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The Economics of Deferral and Clawback Requirements

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ABSTRACT

We analyze the effects of regulatory interference in compensation contracts, focusing on recent mandatory deferral and clawback requirements restricting incentive compensation of material risk-takers in the financial sector. Moderate deferral requirements have a robustly positive effect on risk-management effort only if the bank manager's outside option is sufficiently high; otherwise, their effectiveness depends on the dynamics of information arrival. Stringent deferral requirements unambiguously backfire. Our normative analysis characterizes whether and how deferral and clawback requirements should supplement capital regulation as part of the optimal policy mix.

"Compensation schemes overvalued the present and heavily discounted the future, encouraging imprudent risk-taking and short-termism."
Mark Carney, Governor Bank of England, 2014

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SIMILAR DIAGNOSES OF THE ROLE of compensation practices in the recent financial crisis have motivated various regulatory initiatives around the world to intervene in bankers' compensation packages by prescribing *minimum deferral requirements* for bonuses and malus clauses for unvested deferred compensation (*clawbacks*). For instance, the United Kingdom now mandates that variable pay compensation of banks' "material risk takers" is subject to deferral periods of three to seven years, with the respective incentive pay subject to clawback upon severe underperformance for 7 to 10 years.[1] Similar interventions have been implemented throughout all Financial Stability Board member jurisdictions (see Appendix C). One may paraphrase the regulators' rationale for these interventions as follows. "Short-termist" compensation packages caused short-termist behavior of bank managers. If compensation packages paid out later in the future, managers would take a more long-term perspective, reduce excessive risks, and ultimately make banks safer.

What this "silver bullet" view of compensation regulation fails to account for is the Lucas critique. Compensation packages are endogenous: Shareholders (the principal) design a compensation contract to incentivize the manager (the agent) to take a particular action. Thus, it is the principal rather than the agent that "chooses" the action in equilibrium, and whichever distortion leads shareholders to incentivize excessively risky actions in the first place, it is still present if they face regulatory constraints on compensation design. The relevant question therefore is how shareholders adjust unregulated dimensions of the compensation package in response to such regulation.

To account for the Lucas critique, we endogenize compensation contracts in a parsimonious principal-agent setting with three central features. First, the bank manager is a "material risk-taker," as targeted by real-world regulation, able to affect the survival of the entire financial institution. Second, to capture the concern of regulators that "Bad bets by financial-services firms take longer than three years to show up" (Borak, Ackerman, and Rexrode (2016)), we assume that the bank manager's unobservable risk-management effort has long-lasting effects on the bank's failure rate. Thus, relevant information about the quality of risk management is gradually revealed over time through the absence of disasters (bank failure). Bilateral risk-neutrality implies that optimal unregulated compensation contracts pay out a survival contingent bonus, whose timing is endogenously determined by the trade-off between better information upon a later payout and relative impatience of the agent. Finally, scope for regulatory intervention arises as bailout expectations allow bank shareholders to finance risky projects with subsidized debt (see Atkeson et al. (2018) and Duffie (2018) for empirical evidence). Shareholders therefore do not fully internalize the social cost of bank failure and incentivize too little risk-management effort.[2]

[1] For Barclays alone, this regulation affected 1,555 material risk-takers in 2021 (see its Pillar 3 report).

[2] Our main insights do not depend on the precise friction motivating regulatory interference, for example, our analysis can be easily modified to capture corporate governance problems instead

To illustrate that deferral regulation is not a "silver bullet" even within this bare-bones framework, consider a naïve attempt to evaluate its effects—how would agent effort incentives change if the bonus payout date is deferred further, holding all other dimensions of the laissez-faire compensation contract constant? There are two opposing channels. First, incentives increase since bonus payments now condition on more informative performance signals—the absence of a disaster for a longer time (information channel). Second, incentives decrease since a later payout reduces the value of the fixed size bonus to the agent (compensation value channel), due to both the time value of money and a lower probability of getting the bonus due to accidental failure. As a result, the net effect of such an exogenous contract change on equilibrium effort is unclear.

To make things worse, this naïve attempt ignores the most important element, the Lucas critique, which applies since compensation contracts are endogenously set by shareholders. Consequently, unregulated contract dimensions cannot be treated as constant. In particular, by adjusting the size of the bonus or by substituting incentive with upfront base pay, shareholders facing minimum deferral requirements are still able to incentivize any level of risk-management effort. Thus, the regulation's effect on equilibrium effort ultimately depends on how it affects shareholders' willingness to provide these incentives, which, in turn, is pinned down entirely by which actions become more costly to implement. Intuitively, adding a (regulatory) constraint on compensation design must raise shareholders' costs of implementing any given action, strictly so if it forces them to deviate from the cost-minimizing laissez-faire contract. The increase in compensation costs acts similar to a tax levied on shareholders upon implementing this action.[3] So, whether compensation regulation is successful in pushing shareholders to incentivize higher risk-management effort boils down to whether high effort is taxed relatively less than low effort (the "marginal tax").

