtain that $T^*(a)$ is strictly increasing in a, while it is strictly decreasing for a mixed distribution $S(t|a) = aS_L(t) + (1-a)\,S_H(t)$ with $a \in [0,1]$ and where $S_L(t)$ dominates $S_H(t)$ in the hazard rate order, i.e., $\lambda_L(t) < \lambda_H(t)$.

shareholders can do better by using the additional "survival" signals that arrive after $T^*(a)$ to reduce the agency rent given that they are forced to defer payouts until $T_{\min}$ anyway. Hence, when facing a binding deferral constraints, shareholders' optimal contract endogenously satisfies the clawback constraint (CLAW). More formally, we obtain

Proposition 2 *Suppose (PC) is slack and the minimum deferral period satisfies $T_{\min} > T^*(a)$. Then, the optimal contract under Γ_R can be implemented with a single payout date that maximizes the discounted informativeness among all permissible payout dates*

$$T_R^*(a) = \underset{t \geq T_{\min}}{\arg\max}\, e^{-\Delta r t} \mathscr{I}(t|a). \tag{14}$$

The shadow cost of (CLAW) is zero. The manager receives a bonus if and only if $X_{T_R^*(a)} = 0$ and values the compensation package at $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}\left(T_R^*(a)|a\right)} < B(a)$. The compensation cost to bank shareholders is

$$W(a|\Gamma_R) = c'(a)\frac{e^{\Delta r T_R^*(a)}}{\mathscr{I}(T_R^*(a)|a)} > W(a). \tag{15}$$

Proposition 2 captures three general insights pertaining to regulatory interference in the design of compensation contracts. First, facing restrictions on designing one dimension of the compensation contract, the shareholders are forced to adjust other dimensions of the compensation contract to implement the same action. Here, they optimally adjust the bonus size and contingency of pay. Second, these adjustments must be costly to bank shareholders by revealed preference (as they could have chosen the adjusted contract in the absence of regulation). Third, the shareholders may choose a payout time that strictly exceeds the minimum deferral period, $T^*(a|T_{\min}) > T_{\min}$, and, yet, regulation constrains the shareholders, i.e., $T_{\min} > T^*(a)$, and is, thus, costly to them. This unconventional case requires sufficient changes in the growth rate of informativeness after $T_{\min}$. A sufficient condition for the conventional case of $T^*(a|T_{\min}) = T_{\min}$ to obtain is that the convexity condition (12) holds for all $t \geq T_{\min}$.[30]

4.1.2 Optimal action choice and the effects of deferral regulation

We now analyze which action shareholders induce in equilibrium and how it is affected by the minimum deferral period. To abstract from technical details, we omit a possible zero-profit constraint on the side of shareholders and suppose that their problem in (3)

[30] See Jewitt, Kadan, and Swinkels (2008) for a related point when the principal is subject to a minimum wage constraint.

is strictly concave.[31] Hence, the induced equilibrium effort a_R^* is uniquely determined by the associated first-order condition

$$\Pi'(a_R^*) = W'(a_R^*|\Gamma) + \Delta W'(a_R^*). \tag{16}$$

Initially, consider the case without compensation regulation, so that the regulatory tax satisfies $\Delta W(a) = 0$ for all a. We denote the equilibrium action for this benchmark case by a^*. Then (16) implies that shareholders underinvest in risk-management compared to the second-best outcome since $\Pi'(a) < V'(a)$, i.e., $a^* < a_{SB}^*$.

Does a mandatory deferral period $T_{\min} > T^*(a^*)$ nudge the shareholders to induce higher or lower risk management from the manager? As argued in our general Section 2, changes of the equilibrium action in response to compensation regulation are determined by the properties of the indirect Pigouvian tax function $\Delta W(a)$. To transparently highlight how deferral regulation shapes the Pigouvian tax function (and, hence, the equilibrium action), we *initially* posit

Assumption 1 *The optimal unconstrained payout time, $T^*(a)$, is strictly increasing in a.*

Economically, this monotonicity restriction on comparative statics of unconstrained contracts (as satisfied, e.g., in Example 1 if $\beta > 1$) gives *minimum* deferral regulation the "best shot" as it implies that sufficiently high effort levels (with long payout dates $T^*(a)$ in the absence of regulation) are tax-exempt. Put differently, Assumption 1 ensures correctness of the regulator's diagnosis underlying the use of *minimum* deferral regulation in the financial sector. That is, the laissez-faire compensation contract is indeed "too short-termist" in the sense that $T^*(a^*) < T^*(a_{SB})$ from $a^* < a_{SB}$. Of course, when the diagnosis is incorrect, there is no role for deferral compensation in optimal regulation (see further discussion in Section 5). Formally, the following result then is a direct extension of Corollary 1 to the continuous action case.

Lemma 2 *Under Assumption 1, the lowest action for which the shareholders can write unconstrained optimal compensation contracts, $\underline{a}(T_{\min})$, is strictly increasing in $T_{\min}$ for any $T_{\min} \in (T^*(0), \lim_{a\to\infty} T^*(a))$.*

[31] Global concavity of the shareholders' problem can be ensured if the marginal costs of effort are sufficiently convex (so that W is strictly concave in a, see, e.g., Jewitt, Kadan, and Swinkels (2008) for a similar argument). Still, our comparative statics results continue to hold, in the respective monotone comparative statics sense, if there are multiple solutions to the shareholders' problem. The implication of a zero-profit constraint is straightforward in that it simply implies an upper bound on the risk-management effort.

So, while the Pigouvian tax

$$\Delta W(a) = c'(a)\left[\frac{e^{\Delta r T_R^*(a)}}{\mathscr{I}(T_R^*(a)\,|a)} - \frac{e^{\Delta r T^*(a)}}{\mathscr{I}(T^*(a)\,|a)}\right], \tag{17}$$

is unambiguously positive when deferral regulation binds ($\Delta W(a) > 0$, for $0 < a < \underline{a}(T_{\min})$), the effects on the equilibrium action depend, from (16), on whether regulation lowers or raises the marginal tax, $\Delta W'(a)$. The following key Lemma shows that the Pigouvian tax is non-monotonic in a for any given deferral period $T_{\min}$.

Lemma 3 *Suppose Assumption 1 holds and that* $T_{\min} \in (T^*(0), \lim_{a\to\infty} T^*(a))$. *Then* $\Delta W(a)$ *is zero for* $a = 0$ *and* $a \geq \underline{a}(T_{\min})$ *and strictly positive, otherwise. For* $a \in (0, \underline{a}(T_{\min}))$, $\Delta W(a)$ *is strictly increasing in* a *for* a *sufficiently small and strictly decreasing for* a *sufficiently close to* $\underline{a}(T_{\min})$ *with* $\Delta W'(\underline{a}(T_{\min})) = 0$.

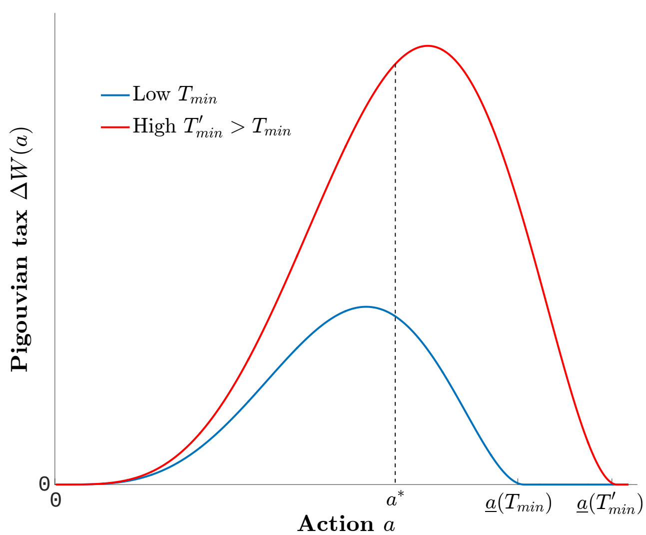

Figure 1. Properties of the indirect Pigouvian tax: The figure plots the regulatory tax, $\Delta W(a) = W(a|\Gamma_R) - W(a|\Gamma)$, as a function of a for two levels of $T_{\min} > T^*(0)$, with a generalized gamma arrival time distribution as specified in Example 1. The chosen parameter values are $\Delta r = 0.75$, $p = 1$, $\beta = 3$, $T_{\min} = 2.3$ and $T'_{\min} = 2.4$, with effort costs $c(a) = a^3/3$ and hazard rate $\lambda(a) = 5/a$.

The intuition behind the non-monotonicity of the regulatory tax (see Figure 1) results from two countervailing effects that jointly determine how deferral regulation operates, which we interpret as a "tax-rate" effect and a "tax-base" effect. First, since the regulator correctly diagnoses the comparative statics of contracts ($T^*(a)$ increasing in a, see Assumption 1), minimum deferral regulation forces banks to adjust the payout time most severely for low actions (relative to the unregulated choice of $T^*(a)$). We interpret this effect as the "tax-rate" effect. It is "good news" for regulation aiming at increasing a as low effort levels are taxed with the highest tax-rate whereas high effort levels, $a \geq \underline{a}(T_{\min})$ are "tax-exempt."