Exploiting this tax approach to compensation regulation, we derive the following results. Moderate deferral requirements have a robustly positive effect on equilibrium risk-management effort only if competition for managerial talent is sufficiently high, so that the value of the manager's compensation package is determined by her outside option. Otherwise, the effectiveness of moderate deferral requirements depends on the information environment. In contrast, sufficiently stringent interventions backfire unambiguously regardless of the information environment or the manager's outside options. Additional clawback requirements may prevent backfiring only if the manager's outside option is sufficiently high and these clawbacks pertain not only to bonuses but also to base pay. We characterize conditions under which

(see Section III for a discussion). Regardless of whether the board chooses what shareholders want, the key is that the contract designer does not choose what society wants.

[3] That this "tax" does not result in revenue to the regulator is irrelevant for shareholders' choices.

compensation regulation alone can achieve second-best welfare and how it interacts with capital regulation.

To build intuition for our results, we initially consider the effect of marginally binding deferral regulation, that is, a minimum deferral period just exceeding the optimal laissez-faire payout time. Our first general insight is that marginally binding deferral regulation raises equilibrium effort if and only if, *absent regulation*, higher effort is optimally implemented with later payouts. Intuitively, in this case, compensation costs to implement effort strictly above the optimal laissez-faire level are unaffected by regulation since, for these effort levels, unconstrained optimal contracts feature sufficiently late payouts anyway. In contrast, for effort at or below the optimal laissez-faire level, the regulatory minimum deferral period exceeds the unconstrained optimal payout time, causing a strict increase in compensation costs. Given this tax push, the principal optimally responds by incentivizing higher effort. Understanding the comparative statics of *unconstrained* optimal payout times in effort—which we label the *timing-of-pay force*—is thus both necessary and sufficient to evaluate the equilibrium effects of marginally binding deferral regulation.

Based on this general insight, we relate these comparative statics to primitives within our framework. We show that payout times are unambiguously increasing in effort if the manager's participation constraint binds. Intuitively, if the manager's compensation value is fixed by her outside option, incentives for higher effort can only be provided by conditioning pay on more informative outcomes, that is, on longer survival. Hence, marginally binding deferral regulation increases equilibrium effort.

In contrast, if the manager's participation constraint is slack, shareholders can choose whether to implement higher effort by paying later based on the additional information, or by increasing the manager's compensation value via a higher bonus. The information environment determines how the optimal timing of pay depends on effort: higher effort is optimally implemented with later payouts if and only if the information gain associated with additional deferral is increasing in effort. Under this restrictive condition, marginally binding deferral regulation leads to higher risk-management effort; otherwise, it reduces it.

For more stringent deferral requirements, our analysis highlights the relevance of an additional force. Intuitively, the increase in compensation cost due to deferral regulation (the tax) is also affected by the size of the bonus package that has to be deferred. Since, ceteris paribus, higher effort requires larger bonus packages, and larger bonus packages are more expensive to defer, this *size-of-pay force* unambiguously pushes against higher effort. For sufficiently stringent deferral regulation, this force dominates—regardless of the information environment and outside options—so that deferral regulation lowers equilibrium effort, pointing to the danger of overshooting.

Additional clawback requirements on bonuses are not effective in this environment. Here, clawback clauses can be interpreted as contingency restrictions on bonus payouts, triggered by bank failure within a certain time period. The reason for their ineffectiveness is that shareholders' optimal response to pure deferral regulation already includes a clawback clause: if regulation forces shareholders to defer bonuses up to year 4 anyway (rather than the privately optimal choice of, say, three years), they optimally make use of the additional information arriving between year 3 and year 4 to provide incentives by conditioning the bonus payout on survival until year 4. Now, if competition for talent is high enough such that the agent's participation constraint binds, shareholders, in addition, partly convert fully contingent bonuses to base pay to still be able to meet the manager's outside option. Since such conversion of bonuses to base pay is not prohibited under current regulation (see concerns by regulators reported by Binham (2015)), banks can effectively circumvent clawback regulation. Only a more stringent policy of extending clawbacks to wages, as discussed by regulators, would prohibit such a switch to more unconditional pay, and thus can be an effective supplement to pure deferral regulation.

We conclude by analyzing the welfare effects of compensation regulation. First, we find that marginally binding deferral requirements increase welfare if and only if they are successful in raising equilibrium effort. As indicated in our positive analysis, this is robustly the case whenever competition for talent is high. Second, for this robust case, we go a step further and characterize the optimal deferral period and conditions under which deferral regulation alone can achieve second-best welfare. This is the case if and only if the distortion in privately optimal risk-management effort is sufficiently small, for example, because effective capital regulation is in place, thereby linking the effectiveness of compensation regulation to capital regulation (and, more broadly, the overall regulatory environment). Capital regulation leads to the implementation of a socially superior action by *directly* reducing the bailout distortion in shareholders' preferences. It thus operates very differently from compensation regulation that does not target the source but rather a symptom of these distortions, the compensation contract. When second-best welfare can be achieved, the optimal policy mix then features a form of substitutability: laxer capital requirements must be optimally compensated by stricter interventions in the compensation package. If regulators need to induce large changes via compensation regulation, not only do they need to require long deferral periods, but they also must impose a clawback requirement that extends to base pay.

Literature. Our paper contributes to the literature on the regulation of incentive contracts, particularly 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, for example, Thanassoulis (2012)).[4]

[4] 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 with standard financial instruments. See, for example, Benmelech, Kandel, and Veronesi (2010).