However, there is a countervailing effect since the total tax burden $\Delta W(a)$ is not just a function of the tax rate, but also of the tax base. Mandatory deferral of the compensation package is more costly to bank shareholders if the size of the overall compensation package — akin to the tax base — is larger. This effect is "bad news" for deferral regulation since the required incentive pay increases with the induced action. In particular, in the extreme case when no incentive pay needs to be provided, as $a = 0$, the tax base is zero as $c'(0) = 0$ (see (17)). Since deferring a payout of zero is not costly to the shareholders we obtain that $\Delta W(0) = 0$. Taken together, the properties of $\Delta W(a) = 0$ at the corners and $\Delta W(a) > 0$ in the interior imply the non-monotonicity of the Pigouvian tax function.

The slope of the Pigouvian tax function as characterized in Lemma 3 is now key to understand the comparative statics of the optimal action choice with respect to changes in the minimum deferral period $T_{\min}$. To see this it is useful to rewrite the necessary condition for the optimal interior action choice in (16) as

$$\Pi'(a_R^*) - W'(a_R^*) = \Delta W'(a_R^*), \tag{18}$$

equating marginal profits net of marginal unconstrained wage costs with the marginal Pigouvian tax. Hence, if the marginal tax is negative (positive), the optimal action is larger (smaller) than the unconstrained optimal choice. Based on this intuition, the following Proposition now summarizes how changes in $T_{\min}$ (and, hence, shifts of the entire Pigouvian tax function) affect the equilibrium action.

Proposition 3 *Suppose Assumption 1 holds. Then, for any binding minimum deferral period $T_{\min} > T^*(a^*)$, the equilibrium action a_R^* is strictly bounded above by $\underline{a}(T_{\min})$, i.e., $a_R^* < \underline{a}(T_{\min})$. Further, a sufficiently small increase of $T_{\min}$ above the unconstrained optimal payout time $T^*(a^*)$ induces an increase in the action relative to laissez-faire, $a_R^* > a^*$. while, the action decreases $a_R^* < a^*$ for $T_{\min}$ sufficiently high with $\lim_{T_{\min}\to\infty} a_R^* = 0$.*

The Proposition first establishes that the constrained-optimal action choice is interior, i.e., $a_R^* < \underline{a}(T_{\min})$, such that the first-order condition (18) applies. Intuitively, when facing binding deferral regulation, shareholders find it optimal to adjust both the action to be implemented as well as the contract used to implement this action choice, thereby optimally balancing the marginal inefficiency of deviating from the *unconstrained* optimal action choice, $\Pi' - W'$, with the marginal taxation costs arising from having to write an inefficient compensation contract $\Delta W'$.

Whether binding deferral regulation then raises or lowers the equilibrium action relative to a^* depends on the severity of the deferral period. If the minimum deferral period is sufficiently close to the unconstrained optimal payout time $T^*(a^*)$, as is the case for $T_{\min}$ in Figure 1, the unregulated choice $a^* < \underline{a}(T_{\min})$ is close to $\underline{a}(T_{\min})$. Lemma 3 then implies that the marginal regulatory tax is negative for $a \in (a^*, \underline{a}(T_{\min}))$. From (18) it, thus, is strictly beneficial for bank shareholders to induce higher effort from the bank manager. For sufficiently stringent minimum deferral periods, the implied outwards shift in the Pigouvian tax function (compare Lemma 2) always results in a positive marginal tax (see $T'_{\min}$ in Figure 1 for an illustration) inducing shareholders to implement lower effort. Finally, in the "trivial" limit, as $T_{\min} \to \infty$, the *marginal* compensation cost of inducing *any* action $a > 0$ that requires some incentive pay approaches infinity. Thus, the action must go to zero in the limit.

Summing up, imposing a binding mandatory deferral period indeed leads to a strictly higher equilibrium level of a as long as the imposed deferral period is not too onerous. While deferral regulation causes an increase in the level of compensation costs it is effective at raising a because it taxes marginally higher effort choices less. The left panel of Figure 2 plots an example specification illustrating these comparative statics results. By Proposition 2, the implemented action choice is unaffected by the clawback requirement.

We note that the success of mild minimum deferral regulation crucially depends on the assumption that higher risk-management effort a is optimally implemented with longer payout dates, i.e., $\frac{d}{da}T^*(a) > 0$ (see Assumption 1). In the (trivial) opposite case, $\frac{d}{da}T^*(a) < 0$, only high risk-management effort would be taxed such that both the tax rate as well as the tax base effect push towards lower effort. Taken together, the success of moderate minimum deferral regulation to raise equilibrium effort requires that the regulator correctly diagnoses comparative statics of unconstrained optimal deferral periods, and, accordingly, the information environment the bank is operating in (cf., Result 1). We will now see that the case for compensation regulation is stronger when the manager's participation constraint binds.

4.2 Binding participation constraint

We now consider the case where the manager has a strictly positive reservation value $U > 0$. This value could be interpreted as the manager's outside option reflecting for instance the degree of competition for scarce managerial talent. From the perspective of the shareholders of a particular bank, this outside option is exogenously given by the value of

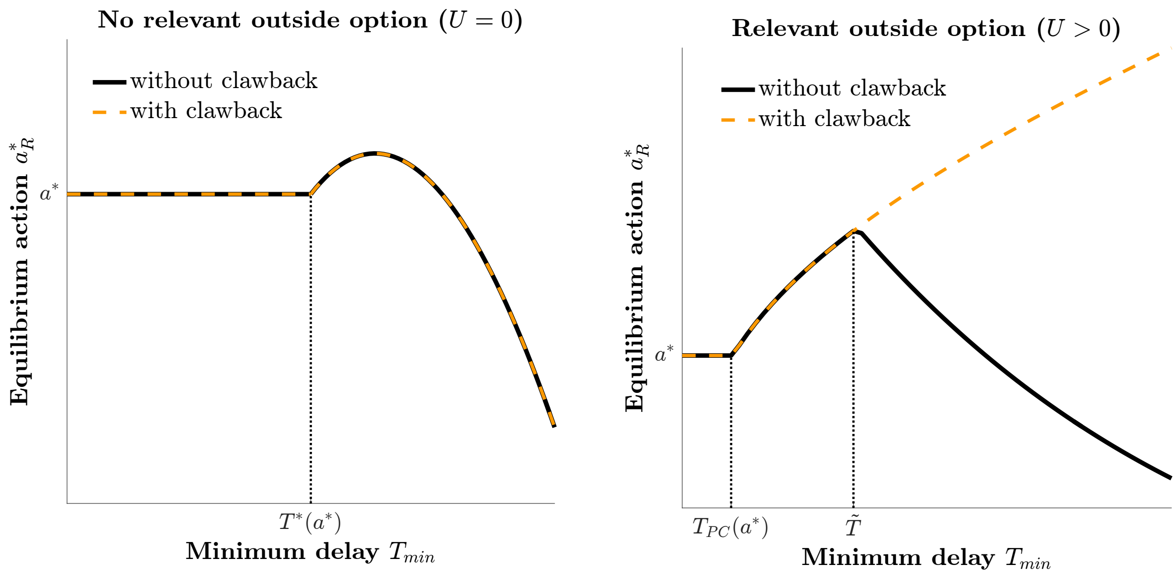

Figure 2. Equilibrium action: The figure plots the equilibrium action as a function of the minimum deferral period $T_{\min}$ for the case of $U = 0$ (left panel) and $U > 0$ (right panel). The information environment is as in Example 1 with a generalized gamma arrival time distribution. The chosen parameter values are $p = 1$, $\beta = 3$, $r = 0.05$, $\Delta r = 3$, $y = 100$, $k_{\min} = 0.1$, $U = 0$ (left panel) and $p = 1$, $\beta = 1$, $r = 0.05$, $\Delta r = 3$, $y = 100$, $k_{\min} = 0.1$, $U = 1.5$ (right panel), with costs $c(a) = \frac{1}{3}a^3$ and hazard $h(a) = \frac{5}{a}$.

the manager's alternative employment opportunities, e.g., in the (unregulated) financial sector.[32] When the manager's outside option determines the value of her compensation package bank shareholders' rent-extraction motive is absent. Still, the structure of our subsequent analysis mirrors the one in the rent-extraction case. First, we consider the shareholders' compensation design problem of implementing a given action a at lowest cost as formally stated in Problem 1. Second, we study the equilibrium action choice problem given in Problem 2.

4.2.1 Compensation design with binding PC

The interesting (and novel) case to study is the design of optimal contracts when the manager's outside option is sufficiently high such that the participation constraint binds. (Otherwise, Lemma 1 and Proposition 2 still apply in the presence of a strictly positive, but irrelevant outside option). To abstract from additional case distinctions, we suppose from now on that the convexity condition (12) holds for all t.[33]

[32] It may be interesting to analyze how industry-wide compensation regulation may affect the value of (within-industry) outside employment opportunities.

[33] Optimal unconstrained contracts with a binding participation constraint may otherwise require two payout dates (cf., Lemma 4 in Hoffmann, Inderst, and Opp (2017)). While this analysis brings out novel

Unregulated optimal compensation contracts (PC binds). If the manager's participation constraint (PC) binds, her valuation of the compensation package inducing action a is pinned down by her participation constraint, $B(a) = U + c(a)$. The timing of payouts under the optimal contract does, thus, not reflect a rent-extraction motive, but aims at minimizing deadweight impatience costs subject to incentive compatibility. Applying Lemma 4 in Hoffmann, Inderst, and Opp (2017) to our concrete information setting we obtain:

Lemma 4 *Suppose (PC) binds. Then, the manager receives a bonus if and only if* $X_{T_{PC}(a)} = 0$ *where the single payout date* $T_{PC}(a)$ *solves*

$$\mathscr{I}(t|a) = -\frac{d\Lambda(t|a)}{da} = \frac{c'(a)}{U + c(a)}. \tag{19}$$

Shareholders' compensation costs are $W(a) = (U + c(a))\, e^{\Delta r T_{PC}(a)}$.

Optimal compensation contracts with and without binding (PC) share the feature that bonus payments are only made conditional on bank survival at a single payout date. The crucial difference is that the optimal payout time with binding (PC) does not aim at extracting the manager's agency rent, trading off informativeness *growth* at the margin with impatience costs resulting from $\Delta r > 0$, but at minimizing deadweight impatience costs subject to incentive compatibility. In particular, the right-hand side of the optimality condition in (19), $\frac{c'(a)}{U+c(a)}$, can be interpreted as the *level* of informativeness required for any compensation contract with binding participation constraint to be incentive-compatible.[34] Hence, in order to minimize deadweight impatience costs, it is optimal to pay out at the earliest date at which the informativeness contained in the survival history, $\mathscr{I}(t|a) = -\frac{d\Lambda(t|a)}{da}$, attains the value $\frac{c'(a)}{U+c(a)}$. This date is defined as $T_{PC}(a)$.[35]

Again, it is crucial for our subsequent analysis of the effects of deferral regulation to understand the comparative statics of the unconstrained optimal payout time $T_{PC}(a)$ in

insights for optimal compensation design, it does not generate additional insights regarding the effects of compensation regulation which is the focus of this paper.

[34] Informativeness is appropriately measured as the pay-weighted average log-likelihood ratio associated with payout histories (contingency and timing) stipulated in a compensation contract.

[35] If shareholders instead stipulated that all payments occur before date $T_{PC}(a)$ to economize on impatience costs, the maximal available informativeness at any date $t < T_{PC}(a)$ is not sufficient to satisfy (IC) for any compensation package valued at $U + c(a)$. If instead shareholders stipulated that all payments occur after date $T_{PC}(a)$ still fixing the manager's valuation of the compensation package at $U + c(a)$, they would incur higher impatience costs. Further, the convexity condition implies that contracts featuring a combination of short-term payout dates, $T_S < T_{PC}$, and long-term payout dates, $T_L > T_{PC}$ are strictly dominated by a contract with single payout date at T_{PC}.

the induced effort level a. Since binding (PC) eliminates the subtle analysis of how the trade-off between informativeness growth and impatience costs differs across actions (see (13)), we now obtain unambiguous comparative statics. Higher risk-management effort is not only implemented with higher total compensation for the manager, $U+c(a)$, to satisfy (PC), but also requires longer deferral periods to condition pay on more informative performance signals in order to satisfy (IC).

Lemma 5 *The payout date $T_{PC}(a)$ is strictly increasing in a.*

Thus, when there is strong competition for managerial talent, so that U is sufficiently high, we obtain comparative statics that unambiguously support the case for *minimum* deferral regulation according to Corollary 1 independent of the underlying arrival time distribution, i.e., a restriction akin to Assumption 1 is no longer required.

Constrained optimal compensation contracts (PC binds). We now study the optimal restructuring of contracts when the minimum deferral period prohibits the unconstrained optimal contract. To highlight the incremental effect of the clawback clause with binding participation constraint, we will consider both the cases of i) pure deferral regulation and ii) deferral regulation *plus* clawback requirements.

Proposition 4 *The participation constraint (PC) binds if and only if $U > \overline{U} := \frac{c'(a)}{\mathscr{I}(T_R^*(a)|a)} - c(a)$. Suppose that $U > \overline{U}$ and $T_{\min} > T_{PC}(a)$ such that shareholders cannot write the unconstrained optimal contract:*
i) *If shareholders only face (DEF), then all payouts under an optimal contract are made at date $T_{\min}$ including strictly positive rewards for some failure histories, $X_{T_{\min}} = 1$. The resulting wage costs are $W(a) = (U + c(a))\, e^{\Delta r T_{\min}}$.*
ii) *If shareholders face both (DEF) and (CLAW), the action cannot be implemented.*

As discussed before, binding (IC) and (PC) require that the payout-weighted informativeness be equal to $\frac{c'(a)}{U+c(a)}$. Since the informativeness contained in the survival history at any date $T_{\min} > T_{PC}(a)$ exceeds this level, i.e., $\mathscr{I}(T_{\min}|a) > \frac{c'(a)}{U+c(a)}$, the *only* way to induce action a is to deviate from purely survival-contingent contracts. This directly explains why the action cannot be implemented if shareholders additionally have to respect the clawback requirement (CLAW). Economically, this non-implementability result follows from the fact that the shareholders can no longer adjust the contract in response to regulation as they are (exogenously) constrained on all available margins: The manager's value of the compensation package is fixed by her outside option, and the timing as well as contingency of pay are restricted by (DEF) and (CLAW) respectively. As a result the set of incentive compatible contracts is empty whenever deferral regulation binds. When (CLAW) is absent, shareholders instead can adjust the contingency of pay by partially rewarding failure histories. A natural implementation of the constrained optimal contract then is to condition the $T_{\min}$-bonus on survival only up to date $T_{PC}(a) < T_{\min}$, i.e., to ignore any (failure) signals between dates $T_{PC}(a)$ and $T_{\min}$. We now turn to the question whether shareholders ever have an incentive to write such contracts in equilibrium, i.e., for an optimally chosen action.

4.2.2 Optimal action choice and the effects of deferral regulation (PC binds)

We now analyze bank shareholders' optimal action choice and how it is affected by changes in compensation regulation using our Pigouvian tax approach. As shown in Corollary 1 and the discussing following Assumption 1, the impact of the minimum deferral period on equilibrium risk-management effort a_R^* is closely linked to the comparative statics of the unconstrained optimal payout time in a. In contrast to the previously studied rent-extraction case (cf., Lemma 1) the optimal contract with binding (PC) unambiguously *implies* that $\frac{d}{da}T_{PC}(a) > 0$ (see Lemma 5). Hence, independently of the concrete information environment, imposing a minimum deferral period T_{min} prevents the bank from using the unregulated compensation contract for all actions below but not for those above a cutoff action which we again denote — with slight abuse of notation — by $\underline{a}(T_{\min})$, eventhough the functional form differs from the rent-extraction case as it now solves $T_{\min} = T_{PC}(a)$ (rather than $T_{\min} = T^*(a)$). As before, $\underline{a}(T_{\min})$ is an increasing function of $T_{\min}$ (cf., Lemma 2).

Lemma 6 *The Pigouvian tax $\Delta W(a)$ is zero for all $a \geq \underline{a}(T_{\min})$. For case i) of pure deferral regulation $\Delta W(a) = (U + c(a))\left[e^{\Delta r T_{\min}} - e^{\Delta r T_{PC}(a)}\right] > 0$ for any $a < \underline{a}(T_{\min})$ with $\lim_{a \uparrow \underline{a}(T_{\min})} \Delta W'(a) < 0$. For case ii) when shareholders face additional clawback requirements, actions $a < \underline{a}(T_{\min})$ are non-implementable and we set $\Delta W(a) = \infty$.*

First, since by Proposition 4 low actions $a < \underline{a}(T_{\min})$ cannot be implemented when subject to the clawback clause (case ii) shareholders effectively face an infinite tax on these actions. For case i) of pure deferral regulation, any action $a < \underline{a}(T_{\min})$ is still implementable, yet only with inefficient compensation contracts that partially reward failure, resulting in a positive, but finite, tax. As for the case with slack participation constraint the resulting Pigouvian tax function is shaped by the interaction between the "tax base" as given by the value of the compensation package, $(U + c(a))$, and the "tax rate" as given by the timing inefficiency $\left[e^{\Delta r T_{\min}} - e^{\Delta r T_{PC}(a)}\right]$, which for the case illustrated in Figure 3 gives rise to the familiar non-monotonicity (see the solid red line).

However, the Pigouvian tax function with binding (PC) also features an important novel characteristic in that there is a kink at the cut-off action $\underline{a}(T_{\min})$.[36] In contrast to the case with (PC) slack where the Pigouvian tax function was smooth, this implies that even *marginal* regulatory distortions in the timing of payouts generate *first-order* losses to shareholders. Economically, the kink results from the fact that with binding (PC) shareholders can no longer use the additional information that arrives between $T_{PC}(a)$ and $T_{\min}$ to reduce managerial rents in order to offset the forced timing inefficiency.