For firms outside the financial sector, regulatory intervention in executive compensation contracts is typically motivated by a perceived corporate governance problem (see, for example, Bebchuk and Fried (2010) or Kuhnen and Zwiebel (2009)). According to this view, compensation regulation should therefore benefit shareholders.

An alternative view is that the board may indeed pursue the maximization of shareholder value, but this 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 and Tirole (1994), 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.[5]

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 literature in banking regulation (Admati et al. (2011)) thus points out that a key role of capital requirements is to increase loss-absorbing capacity ex post and reduce risk-taking incentives ex ante.[6] 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.[7] We characterize conditions under which such compensation regulation can work as a substitute for direct taxation of the externality.

Finally, our paper builds on recently developed technical tools that permit a tractable characterization of optimal compensation design in principal-agent models with persistent effects (see Hoffmann, Inderst, and Opp (2021)). The particular modeling of a (potentially rare) negative event is shared with Biais et al. (2010) and notably Hartman-Glaser, Piskorski, and Tchistyi (2012) as well as Malamud, Rui, and Whinston (2013). However, all four of these papers focus purely on optimal compensation design absent regulation. In particular, they do not analyze optimal contracts under regulatory constraints, the effect of regulation on the implemented action, and the welfare implications of such regulatory intervention, which are the key focus of our analysis.

[5] Alternatively, in a multibank 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).

[6] To tame risk-taking, Bolton, Mehran, and Shapiro (2015) propose making CEO compensation a function of a bank's credit default swap (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.

[7] A recent paper by Eufinger and Gill (2017) proposes to link banks' capital requirements to CEO compensation, but does not analyze deferred incentive pay or 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.

Outline. This paper is organized as follows. Section I develops the model and establishes a key preliminary result regarding the effects of moderate deferral regulation. Section II presents the main analysis. Section III discusses robustness of our predictions regarding alternative model specifications. Section IV concludes. The Appendices contain proofs not in the main text as well as additional material.

I. Model

We develop a tractable principal-agent model that aims to speak to the effects of compensation regulation in the banking sector. Our framework features a bank (the principal) and a bank manager (the agent) as the two contracting parties, and a regulator that imposes constraints on compensation contracts in the form of minimum deferral requirements. To evaluate such regulatory interventions, we provide a parsimonious framework that endogenizes both compensation contracts, in particular optimal contractual payout times, and the actions incentivized by these contracts in equilibrium.

We consider an infinite-horizon continuous-time setting in which time is indexed by $t \in \mathbb{R}^+$. 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.[8] At time 0, the bank has access to an investment technology that requires both a *one-time fixed-scale* 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 $c(0) = c'(0) = 0$ and satisfies $\lim_{a\to\infty} c'(a) = \infty$.

In line with the regulator's concern (see, for example, quote in introduction), the manager's action has persistent effects such that relevant outcomes are only observed over time, providing a rationale for deferring pay. More concretely, we assume that the manager's one-time action reduces the bank's failure rate $\lambda(t|a)$ for all $t \geq 0$,[9]

$$\lambda_a(t|a) < 0, \ a \in \mathscr{A}, \tag{1}$$

where the function λ is twice continuously differentiable in both arguments and the subscript notation $\lambda_a := \frac{\partial \lambda}{\partial a}$ denotes the partial derivative with respect to a (similarly for all other functions used below). For example, if the failure time is exponentially distributed with mean failure time a, we obtain the benchmark case of a time-invariant hazard rate, $\lambda(t|a) = \frac{1}{a}$, which clearly

[8] See, for example, DeMarzo and Duffie (1999), DeMarzo and Sannikov (2006), or Opp and Zhu (2015) for standard agency models with relative impatience of the agent. In our model, the relevant implication of this assumption is that deferring compensation is costly for the principal. We discuss robustness with respect to alternative costs of deferral arising from the agent's risk-aversion in Section III.

[9] Formally, this assumption plays a similar role as the monotone likelihood ratio property (MLRP) in principal-agent models with immediately observable signals. See, for example, Rogerson (1985).

satisfies (1). One may best interpret the managerial action as an investment in the quality of the bank's risk-management model.[10]

Let $X_t = 1$ refer to the observable signal that the bank has failed by date t, and $X_t = 0$ otherwise. Formally, $\{X_t\}_{t\geq 0}$ 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

$$S(t|a) := \Pr(X_t = 0|a) = e^{-\int_0^t \lambda(s|a)ds}, \tag{2}$$

and it follows directly from (1) that the survival probability is increasing in a for each t.

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

$$Y_t = \begin{cases} y & \text{if } X_t = 0, \\ 0 & \text{if } X_t = 1. \end{cases} \tag{3}$$

The parsimonious cash flow process governed by (1) and (3) captures two features that are frequently mentioned to motivate regulatory interventions in banker compensation. 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 the introduction). Second, information about their actions arrives gradually over time only through the absence of 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 be distinguished better in the long run, for example, 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 (risk-management) effort a. Then the net present value of cash flows generated by the project is $V(a) := \mathbb{E}^a[\int_0^\infty e^{-rt} Y_t dt] - 1$. Using (2) and (3), $V(a)$ can be written as

$$V(a) = y \int_0^\infty e^{-rt} S(t|a)\, dt - 1. \tag{4}$$

In the absence of an agency problem, first-best risk-management effort simply maximizes total surplus $\Theta^{FB} := \max_{a\in\mathscr{A}} V(a) - c(a)$.