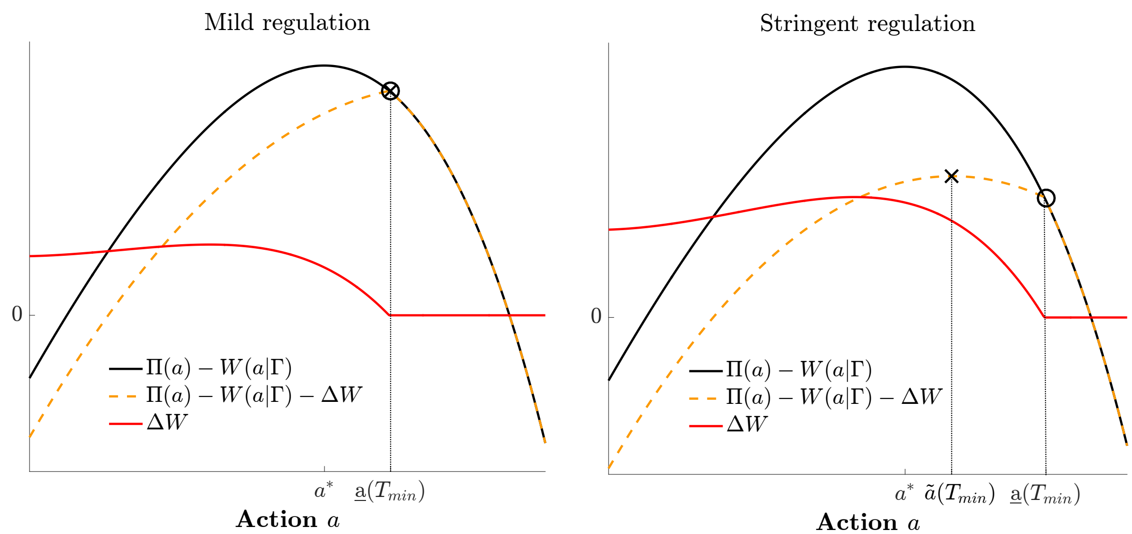

Figure 3. Pigouvian tax function (PC binds): The two panels plot the unregulated and regulated net profit as well as the Pigouvian tax with binding participation constraint as a function of a for two different values of $T_{\min} > T_{PC}(a^*)$. The arrival time distribution is exponential (Example 1 with $p = \beta = 1$) and the chosen parameter values are $\Delta r = 0.75$, $r = 0.05$, $U = 2$, $k_{\min} = 0.2$, $y = 30$, $T_{\min} = 0.75$ (left panel) and $T_{\min} = 1$ (right panel) with effort costs $c(a) = a^2/2$ and hazard rate $\lambda(a) = 5/a$. In both panels, the black cross indicates the maximal net profit under pure deferral regulation, while the black circle marks the respective value when an additional clawback clause applies.

We now turn to how the shape of the Pigouvian tax affects the equilibrium action choice. For ease of exposition, we again assume that the shareholders' unconstrained problem is strictly concave in a and that the participation constraint is sufficiently high so that it binds already in the absence of regulation.[37] Then from Problem 2 the laissez-

[36] The second novel feature is that for any $T_{\min} > 0$ the tax of implementing $a = 0$ is strictly positive, i.e., $\Delta W(0) = U\left[e^{\Delta r T_{\min}} - 1\right] > 0$. However, this feature turns out to be largely irrelevant for the subsequent analysis.

[37] One can show that for any $U > 0$ there exists a threshold $T_1 \geq 0$ such that PC binds for any sufficiently long deferral period $T_{\min} \geq T_1$. This result follows from the fact that as $T_{\min}$ grows large and,

faire action a^* is uniquely determined by the first-order condition $\Pi'(a) = W'(a)$ with $W(a) = (U + c(a))\, e^{\Delta r T_{PC}(a)}$.

Proposition 5 *Let $\tilde{a}(T_{\min})$ denote the unique solution to $\Pi'(a) = c'(a)\, e^{\Delta r T_{\min}}$.*
i) For pure deferral regulation, equilibrium risk management effort is given by:

$$a_R^* = \begin{cases} \underline{a}(T_{\min}) & T_{\min} \in [T_{PC}(a^*), \tilde{T}], \\ \tilde{a}(T_{\min}) & T_{\min} > \tilde{T}, \end{cases}$$

where the threshold $\tilde{T}$ is the unique solution to $\underline{a}(T_{\min}) = \tilde{a}(T_{\min})$. The action is strictly increasing in the minimum deferral period for $T_{\min} \in [T_{PC}(a^*), \tilde{T}]$ and strictly decreasing for $T_{\min} > \tilde{T}$. In the latter case shareholders write equilibrium compensation contracts that partially reward failure.
ii) With additional clawback requirements, equilibrium effort is $a_R^* = \underline{a}(T_{\min})$ and, hence, strictly increasing in $T_{\min}$ for any binding deferral period.

Consider, first, the case with clawback for which the Pigouvian tax associated with any action $a < \underline{a}(T_{\min})$ is infinite, while it is zero when inducing any action $a \geq \underline{a}(T_{\min})$ (see Lemma 6). Thus, with binding deferral regulation, $T_{\min} > T_{PC}(a^*)$, the shareholders' problem is akin to maximizing the *unconstrained* objective, $\Pi(a) - W(a|\Gamma)$ (solid black line in Figure 3), subject to a regulatory implementability constraint $a \geq \underline{a}(T_{\min})$. When the latter binds, the constrained-optimal choice $a_R^* = \underline{a}(T_{\min})$ minimizes the regulatory action distortion relative to the laissez-faire action a^* (see black circle in left and right panel of Figure 3).[38] By Lemma 5 equilibrium effort $\underline{a}(T_{\min})$ then is strictly increasing in the deferral period.

We now turn to the equilibrium action choice absent a clawback requirement. In this case actions $a < \underline{a}(T_{\min})$ can still be implemented by partially rewarding failure, which results in a strictly positive, yet finite tax (see red line in Figure 3). However, when $T_{\min}$ is sufficiently small, a strictly positive tax is sufficient to induce the same equilibrium outcome as in the case with an additional mandatory clawback constraint discussed previously. To see this, consider the case where $T_{\min}$ is slightly above $T_{PC}(a^*)$ (see left panel of Figure 3). Since taxation costs arising from writing inefficient compensation contracts that partially reward for failure are *first-order* for all actions $a < \underline{a}(T_{\min})$ even in the limit as $\lim_{a \uparrow \underline{a}(T_{\min})} \Delta W'(a) < 0$, whereas private losses due to marginal deviations

thus, the informativeness of available performance signals improves, the equilibrium action in the relaxed problem without (PC) goes to zero. Both effects - lower action and better performance measurement - imply that the manager's rent eventually goes to zero.

[38] Formally, this follows from strict concavity of the unconstrained objective.

from the *unconstrained* optimal action choice a^*, $\Pi'(a) - W'(a)$, are initially second-order by the envelope theorem, shareholders again choose to implement the lowest action that is tax-exempt $a_R^* = \underline{a}(T_{\min})$, as indicated by the black cross in the left panel Figure 3. Hence, for mild deferral regulation the equilibrium outcomes with and without clawback constraint are identical.

However, as $T_{\min}$ rises and with it $a_R^* = \underline{a}(T_{\min})$, the marginal private losses from action distortions relative to the unconstrained optimum, $\Pi'(\underline{a}(T_{\min})) - W'(\underline{a}(T_{\min}))$, become larger and larger until they match the first-order taxation costs arising from not further increasing the action for $T_{\min} = \tilde{T}$. From that point onwards, $T_{\min} > \tilde{T}$, shareholders find it optimal to balance marginal action distortions with marginal taxation costs (see right panel of Figure 3), implementing an equilibrium action that is interior $a_R^* = \tilde{a}(T_{\min}) < \underline{a}(T_{\min})$ and decreasing in the minimum deferral period. The latter feature follows directly from Lemma 6 as the marginal tax is increasing in the minimum deferral period $\partial^2 \Delta W(a) / \partial a \partial T_{\min} = c'(a) \Delta r e^{\Delta r T_{\min}}$. Interestingly, equilibrium contracts under pure deferral regulation, thus, partially reward failure for $T_{\min} > \tilde{T}$, see black cross in the right panel Figure 3, such that an additional clawback constraint binds. One may have conjectured that this cannot be optimal since it implies that (IC) is slack such that shareholders could costlessly induce higher effort by shifting rewards towards survival histories. However, Proposition 5 reveals that this conjecture is wrong. The logic fails since shareholders still need to compensate the bank manager for higher effort costs — by binding (PC) — and an additional markup due to impatience costs.