In our setting, the bank's objective function differs from surplus maximization for two reasons. First, as is standard in any agency setting, the manager needs to be provided with incentives. This results in wage costs, $W(a)$, that

[10] Many of our insights also hold when the manager's action is multidimensional, allowing for both value-increasing effort as well as explicit risk-taking (rather than effort to prevent risks), or if there are repeated actions (see Section III).

exceed the manager's effort cost, $W(a) > c(a)$. The compensation cost function, $W(a)$, will be endogenized below.

Second, there is a wedge between the *social* value creation of the underlying real project, $V(a)$, and the *private* value creation for bank equity holders, $\Pi(a)$. While the source of this wedge is largely irrelevant for our analysis of the effects of deferral regulation, for concreteness, we make the standard assumption that banks' financing decisions are distorted by (i) tax-payer guarantees on their debt and (ii) regulatory minimum capital requirements (see, for example, Hellmann, Murdock, and Stiglitz (2000) or Repullo and Suarez (2013)).[11] Then, given a minimum capital requirement of $k_{\min} < 1$, banks find it optimal to take on as much debt as possible, so that the overall gross payoff to bank equity holders, $\Pi(a)$, can be written as

$$\Pi(a) = V(a) + \left(1 - k_{\min}\right)\left(1 - r\int_0^\infty e^{-rt} S(t|a)\, dt\right). \tag{5}$$

The positive wedge between $\Pi(a)$ and $V(a)$ can be interpreted as the value of the bailout financing subsidy to bank equity holders.[12] Intuitively, it is larger for lower capital requirements $k_{\min}$ and the lower the survival probability $S(t|a)$ at each date t. Since improved risk management (higher a) increases $S(t|a)$ from (1) and thus lowers the financing subsidy, bank shareholders do not fully internalize the benefits of improved risk management, that is, $0 < \Pi'(a) < V'(a)$. Shareholders optimally trade off these benefits, $\Pi(a)$, against associated compensation costs, which we endogenize next.

Bank Shareholders' Compensation Cost Function: Bank shareholders design a compensation contract that induces the manager to exert (risk-management) effort a at the lowest possible wage costs. A contract specifies transfers from shareholders to the manager depending on (the history of) bank survival and failure. As is standard, we assume that shareholders can commit to any such contract and that the manager is protected by limited liability. Since current real-world regulation mandates a minimum deferral period, $T_{\min}$, for bonuses but not fixed wages, we decompose the compensation contract as follows: compensation consists of a date-0 unconditional (wage) payment $w \geq 0$ and a cumulative bonus process b_t progressively measurable with respect to the filtration generated by $\{X_t\}_{t\geq 0}$ (the information available at time t).[13] In particular, $db_t \geq 0$ refers to the instantaneous bonus payout to the manager at date t. It is without loss of generality to restrict wages to be paid out at date 0, since it would be strictly inefficient to stipulate an unconditional payment at a later date (due to agent impatience).

[11] Our main results would remain unchanged if regulatory intervention were instead motivated by negative externalities of bank failure on other banks, borrowers, or depositors (see Section III for a discussion).

[12] Since debt is priced competitively by debt holders (accounting for the bailout), the value accrues to bank equity holders (see, for example, Harris, Opp, and Opp (2020)).

[13] Note that this decomposition is only for notational convenience in expressing regulatory constraints. Formally, bonus payments—as captured by the process b_t—can clearly be unconditional.

The formal compensation design problem of implementing action a at the lowest expected discounted cost to bank shareholders—the first problem in the structure of Grossman and Hart (1983)—can then be stated as follows.

PROBLEM 1 (Cost-minimizing contracts to implement given action a):

$$W(a|T_{\min}) := \min_{w,b_t} w + \mathbb{E}^a\left[\int_0^\infty e^{-rt}db_t\right] \quad s.t.$$

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

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

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

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

Except for the final constraint (DEF), all constraints are standard and also apply for the derivation of the optimal unregulated contract whose compensation costs we denote as $W(a) := W(a|0)$. The first constraint is the bank manager's time-0 participation constraint (PC). The present value of compensation discounted at the manager's rate, which we refer to as *compensation value*, net of effort costs, must at least match the manager's outside option U.[14] 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, for example, Holmstrom (1979) and Shavell (1979)), we simplify the exposition by assuming that the first-order approach applies. Within our setting, validity of the first-order approach is ensured if the survival function S is concave in a for all (t, a).[15]

We now turn to the deferral constraint (DEF), which is motivated by real-world regulation. This constraint prevents bank shareholders from making any bonus payout to the bank manager before date $T_{\min}$, that is, $db_t = 0$

[14] Since the manager in our model chooses an action only once at time 0 and is protected by limited liability, (PC) needs to be satisfied only at $t = 0$. We discuss endogenous outside options in Section III.

[15] For the formal argument, see the proof of Lemma 2. This condition is essentially the same sufficient condition as the convexity of the distribution function condition (CDFC) in static moral hazard environments (see Rogerson (1985)) and is generally satisfied for the mixed exponential distribution $S(t|a) = ae^{-\lambda_1 t} + (1-a)e^{-\lambda_2 t}$ with $\lambda_2 > \lambda_1$ and the Lomax distribution $S(t|a) = a/(t + a)$. See Bond and Gomes (2009) for an analysis when the first-order approach breaks down.

$\forall t < T_{\min}$. For expositional reasons, we initially abstract from clawback requirements, which are additional restrictions on the contingency of pay. As we show in Section II.C.2 below, such additional constraints bite only if clawbacks also extend to wages. While our analysis is mostly positive in that we analyze the effect of exogenously given regulatory tools, we analyze the welfare implications of such regulation in Section II.C.

Overall Objective: Given the solution to the compensation design problem, shareholders induce the action that maximizes gross profits net of compensation costs—the second problem in the structure of Grossman and Hart (1983).

PROBLEM 2 (Shareholders' optimal action choice a^*): *Shareholders implement effort* $a^*(T_{\min}) = \arg\max_{a\in\mathscr{A}} \Pi(a) - W(a|T_{\min})$ *in equilibrium.*

For ease of exposition, we omit a possible participation constraint on the side of shareholders, that is, weakly positive profits, and suppose that their unconstrained objective function, $\Pi(a) - W(a)$, is strictly concave.[16] These assumptions ensure that the optimal laissez-faire effort choice, denoted as $a^* := a^*(0) > 0$, is uniquely characterized by the first-order condition $\Pi'(a^*) = W'(a^*)$.

It is now useful to decompose the bank shareholders' overall objective as

$$a^*(T_{\min}) = \arg\max_{a\in\mathscr{A}} \Pi(a) - W(a) - \Delta W(a|T_{\min}), \tag{6}$$

where $\Delta W(a|T_{\min}) := W(a|T_{\min}) - W(a)$ measures the change in the (minimum) wage costs required to implement action a if a minimum deferral period $T_{\min}$ is imposed.

Since minimum deferral regulation, as any type of compensation regulation, constrains the space of feasible contracts, we generically obtain that $\Delta W(a|T_{\min}) \geq 0$, which is similar to an indirect tax on the principal upon implementing action a. Importantly, while this *indirect* tax does not constitute a direct transfer from the principal to the government, the regulatory constraint affects the equilibrium action in (6) "as if" the regulator could observe the action a and imposed an effort-contingent tax of size $\Delta W(a|T_{\min})$. Knowledge of this tax function $\Delta W(a|T_{\min})$ is therefore sufficient to determine the effect of a given deferral constraint $T_{\min}$ on equilibrium effort.

To guide the analysis below, we exploit this taxation analogy to establish a one-to-one link between the comparative statics of *unregulated* cost-minimizing contracts implementing a given action a (from Problem 1) and

[16] While sufficiently stringent deferral regulation may indeed lead to negative bank profits, we abstract from this additional constraint for expositional reasons since it will never bind under optimal deferral regulation (see Section II.C.1). Global concavity of the shareholders' problem can, in turn, be ensured if marginal effort costs are sufficiently convex (so that W is strictly convex in a. See in a related context Jewitt, Kadan, and Swinkels (2008)). Our comparative statics results continue to hold, in the respective monotone comparative statics sense, if there are multiple solutions to the shareholders' problem.

the effect of *marginally binding* deferral regulation on equilibrium effort (from Problem 2).

LEMMA 1 (Effect of marginally binding deferral regulation): *Let $T^*(a)$ denote the earliest date for which an unregulated cost-minimizing contract stipulates a bonus to incentivize a given action a. Equilibrium effort increases, $a^*(T_{\min}) > a^*$, in response to marginally binding deferral regulation—that is, a minimum deferral period $T_{\min}$, which marginally exceeds the laissez-faire payout time $T^*(a^*)$—if and only if $\frac{dT^*(a)}{da}|_{a=a^*} > 0$.*

The result follows from two observations. First, in the absence of regulation, the principal is locally indifferent between effort choices around the laissez-faire choice a^*, since this optimal action is pinned down by a first-order condition. Second, the comparative statics $\frac{dT^*(a)}{da}$ determine whether the deferral constraint restricts the principal's compensation design when implementing high or low actions. Suppose for ease of exposition that $\frac{dT^*(a)}{da} > 0$ holds globally. Then a minimum deferral period that marginally exceeds $T^*(a^*)$ binds for all actions below and including a^*, which are therefore taxed, that is, $\Delta W(a^*|T_{\min}) > 0$ for $a \leq a^*$. In contrast, such a minimal deferral requirement does not impose a tax on actions that exceed a^* (since the deferral constraint is endogenously satisfied), that is, $\Delta W(a^*|T_{\min}) = 0$ for $a > a^*$. Due to this taxation push "from the left," higher effort becomes relatively cheaper to implement, and the principal optimally responds by increasing effort. Of course, if the comparative statics are reversed, $\frac{dT^*(a)}{da}|_{a=a^*} < 0$, marginally binding minimum deferral regulation taxes higher (rather than lower) effort and hence leads to lower equilibrium effort (backfiring). Finally, if $\frac{dT^*(a)}{da}|_{a=a^*} = 0$, marginally binding deferral regulation has no effect since it does not target high versus low effort differentially.