Taken together, these results suggest that the qualitative effect of pure deferral regulation on the equilibrium action choice is robust regardless of whether (PC) binds or not: Moderate deferral periods induce an increase in equilibrium risk management effort, whereas too onerous deferral periods unambiguously backfire (cf., Figure 2). Recall, however, that, when (PC) is slack, the positive effects of mild regulatory intervention on equilibrium effort apply if and only if Assumption 1 is satisfied, which essentially requires the regulator to know specifics of the information environment (the arrival time distribution), whereas for (PC) binding these results hold generally.[39] Further, both cases crucially differ in terms of the contract adjustments that shareholders undertake in response to deferral regulation. While the rent extraction equilibrium marginally balances contracting inefficiencies (Pigouvian tax) with action distortions for any regulatory intervention in the timing of pay, when (PC) binds, moderate deferral regulation ($T_{\min} < \tilde{T}$) exclusively causes (privately costly) changes in the equilibrium action, but no contracting

[39] See Figure 3 depicting the case with an exponential arrival time distribution not satisfying Assumption 1 as an illustration.

inefficiencies, i.e., the Pigouvian tax at the equilibrium action is zero. When facing stringent deferral periods, shareholders eventually start writing inefficient contracts also with binding (PC) in order to implement lower (less costly) actions, which requires payouts following (some) failure histories. Hence, a clawback clause, which imposes constraints on the contingency of pay, has a bite only when the manager has a relevant outside option. As the addition of such a contingency requirement then prevents the eventual backfiring of pure deferral regulation, a clawback clause is required if the regulator aims to induce large (and costly) deviations from privately optimal decisions (see right panel of Figure 2).

5 Normative analysis

While our positive analysis took regulation as given, we now analyze the regulator's optimal choice of capital and compensation regulation, and when these tools are sufficient to implement the second-best outcome. Here, second-best welfare refers to the maximal welfare subject to the moral hazard problem, which could be achieved, e.g., if the regulator could write compensation contracts directly.[40] Given our welfare criterion in (9) the corresponding welfare is given by $\Omega\left(a^{SB}\right)$ where

$$a^{SB} = \arg\max_{a\in\mathscr{A}} V\left(a\right) - W\left(a|\Gamma\right).$$

Importantly, achieving second-best welfare not only requires that a^{SB} be implemented (action efficiency), but also that it be implemented with an unconstrained optimal compensation contract (contracting efficiency).

Our normative analysis restricts the available regulatory tool set to capital regulation and the considered regulatory constraints on compensation design, (DEF) and (CLAW). The formal problem of the regulator can, thus, be stated as:[41]

Problem 3 (Optimal policy mix) *The regulator chooses $T_{\min} \geq 0$ and $k_{\min}$ to solve*

$$\max_{k_{\min},T_{\min}} V\left(a_R^*\left(k_{\min},T_{\min}\right)\right) - W\left(a_R^*\left(k_{\min},T_{\min}\right)|\Gamma_R\right), \tag{20}$$

$$s.t.\ a_R^*\left(k_{\min},T_{\min}\right) = \arg\max_{a\in\mathscr{A}} \Pi\left(a|k_{\min}\right) - W\left(a|\Gamma\right) - \Delta W\left(a|T_{\min}\right).$$

[40] Prescribing the entire compensation contract, in contrast to structural constraints, is neither legally feasible nor desirable if the regulator faces additional informational constraints, such as imperfect knowledge of model parameters. We discuss such constraints in the conclusion.

[41] Since the clawback clause never hurts under optimal regulation, we can reduce the dimensionality by optimizing solely over the choice of $T_{\min}$ and $k_{\min}$.

As can be seen from Problem 3, both compensation and capital regulation affect welfare *indirectly* via bank shareholders' optimal action choice a_R^*, which is now highlighted in our notation by making the dependence on $k_{\min}$ and $T_{\min}$ explicit. However, the mechanism of how a_R^* changes with regulation is quite different for the two regulatory tools. In our setting, capital regulation operates by reducing the wedge between private (bank) profits and societal welfare $\Pi(a|k_{\min}) - V(a)$ (see (10)), and, thus, directly addresses the root of the shareholders' preference distortion.[42] In contrast, compensation regulation does not target the root of the distortion, i.e., it does not cause bank shareholders to internalize tax payer losses upon bank failure. Yet, by acting as a Pigouvian tax, $\Delta W(a|T_{\min})$, it may be effective in changing actions via its differential effect on implementation costs (see our discussion in Section 2). In addition, compensation regulation (but not capital regulation) also enters the regulator's objective function (20) *directly* via the dependence of compensation costs on the space of admissible contracts Γ_R.

We now analyze the optimal policy mix as given by the solution to Problem 3. If the solution is not unique, we suppose that the regulator selects the one that minimizes costs to the tax payer.[43] The following immediate result provides a useful benchmark:

Lemma 7 *If there are no costs associated with equity financing, sufficiently high capital regulation alone, $k_{\min} = 1$, achieves the second-best outcome.*

The intuition for this result is straightforward: If raising capital is not costly optimal regulation simply eliminates the bailout distortion in shareholders' preferences and lets shareholders work out the optimal compensation package. As capital regulation eliminates the "source of distortions," the privately optimal action choice is also socially optimal and so is the compensation package used to implement it. Hence, there is no need for compensation regulation.

While this benchmark result highlights an important intuition, it assumes away any costs of increasing minimum capital requirements. This is not realistic for several reasons. First, as is a standard assumption in the literature (see e.g., Repullo and Suarez (2013) or Harris, Opp, and Opp (2018)), issuance of additional equity, $\Delta K > 0$, may involve additional costs.[44] If these costs of raising equity are prohibitively high (as in Malherbe (2017)) and regulators want to ensure that banks are able to finance the fixed-scale

[42] Put differently, capital regulation acts as if the regulator could charge an "ex-post" tax on bank shareholders for bank failure where the upper bound for tax collection is given by the capital provided ex ante by bank shareholders (due to their limited liability). Shareholders, thus, internalize (part of) the losses otherwise borne by the tax payer.

[43] One could formalize this selection criterion by incorporating dead-weight taxation costs for bailouts and taking the limit as the taxation costs go to zero.

[44] In contrast, paying out dividends, $\Delta K \leq 0$, is usually assumed to be costless to shareholders.

investment of size 1, capital ratio requirements are effectively bounded above by the existing capital, K_0, i.e., $k_{\min} \leq K_0$. Similarly, significant bank leverage reductions should be expected to involve social costs, when accounting for banks' role in producing socially valuable liquid claims (see e.g., DeAngelo and Stulz (2015)). Moreover, capital regulation may also be restricted due to political economy frictions, reflecting bankers' effective lobbying for low capital requirements. In order to account for these various potential constraints on minimum capital requirements in the simplest possible way, we now proceed by imposing an upper bound on $k_{\min}$, which we denote by $k^*_{\min}$.[45]

In particular, moving beyond the benchmark in Lemma 7, we next study whether there is a role for the considered compensation regulation when $k^*_{\min} < 1$. In line with the structure of our positive analysis, we again make a case distinction based on the value of the manager's outside option. Let $\overline{U}^{SB}$ denote the lowest outside option for which (PC) binds if the second-best action a^{SB} is implemented with an *unconstrained* optimal compensation contract. This threshold level is given by

$$\overline{U}^{SB} := \frac{c'(a^{SB})}{\mathscr{I}(T^*(a^{SB})|a^{SB})} - c\left(a^{SB}\right).$$

Proposition 6 *Suppose $U < \overline{U}^{SB}$. If Assumption 1 holds, then it is optimal to complement capital regulation, $k_{\min} = k^*_{\min}$, with a binding deferral period of $T_{\min} > T^*(a^*)$. The optimal policy mix cannot achieve second-best welfare and $a^*_R < a^{SB}$.*

The intuition for this Proposition builds on results of the previous section. When the manager's participation constraint is slack, any binding deferral regulation, $T_{\min} > T^*(a^*)$, will induce inefficient compensation contracts in equilibrium, i.e., $\Delta W(a^*_R) > 0$ (see Proposition 3). As a result, it is strictly optimal for the regulator to first exhaust the (costless) lever of capital regulation up to the maximum, thereby reducing the gap between the privately chosen action and a^{SB}. However, since capital regulation cannot go all the way, there is potential scope for (costly) minimum deferral regulation.

A strict welfare improvement of marginal deferral regulation follows from the fact that the associated costs in terms of small timing inefficiencies cause second-order taxation costs, while the associated welfare benefits arising from higher risk-management effort and, thus, a smaller bailout distortion are first-order. However, as the deferral period is further increased, the regulator eventually needs to account for first-order taxation costs, and, hence, optimally induces risk-management effort below a^{SB}. Hence, second-best

[45] All of our insights with regards to compensation regulation are robust if $k^*_{\min}$ was endogenously determined (say via convex cost of raising equity) or if the investment technology allowed for continuous investment.

welfare cannot be achieved.

The welfare implications of the optimal mix of capital and minimum deferral plus clawback regulation are considerably different when the manager's outside option is sufficiently large.