As the discussion of the forces behind Lemma 1 reveals, all relevant aspects of the agency problem such as the information structure, outside options, preferences, etc. matter only to the extent that they affect the comparative statics of unregulated, cost-minimizing contracts. Hence, conditional on these comparative statics, the directional prediction regarding effort is independent of the concrete assumptions of our framework including, for example, the specification of the principal's profit $\Pi(a)$. We exploit this general result in Lemma 1 to structure our subsequent analysis. We first consider *marginal* interventions and use our concrete modeling framework to link the comparative statics of bonus payout times to economic primitives such as the information structure and outside options. Second, we study *nonmarginal* interventions, for which we cannot rely only on the comparative statics of unregulated contracts, but also need to analyze how shareholders optimally restructure contracts in response to regulation.

To keep this analysis tractable and reduce the number of case distinctions, we restrict attention to information environments that give rise to a single bonus payout date in *unregulated* optimal contracts so that, going forward, $T^*(a)$ is simply "the" bonus payout date in unregulated, cost-minimizing contracts.[17] This assumption boils down to imposing the convexity condition

$$\frac{\partial \log \lambda_a(t|a)}{\partial t} = \frac{\lambda_{at}(t|a)}{\lambda_a(t|a)} < \Delta r \qquad \forall a, t > 0. \tag{7}$$

Economically, (7) describes information environments in which the incremental information benefit of deferring pay further (due to "learning" from the absence of bad events) decreases over time *relative* to the associated cost (captured by the manager's relative impatience Δr). It is satisfied, for example, in standard information environments exhibiting (weakly) decreasing returns to deferral such as in the exponential distribution case that exhibits a time-invariant default rate $\lambda(t|a) = \frac{1}{a}$.

II. Analysis

A. The Effects of Small Regulatory Interventions

Following the recipe of Lemma 1, the effect of marginally binding deferral regulation is determined entirely by the comparative statics of unregulated cost-minimizing compensation contracts. Thus, in the first step, we need to characterize such contracts (the solution to Problem 1 with $T_{\min} = 0$).

Unregulated, Cost-Minimizing Contracts: As in standard static principal-agent models, bilateral risk-neutrality and agent limited liability imply that optimal contracts take a simple form: since there are no risk-sharing concerns, the agent is rewarded with a positive bonus only for those outcomes that are most informative about the incentivized action (in a likelihood ratio sense), and obtains zero compensation otherwise due to limited liability. Such contracts provide the strongest incentives per unit of expected pay.[18] In our setting, outcomes are histories of bank survival and failure and, for all (t, a), the history "bank survival until date t" is most indicative about the agent having exerted effort. This result follows directly from the assumption that higher effort reduces the bank default rate (see (1)). Formally, fixing t and any desired level of effort a, the survival history is associated with the maximal (log) likelihood ratio of all date-t outcomes

$$\mathscr{I}(t|a) := \frac{\partial \log S(t|a)}{\partial a} = t\left|\bar{\lambda}_a(t|a)\right|, \tag{8}$$

where $\bar{\lambda}(t|a) := \frac{1}{t}\int_0^t \lambda(s|a)ds$ is the average failure rate up to date t. With slight abuse of terminology, we refer to $\mathscr{I}(t|a)$, which captures the quality of date-t information, as date-t *informativeness*. This informativeness function has three intuitive properties. First, informativeness at date 0 is zero, $\mathscr{I}(0|a) = 0$, as

[17] This is without loss of generality if (PC) is slack, in which case unregulated optimal contracts always feature a single payout date, while maximally two payout dates are optimal when (PC) binds (see Hoffmann, Inderst, and Opp (2021)). Importantly, Lemma 1 applies in all cases.

[18] See, for example, Innes (1990) and, for the formal argument in our setting, the proof of Lemma A.1.

the bank initially survives with probability one regardless of the choice of a. Second, informativeness is strictly increasing over time.[19] Third, for a given t, informativeness is larger the more sensitive the (average) failure rate is to the action a. For instance, if the failure time distribution is exponential (with a time-invariant hazard rate of $\frac{1}{a}$), the amount of "learning" is intuitively constant over time, so that informativeness grows linearly in t with $\mathscr{I}(t|a) = t/a^2$.

What differentiates our setup from standard static models is that the timing of pay is optimally determined from the basic trade-off between better information over time and the deadweight costs resulting from the manager's relative impatience. More specifically, the costs of deferring pay are captured by impatience costs, $e^{\Delta rt}$, corresponding to the ratio of bank shareholders' and the manager's respective valuations of any date-t transfer. In turn, as is intuitive, longer survival is more informative about the manager's persistent effort. The implied benefit of deferral for providing incentives is then captured by the increase in informativeness $\mathscr{I}(t|a)$ over time, as the following decomposition of (IC) reveals:

$$\underbrace{\left[S(t|a)\, e^{-(r+\Delta r)t} db_t\right]}_{\text{Agent compensation value}} \mathscr{I}(t|a) = c'(a).^{20} \tag{IC*}$$

Incentives can therefore be provided via two levers: through a higher compensation value, $S(t|a)e^{-(r+\Delta r)t}db_t$, or by conditioning on more informative outcomes (further deferral of survival-contingent pay leading to higher $\mathscr{I}(t|a)$).

LEMMA 2 (Unregulated, cost-minimizing compensation contracts): *For any a, the unregulated cost-minimizing contract stipulates no fixed pay, $w = 0$. The manager obtains a bonus if and only if the bank has survived by date $T^*(a) \le \hat{T}(a) = \arg\max_t e^{-\Delta rt} \mathscr{I}(t|a)$. The agent's compensation value is given by $B(a|T^*(a)) = \frac{c'(a)}{\mathscr{I}(T^*(a)|a)}$. The principal's compensation cost is*

$$W(a) = B\big(a|T^*(a)\big)e^{\Delta r T^*(a)}. \tag{9}$$

The optimal bonus payout date $T^*(a)$ has the following properties: (i) If $U \le B(a|\hat{T}(a)) - c(a)$, (PC) is slack and $T^*(a) = \hat{T}(a)$ solves

$$\frac{\partial \log \mathscr{I}(t|a)}{\partial t} = \Delta r. \tag{10}$$

(ii) If $U > B(a|\hat{T}(a)) - c(a)$, (PC) binds and $T^*(a) < \hat{T}(a)$ solves

$$\mathscr{I}(t|a) = \frac{c'(a)}{U + c(a)}. \tag{11}$$

[19] Intuitively, informativeness increases over time since the principal receives additional informative signals. In our model, informativeness corresponds to the semielasticity of survival with respect to effort, $\frac{\partial \log(S(t|a))}{\partial a}$, which is strictly increasing in time, $\frac{\partial^2 \log(S(t|a))}{\partial a \partial t} = -\lambda_a(t|a) > 0$.

[20] This expression exploits the fact that any bonus payment in optimal contracts is contingent on survival and there is a single bonus payout date, as implied by (7). See the proof of Lemma 2.

To build intuition for this result, note that information about the agent's action is revealed only gradually over time via the absence of defaults, such that the principal does not have access to any informative performance signal at date zero, $\mathscr{I}(0|a) = 0$. Hence, incentive compatibility for any $a > 0$ requires a deferred bonus. Moreover, due to the agent's relative impatience, any such deferred bonus entails deadweight impatience costs, that is, the principal's compensation costs exceed the agent's compensation value. Taken together, the shadow value on (IC) must be strictly positive regardless of the value of the agent's outside option, which explains why it is optimal to provide maximal incentives and make all payments contingent on bank survival.

Further, optimal contracts with and without binding (PC) share the feature that there is only a single payout date. However, the trade-offs determining the optimal timing of pay are fundamentally different: with binding (PC), the optimal payout time is implicitly defined via a condition on the level of informativeness $\mathscr{I}(t|a)$, whereas with slack (PC), the optimal payout time is pinned down by the growth rate $\frac{\partial \log \mathscr{I}(t|a)}{\partial t}$. This difference arises because only with slack (PC) does the optimal timing of pay reflect a rent-extraction motive: the bonus is optimally deferred as long as informativeness growth (and associated reductions in the agent's rent via a lower compensation value B) exceeds the growth rate of impatience costs Δr (see (10)).

In contrast, if (PC) binds, the compensation value to the agent is fixed by the outside option, $B(a|T^*(a)) = U + c(a)$, and the optimal payout time $T^*(a)$ corresponds to the earliest time at which a contingent bonus of value $B = U + c(a)$ provides the agent with sufficient incentives to satisfy (IC*) (see (11). That is, rather than supplementing the deferred bonus under slack (PC)—stipulated at date $\hat{T}(a)$—with sufficiently high upfront pay to match the outside option, it is again optimal to concentrate pay on a single date. To build intuition, note that we consider information environments in which the incremental information benefit of longer deferral decreases over time *relative* to the associated cost; see convexity condition (7). Hence, it is cheaper to make the upfront bonus contingent on some information by shifting it to some $t > 0$, since the incentives this provides allows shareholders to shift the deferred bonus to an earlier date $T^*(a) < \hat{T}(a)$ that reduces impatience costs.[21]

The comparative statics of unregulated, cost-minimizing contracts now directly follow from implicit differentiation of (10) and (11).

LEMMA 3 (Comparative statics of unregulated contracts): *As long as (PC) binds, the optimal payout time $T^*(a)$ is strictly increasing in a. If (PC) is slack, $T^*(a)$ is strictly increasing in a if and only if the growth rate of information $\partial \log \mathscr{I}(t|a)/\partial t$ is strictly increasing in a, that is,* $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}|_{(t,a)=(\hat{T}(a),a)} > 0$.

[21] Formally, (7) ensures that impatience costs $e^{\Delta rt}$ are strictly convex relative to informativeness $\mathscr{I}(t|a)$ (see Figure A.1 in Appendix A for an illustration). In information environments in which the convexity condition is not satisfied, two bonus payout dates may be optimal, as to achieve "convexification." See Lemma 1 and Corollary 1 of Hoffmann, Inderst, and Opp (2021) for a detailed discussion.

Intuitively, if (PC) binds, the compensation value is exogenously fixed by the outside option, so that incentive compatibility (IC*) can only be ensured with further deferral, which explains the unambiguous comparative statics. In contrast, if (PC) is slack, the principal can choose the cheapest combination of compensation value and deferral, which is affected by the growth rate of learning across actions.

Using Lemmas 1 and 3, we can now express the effect of marginally binding deferral regulation on equilibrium effort $a^*(T_{\min})$ in terms of economic primitives, that is, in terms of the value of the manager's outside option as well as the information environment.