Proposition 7 *Suppose $U \geq \overline{U}^{SB}$. Then it is optimal to complement capital regulation, $k_{\min} = k^*_{\min}$, with a binding deferral period of $T_{\min} = T_{PC}\left(a^{SB}\right)$. A clawback clause strictly increases welfare if and only if $k^*_{\min}$ is sufficiently small. Second-best welfare is achieved.*

Interestingly, despite the restrictive set of tools for compensation regulation we consider, second-best welfare can now be achieved independent of the restrictions on capital regulation as captured by $k^*_{\min}$. Qualitatively, the result also implies a substitutability of the intensity of capital regulation and the degree of optimal intervention in compensation contracts: Lower capital regulation optimally requires larger differences between payout times of laissez-faire compensation contracts and imposed minimum deferral periods $T_{PC}\left(a^{SB}\right)$. Moreover, for sufficiently low capital regulation it is even required to intervene in the contingency of payouts and complement pure deferral regulation with a clawback clause.

The crucial difference relative to the case presented in Proposition 6 is that in the presence of a binding participation constraint, shareholders respond to compensation regulation (with clawbacks) by solely adjusting the implemented action rather than sacrificing efficiency of the compensation design, i.e., for any action chosen in equilibrium we obtain $\Delta W\left(a^*_R\right) = 0$. Hence, by imposing a minimum payout time corresponding to the unconstrained optimal payout time of the second-best action, $T_{\min} = T_{PC}\left(a^{SB}\right)$, the regulator nudges the shareholders to just implement the desired second-best action (with an efficient compensation contract).[46] While imposing a clawback constraint never hurts, such a clause is only required as part of an optimal regulation if the difference between the desired second-best action a^{SB} and $a^*_R\left(k^*_{\min}, 0\right)$, the action induced by maximal capital regulation, $k_{\min} = k^*_{\min}$ and no compensation regulation, is sufficiently large. Intuitively, this difference is large if shareholders' preference distortions are large, i.e., $k^*_{\min}$ is low. In that case, pure deferral regulation (without clawbacks) would imply that $T_{PC}\left(a^{SB}\right) > \tilde{T}$ so that equilibrium compensation contracts would inefficiently reward failure (Proposition 5).[47]

[46] Note that this argument does not hold for the case of (PC) slack. If the regulator imposed $T_{\min} = T^*\left(a_{SB}\right)$ then $a^*_R < a_{SB}$ (see Proposition 3). Further, we implicitly assume that bank profits are non-negative at the optimal regulation.

[47] Graphically, the induced action would be located on the *lower* branch in the right panel of Figure 2,

Summary of policy implications Our normative analysis shed light on the welfare effects of two prominent regulatory tools and their interaction. In our setting, the optimal policy mix is as follows. First, it is optimal to exhaust the lever of capital regulation, which causes shareholders to internalize bank failure and, additionally, lowers losses for tax payers. Then, if the outside option of the manager is sufficiently high — which may be realistic in the financial sector — there is a strong case for additional deferral regulation as small increases in mandatory deferral times compared to the laissez-faire contract unambiguously raise welfare. In particular, this is true independently of the information environment. In that sense minimum deferral regulation can be interpreted as "robust." Moreover, it is even possible to achieve the second-best outcome provided that the regulator understands the structure of information arrival over time, and, is, hence, able to calibrate the optimal degree of regulatory intervention. When the manager earns a rent (her participation constraint is slack), the case for deferral regulation is more complex. Whether it should be used at all depends on the information process, and, in particular, whether higher risk management is optimally implemented with longer deferral periods. Then, if the comparative statics go the right way, some deferral regulation indeed raises welfare, but it is not sufficient to induce the second-best outcome.

6 Conclusion

Our paper is motivated by recent regulatory initiatives imposing structural constraints on compensation contracts in the financial sector in an attempt to reduce excessive risk-taking. In particular, we study the positive and normative implications of mandatory deferral and clawback requirements. We find that moderate deferral periods typically improve risk-management while large interventions unambiguously backfire. The mechanism at play behind this non-monotonicity is that the implicit tax imposed by mandatory deferral is, on the one hand, higher for actions for which it is optimal to write short-duration contracts in the absence of regulation, which c.p. is low risk-management effort ("tax rate effect"). On the other hand, the tax is increasing in the size of the compensation packages, and, thus in the incentivized level of effort ("tax base effect"). Additional clawback requirements help prevent backfiring if there is high competition for bank executives. We develop these results using a novel and broadly-applicable Pigouvian tax approach which allows to transparently characterize the *positive* effects of any type of compensation regulation (or, more broadly, restrictions on compensation design) regardless of the friction that motivates regulatory intervention.

i.e., in the region where the induced action is strictly decreasing in $T_{\min}$ as $T_{\min} = T_{PC}(a_{SB}) > \tilde{T}$.

Our analysis suggests several avenues for future research. First, one may apply the results regarding deferral regulation to other economic settings where such interventions may be warranted, such as corporate governance problems at the top executive level, or, incentives for product advisors/insurance agents at the lower level of the hierarchy. Second, our Pigouvian tax approach lends itself naturally to analyze the effects of other regulatory interventions, such as bonus caps or restrictions on equity-based compensation. Third, one could think of the headquarter of a firm or institution as the "regulator" that imposes quasi-regulatory constraints on compensation contracts at subdivisions. Fourth, in our application to financial sector regulation we focus on a parsimonious specification where the manager takes an action only once instead of sequentially and the costs of mandatory deferral result from the manager's relative impatience rather than preferences for intertemporal consumption smoothing as would be the case with a risk-averse manager. While a complete robustness analysis incorporating these realistic features is beyond the scope of this paper, our general Pigouvian tax approach as well as the basic intuition of tax rate and tax base effects developed in our tractable specification continue to apply.

Last but not least, it may be interesting to impose realistic informational constraints on the regulator and analyze optimal regulation as a solution to the implied mechanism design problem rather than restricting the analysis to specific regulatory tools observed in practice.[48] When is it optimal to micromanage the agency problem via interfering in the compensation contract? When is it optimal to directly target the externality? Our analysis of the interaction of capital regulation and deferral/clawback regulation can be thought of as a first, modest step in this direction.

[48] It may also be interesting to extend the optimal corporate taxation mechanism of Dávila and Hébert (2018) by allowing for an internal agency problem within the firm.

Appendix A Proofs

Proof of Proposition 1. See main text. **Q.E.D.**

Proof of Lemma 1. From Theorem B.1 of Hoffmann, Inderst, and Opp (2017) we know that, for any information process, the unregulated optimal contract features a single payout contingent on the most informative performance history (here survival, see main text) at date $T^*(a) = \arg\max_t e^{-\Delta rt} \mathscr{I}(t|a)$. By differentiability of the informativeness function $\mathscr{I}(t|a)$ as given in (11) we then obtain the necessary condition in (13). Sufficiency follows from the fact that $T^*(a)$ must be strictly positive as $\mathscr{I}(t|a)$ is strictly increasing with $\mathscr{I}(0|a) = 0$ and finite by condition (12). The remaining results then follow immediately from substituting the optimal payout time in (IC) and the shareholders' objective. **Q.E.D.**

Proof of Proposition 2. We know from Lemma 1 that, absent regulation, wage costs are given by $W(a) = \min_t c'(a) \frac{e^{\Delta rt}}{\mathscr{I}(t|a)}$. The optimal payout time under (DEF), as given in (14) then follows immediately. Note further that under pure deferral regulation the optimal payout is already contingent on survival up to $T_R^*(a)$ such that (CLAW) is slack.[49] **Q.E.D.**

Proof of Lemma 2. The result follows directly from Assumption 1. **Q.E.D.**

Proof of Lemma 3. Using $T^*(a) := \arg\min_t e^{\Delta rt}/\mathscr{I}(t|a)$, and the definition of T_R^* in (14), the definition of the Pigouvian tax in (17) implies that $\Delta W(a) \geq 0$, with equality if and only if either $T_R^*(a) = T^*(a)$ and/or $c'(a) = 0$.[50] The latter holds if and only if $a = 0$ by the assumptions on the cost function, while the former holds if and only if $a \geq \underline{a}(T_{\min})$ by definition of $\underline{a}(T_{\min})$ and Assumption 1. It then follows by continuity that $\Delta W(a)$ is strictly increasing in a for a sufficiently close to zero and strictly decreasing for a sufficiently close to $\underline{a}(T_{\min})$. That $\Delta W'(\underline{a}(T_{\min})) = 0$ then follows by straightforward differentiation of (17) together with $T_R^*(\underline{a}(T_{\min})) = T_{\min} = T^*(\underline{a}(T_{\min}))$. **Q.E.D.**

Lemma A.1 *Incentive compatibility implies:*

$$\frac{1}{\mathscr{I}(T_{\min}|a)} \frac{c''(a)}{c'(a)} - \frac{\frac{d}{da}\mathscr{I}(T_{\min}|a)}{\mathscr{I}^2(T_{\min}|a)} \geq 1. \tag{21}$$

[49] Conditioning on a less informative performance signal would unambiguously increase wage costs.
[50] Note that informativeness is bounded for finite payout times.

Proof of Lemma A.1. Given a contract, the manager maximizes his value $V_A(\tilde{a}) := \mathbb{E}^{\tilde{a}}\left[\int_0^\infty e^{-(r+\Delta r)t}db_t\right] - c(\tilde{a})$ such that incentive compatibility requires that, at $\tilde{a} = a$, both the manager's first-order condition $B = c'(a)/\mathscr{I}(T_{\min}|a)$ as well as the second-order condition $B\left(\frac{d}{da}\mathscr{I}(T_{\min}|a) + \mathscr{I}^2(T_{\min}|a)\right) - c''(a) \leq 0$ are satisfied. Rearranging yields condition (21). **Q.E.D.**

Proof of Proposition 3. That $a_R^* < \underline{a}(T_{\min})$ for all $T_{\min} > T^*(a^*)$ follows from strict concavity of the shareholders' action choice problem in (3) together with the fact that $\Delta W'(\underline{a}(T_{\min})) = 0$ as shown in Lemma 3. Hence, a_R^* is determined from the first-order condition in (16). For $T_{\min} = T^*(a^*)$ the implicit function theorem then implies that

$$\operatorname{sgn}\left(\frac{da_R^*}{dT_{\min}}\right) = \operatorname{sgn}\left(-\frac{\partial^2 \Delta W(a)}{\partial a \partial T_{\min}}\bigg|_{T_{\min}=T^*(a)}\right) = \operatorname{sgn}\left(\frac{dT^*(a)}{da}\right),$$

where the last equality follows from the fact that, evaluated at $T_{\min} = T^*(a^*)$, $\partial \Delta W(a)/\partial T_{\min} = \partial W(a|\Gamma_R)/\partial T_{\min} = \partial W(a)/\partial T$ and the observation that $T^*(a)$ is minimizing $W(a)$ for each a. The result for marginal regulation then follows directly from Assumption 1. It remains to show that $\lim_{T_{\min}\to\infty} a_R^*(T_{\min}) = 0$. To do so, write

$$\frac{dW(a|\Gamma_R)}{da} = \left[\frac{1}{\mathscr{I}(T_{\min}|a)}\frac{c''(a)}{c'(a)} - \frac{\frac{d}{da}\mathscr{I}(T_{\min}|a)}{\mathscr{I}^2(T_{\min}|a)}\right] e^{\Delta r T_{\min}} c'(a), \tag{22}$$

where we use that $T_R^*(a) = T_{\min}$ for $T_{\min}$ sufficiently by (12). Lemma A.1 implies that the term in brackets is greater than unity, so that marginal costs (and the marginal tax) as expressed in (22) go to infinity as $T_{\min} \to \infty$ for any $a > 0$. The result then follows from strict concavity of the unconstrained objective. **Q.E.D.**

Proof of Lemma 4. The result follows from Theorem B.1 of Hoffmann, Inderst, and Opp (2017), by noting that, in our setting, the function $C(x|a) = e^{\Delta r \inf\{t:\mathscr{I}(t|a)\geq x\}} = e^{\Delta r \mathscr{I}^{-1}(x|a)}$ is strictly convex in x as condition (12) holds for all t.[51] **Q.E.D.**

Proof of Lemma 5. Denote the manager's utility from taking action a given an incentive compatible contract with single survival contingent payout at date t by $V_A(a,t) := \frac{c'(a)}{\mathscr{I}(t|a)} - c(a)$, such that $T_{PC}(a)$ is implicitly defined by $V_A(a, T_{PC}(a)) = U$. Now note

[51] In constructing $C(x|a)$ we have used that $\mathscr{I}(t|a)$ is strictly increasing in t and, hence, invertible.

that strict monotonicity of $\mathscr{I}(t|a)$ implies that $\partial V_A(a,t)/\partial t < 0$, while

$$\begin{aligned}\frac{\partial V_A(a,t)}{\partial a} &= \frac{c''(a)\,\mathscr{I}(t|a) - c'(a)\,\frac{d}{da}\mathscr{I}(t|a)}{\mathscr{I}^2(t|a)} - c'(a)\\ &= \frac{c'(a)}{\mathscr{I}(T|a)}\left(\frac{c''(a)}{c'(a)} - \frac{\frac{d}{da}\mathscr{I}(T|a)}{\mathscr{I}(T|a)}\right),\end{aligned}$$

which is positive from Lemma A.1. The result then follows as $T'_{PC}(a) = -\frac{\partial V_A(a,t)/\partial a}{\partial V_A(a,t)/\partial t} > 0$. **Q.E.D.**

Proof of Proposition 4. Recall, first, that the utility the manager gets from taking action a given an incentive compatible contract with survival contingent payout at date t is given by $V_A(a,t) := \frac{c'(a)}{\mathscr{I}(t|a)} - c(a)$. Hence, it follows directly from Proposition 2 that the manager's agency rent under the optimal rent-extraction contract $V_A(a, T_R^*(a)) - U$ is negative for $U > \overline{U}$, i.e., (PC) binds. Next, note that from the arguments in the proof of Lemma 5 $V_A(a,t)$ is decreasing in t. Hence, the highest utility the manager can get from a contract satisfying (IC), (DEF) and (CLAW) is $V_A(a, T_{\min}) < U$ violating (PC). This proves statement ii). As for statement i), note that $e^{\Delta r T_{\min}}(U + c(a))$ constitutes a lower bound on wage costs given (PC) and (DEF), which can only be achieved when all payments occur at $t = T_{\min}$. Further, from statement ii) payments cannot be completely contingent on survival up to $T_{\min}$. To prove the claim, it is then sufficient to show that there exists a contract satisfying (PC), (IC) and (DEF) and achieving wage costs of $e^{\Delta r T_{\min}}(U + c(a))$: One such contract is the one paying out a bonus of size $\frac{e^{r_A T_{\min}}}{S(T_{PC}(a)|a)}(U + c(a))$ at $T_{\min}$ if and only if no failure occurred until $T_{PC}(a) < T_{\min}$. **Q.E.D.**

Proof of Lemma 6. It remains to show that $\lim_{a \downarrow \underline{a}(T_{\min})} \Delta W'(a) < 0$ in case i), which is immediate, as

$$\lim_{a \downarrow \underline{a}(T_{\min})} \Delta W'(a) = -\left(U + c\left(\underline{a}\left(T_{\min}\right)\right)\right) \Delta r T'_{PC}\left(\underline{a}\left(T_{\min}\right)\right) e^{\Delta r T_{\min}}$$

and $T'_{PC}(a) > 0$ from Lemma 5. All the remaining results follow directly from the definition of the Pigouvian tax in (2) and optimal compensation design (see Proposition 4). **Q.E.D.**

Proof of Proposition 5. Consider, first, case ii) with clawback constraint. Here, it follows directly from the arguments in the main text that $a_R^*(T_{\min}) = \arg\max_{a \geq \underline{a}(T_{\min})} \Pi(a) - W(a)$ and the result follows from strict concavity of the unconstrained objective function and the fact that $\underline{a}(T_{\min})$ is increasing in $T_{\min}$ from Lemma 5.

Consider, next, case i) of pure deferral regulation. Then, the shareholders can potentially improve upon the solution with (CLAW) by implementing an action $a < \underline{a}(T_{\min})$. Note that $a < \underline{a}(T_{\min})$ is equivalent to $T_{\min} > T_{PC}(a)$ such that, from Proposition 4, (IC) is slack under the optimal contract implementing actions $a < \underline{a}(T_{\min})$. Now, take $T_{\min}$ large enough such that (DEF) binds and consider the equilibrium action choice in the relaxed problem ignoring (IC), which is the solution to the following strictly concave problem:

$$\tilde{a}(T_{\min}) = \arg\max_{a} \ \Pi(a) - e^{\Delta r T_{\min}}(U + c(a)). \tag{23}$$

It is obvious from (23) that $\tilde{a}(T_{\min})$ is strictly decreasing in $T_{\min}$ and approaches zero for $T_{\min} \to \infty$. Moreover, recall that $\underline{a}(T_{\min})$ is strictly increasing $T_{\min}$. Then, as $\tilde{a}(0) > \underline{a}(0) \geq 0$, there exists, for any $U > 0$, a finite threshold $\tilde{T} > T_{PC}(a^*)$ such that $\tilde{a}(T_{\min}) = \underline{a}(T_{\min})$. The result then follows as, by definition of the threshold, $\tilde{a}(T_{\min}) < \underline{a}(T_{\min})$ if and only if $T > \tilde{T}$ such that only then the solution to the relaxed problem does satisfy (IC) and, thus, solves the full problem. For $T < \tilde{T}$ it follows from strict concavity of both the relaxed and the full problem that $a_R^*(T_{\min}) = \underline{a}(T_{\min})$. **Q.E.D.**

Proof of Lemma 7. The result is immediate as, for $k_{\min} = 1$, we have from (10) that $\Omega(a) = \Pi(a) - W(a|\Gamma_R)$, such that the regulator's and bank shareholder's objective functions coincide. **Q.E.D.**

Proof of Proposition 6. The optimality of $k_{\min} = k^*$ follows immediately from (10). So, fix $k_{\min} = k^*$ and take, first, the case where (PC) is slack for $T_{\min} = 0$. Then, Proposition 3 implies that $\partial a_R^*(k^*, T_{\min})/\partial T_{\min} > 0$ for $T_{\min} = T^*(a_R^*(k^*, 0))$ whenever Assumption 1 holds. We will now show that a marginal increase in the deferral period $T_{\min}$ strictly increases welfare. It is then useful to rewrite the objective in Problem 3 as

$$\Omega(a_R^*(\cdot), k^*, T_{\min}) = \Pi(a_R^*(\cdot)|k^*) - W(a_R^*(\cdot)|T_{\min}) - (1-k^*)\left(1 - r\int_0^\infty e^{-rt} S(t|a_R^*(\cdot))\, dt\right),$$

such that

$$\left.\frac{d\Omega(a_R^*(\cdot), k^*, T_{\min})}{dT_{\min}}\right|_{T_{\min}=T^*(a_R^*(k^*,0))} = (1-k^*)\left[r\int_0^\infty e^{-rt} \left.\frac{\partial S(t|a)}{\partial a}\right|_{a=a_R^*(\cdot)} dt\right] \frac{\partial a_R^*(\cdot)}{\partial T_{\min}} > 0,$$

where we have used the envelope theorem which implies that

$$\left.\frac{\partial W(a_R^*(k^*,T_{\min})\,|T_{\min})}{\partial T_{\min}}\right|_{T_{\min}=T^*(a_R^*(k^*,0))} = 0 = \left.\frac{\partial\left[\Pi\left(a|k^*\right)-W(a|T_{\min})\right]}{\partial a}\right|_{a=a_R^*(k^*,T_{\min})}.$$

When (PC) is binding at $T_{\min}=0$, the profitability of marginal deferral regulation similarly follows as $\Delta W(a_R^*(k^*,T_{\min})\,|T_{\min})=0$ for $T_{\min}\in[T_{PC}(a^*),\tilde{T}]$ (see Proposition 5 and Lemma 6) together with strict (quasi)concavity of the regulator's objective. It remains to show that second-best welfare cannot be achieved. From $U<\overline{U}^{SB}$, to achieve second-best welfare, a^{SB} needs to be implemented with a single payment at $T^*(a^{SB})$. However, when forced to pay at $T^*(a^{SB})$ bank shareholders optimally implement $a_R^*\left(k^*,T^*(a^{SB})\right)<a^{SB}$ (see Proposition 3). **Q.E.D.**

Proof of Proposition 7. We need to show that the proposed regulation achieves second-best welfare. Take, first, the case with a clawback clause. Then, independently of the concrete value $k_{\min}\leq k_{\min}^*$, setting $T_{\min}=T_{PC}(a^{SB})$ implies from Lemma 6 that actions $a<a^{SB}$ cannot be implemented. Since clearly $a^*<a^{SB}$ deferral regulation is binding. Then Proposition 5 implies that bank shareholders optimally implement $a_R^*=\underline{a}\,(T_{\min})=a^{SB}$ with a contract featuring a single payment at $T_{PC}(a^{SB})$ (see Proposition 4), which from $U\geq\overline{U}^{SB}$ is also the unconstrained optimal contract. Thus, welfare is maximized. From Proposition 5 this outcome can be achieved without a clawback clause if and only if $T_{PC}(a^{SB})\leq\tilde{T}$, which is equivalent to $a^{SB}<\tilde{a}\,(T_{\min})=\tilde{a}\left(T_{PC}(a^{SB})\right)$. The result then follows as for each $T_{\min}$ we have that

$$\frac{d\tilde{a}(T_{\min})}{dk_{\min}}=\frac{\frac{\partial}{\partial k_{\min}}\Pi'\left(a\right)}{-\left[\Pi''\left(a\right)-c''\left(a\right)e^{\Delta rT_{\min}}\right]}=\frac{r\int_0^\infty e^{-rt}\frac{\partial}{\partial a}S\left(t|a\right)dt}{-\left[\Pi''\left(a\right)-c''\left(a\right)e^{\Delta rT_{\min}}\right]}>0.$$

Q.E.D.

Appendix B Compensation regulation in practice

The recent financial crisis triggered regulatory initiatives around the world aiming to align compensation in the financial sector with prudent risk-taking. On a supra-national level the Financial Services Forum (FSF)—which later became the Financial Services Board (FSB)—adopted the Principles for Sound Compensation Practices and their Implementation Standards in 2009. While these do not prescribe particular designs or levels of individual compensation they do, inter alia, set out detailed proposals on compensation structure, including deferral, vesting and clawback arrangements. In this Appendix we summarize the current state of regulation regarding deferral and clawback/malus in different FSB member jurisdictions.[52]

In the United States Dodd Frank Act §956 prohibits *"any types of incentive-based payment (...) that (...) encourages inappropriate risks by covered financial institutions - by providing an executive officer, employee, director, or principal shareholder of the covered financial institution with excessive compensation, fees, or benefits; or that could lead to material financial loss to the covered financial institution."* The joint implementation proposal by the six involved federal agencies[53] includes the following deferral requirements for incentive compensation paid by covered financial institutions with more than \$250 billion in total average consolidated assets: Mandatory deferral of 60% of incentive compensation for senior executive officers (50% for significant risk takers) for at least 4 years from the last day of the performance period for short-term arrangements (2 years for long-term arrangements with minimum 3 year performance period). Clawback requirements extend to a minimum of 7 years from the end of vesting based on Dodd Frank §954.[54]

Similar rules are already in place in the EU based on Directive 2010/76/EU, amending the Capital Requirements Directives (CRDs), which took effect in January 2011, even though implementation varies on country-level. These include mandatory deferral of bonuses for 3-5 years, which are further subject to clawback[55] for up to 7 years. Ad-

[52] See Financial Stability Board (2017) - Implementing the FSB Principles for Sound Compensation Practices and their Implementation Standards - Fifth progress report for a more detailed account.

[53] Office of the Comptroller of the Currency, Treasury (OCC), Board of Governors of the Federal Reserve System (Board), Federal Deposit Insurance Corporation (FDIC), Federal Housing Finance Agency (FHFA), National Credit Union Administration (NCUA), and U.S. Securities and Exchange Commission (SEC).

[54] Further federal statues that provide for clawbacks are Sarbanes-Oxley §304 and the Emergency Economic Stabilization Act §111.

[55] The provision in Article 94(1) of CRD IV is: "The variable remuneration, including the deferred portion, is paid or vests only if it is sustainable according to the financial situation of the institution as a whole, and justified on the basis of the performance of the institution, the business unit and the individual concerned. Without prejudice to the general principles of national contract and labour law, the total

ditionally, as part of CRD IV taking effect in 2016 there is a bonus cap limiting bonuses paid to senior managers and other "material risk takers" (MRTs) to no more than 100% of their fixed pay, or 200% with shareholders' approval.

More broadly, all FSB member jurisdictions have issued some form of deferral requirements which usually apply to MRTs in the banking sector, including senior executives as well as other employees whose actions have a material impact on the risk exposure of the firm.[56] Regulatory requirements for deferral periods for material risk takers vary significantly across jurisdictions, ranging from a minimum of around 3 years (Argentina, Brazil, China, Hong Kong, India, Indonesia, Japan, Korea, Russia, Singapore, Switzerland, Turkey) up to 5 years or more for selected MRTs (US, UK, European Single Supervisory Mechanism - SSM - jurisdictions), with the maximum of 7 years applying to the most senior managers in the UK. Equally, the proportion of variable compensation that has to be deferred is highly country specific ranging from 25-60% in Canada, 40% in Argentina, Australia, Brazil and Hong Kong, 33-54% in Singapore, to more than 40% in China and Turkey, 40-55% in India, 40%-60% in SSM jurisdictions, the UK and the US, to 50-70% in Korea, and 70%-75% in Switzerland.[57] Further, some countries impose regulatory restrictions on the proportion of fixed remuneration as a percentage of total remuneration (as the EU "bonus cap") ranging from 30% in Switzerland, 35% in Australia, China, 22-56% in Singapore, 54% in the UK, 58% in Hong Kong and SSM jurisdictions, to about 60% in India. Such requirements are not set out in Argentina, Brazil, Canada, Indonesia, Russia, South Africa and the US. Finally, in all FSB member jurisdictions there are regulatory requirements for the use of ex post compensation adjustment tools such as clawback and malus clauses. However, in a number of jurisdictions the application of these ex post tools, in particular clawbacks, is subject to legal impediments and enforcement issues such that applications are still rare.

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variable remuneration shall generally be considerably contracted where subdued or negative financial performance of the institution occurs, taking into account both current remuneration and reductions in payouts of amounts previously earned, including through malus or clawback arrangements. Up to 100% of the total variable remuneration shall be subject to malus or clawback arrangements. Institutions shall set the specific criteria for the application of malus and clawback. Such criteria shall in particular cover situations where the staff member: (i) participated in or was responsible for conduct which resulted in significant losses to the institution; (ii) failed to meet appropriate standards of fitness and propriety."

[56] Here, methodologies for identifying MRTs vary and are, in most jurisdictions, largely the responsibility of individual firms subject to regulatory oversight. Criteria for the identification of MRTs include role, remuneration, and responsibilities.

[57] Within jurisdictions these values may again vary across different MRTs. Some jurisdictions do not lay out specific regulatory requirements regarding the proportions of compensation that need to be deferred (Indonesia, South Africa).

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