COROLLARY 1 (Determinants for effectiveness of small regulatory interventions): *Marginally binding deferral regulation strictly increases equilibrium effort, $a^*(T_{\min}) > a^*$, if either $U \geq \hat{U}$, so that (PC) binds, or $U < \hat{U}$ and $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}|_{(t,a)=(T^*(a^*),a^*)} > 0$, where the threshold $\hat{U}$ is explicitly characterized in Appendix A; otherwise, it backfires.*

Zooming in on the ambiguous case with slack (PC), all comparative statics are generically possible even within a common parametric family of survival distributions.

EXAMPLE 1: *Consider the Gamma survival time distribution with $S(t|a) := \frac{\Gamma(\beta, \frac{t}{a})}{\Gamma(\beta,0)}$, where $\Gamma(\beta, x) := \int_x^\infty s^{\beta-1}e^{-s}ds$ denotes the upper incomplete Gamma function.*[22] *Then if (PC) is slack, the payout date is decreasing in a if $\beta < 1$, independent of a if $\beta = 1$, and strictly increasing in a if $\beta > 1$.*

Figure 1 illustrates the effect of deferral regulation on equilibrium effort for the three possible regimes $\frac{dT^*(a^*)}{da} \gtreqless 0$ based on β, for both marginally binding deferral regulation (see Corollary 1 and Example 1), that is, $T_{\min} = T^*(a^*)$, and more stringent interventions. As can already be inferred from Figure 1, sufficiently stringent deferral regulation leads to backfiring regardless of the information environment. Our analysis of nonmarginal interventions below shows that this result can be linked to a novel force, the size-of-pay force, which robustly pushes against higher equilibrium effort.

B. Nonmarginal Interventions

To evaluate the effects of nonmarginal interventions, $T_{\min} \gg T^*(a^*)$, we first need to determine how bank shareholders optimally restructure compensation contracts in the presence of binding deferral regulation. This restructuring determines the additional compensation cost that the principal faces upon implementing a given action a.

[22] In terms of hazard rate fundamentals, the informativeness of the marginal performance signal, $\lambda_a(t|a)$, is strictly decreasing over time if $\beta < 1$, constant if $\beta = 1$ (exponential distribution), and strictly increasing over time if $\beta > 1$. If $\beta > 1$, the Gamma distribution violates condition (7), but this is irrelevant for (PC) slack (see Hoffmann, Inderst, and Opp (2021) for discussion).

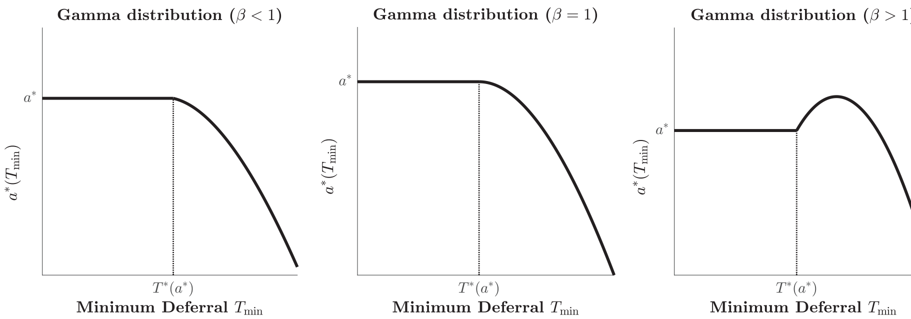

Figure 1. Effect of deferral regulation on equilibrium effort (slack PC). We plot the equilibrium action $a^*(T_{\min})$ as a function of the minimum deferral period for three different information environments as captured by the parameter β of the Gamma survival distribution (see Example 1) with $\beta = 0.5$, $\beta = 1$, and $\beta = 3$. The remaining parameter values are $r = 0.05$, $\Delta r = 3$, $\kappa = 5$ (scaling the effect of the action on $S(t|a) = \Gamma(\beta, \kappa \frac{t}{a})/\Gamma(\beta, 0)$), $y = 100$, $k_{\min} = 0.1$, and $U = 0$, with $c(a) = a^3/3$.

B.1. Cost-Minimizing Contracts under Binding Deferral Regulation

PROPOSITION 1 (Optimal contracts with binding regulation): *Suppose that the minimum deferral period exceeds the payout time in unregulated, cost-minimizing contracts for a given action a. Then the agent receives a positive bonus if and only if the bank has survived by date $T_{\min}$. At date 0, the agent values the bonus at $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}(T_{\min}|a)}$. The principal's compensation cost satisfies*

$$W(a|T_{\min}) = w + B(a|T_{\min})\, e^{\Delta r T_{\min}} > W(a). \tag{12}$$

- *(i) If $U \leq B(a|T_{\min}) - c(a)$, (PC) is slack and the agent receives no fixed pay, $w = 0$.*
- *(ii) Otherwise, (PC) binds and the agent receives fixed pay $w = U + c(a) - B(a|T_{\min}) > 0$.*

Proposition 1 captures two general insights pertaining to regulatory interference in the design of compensation contracts. First, facing restrictions on one dimension of the compensation contract—here, the timing—shareholders are forced to adjust other dimensions to implement the same action—here, the bonus size and the contingency of pay. Within the context of our model, given that survival until $T_{\min} > T^*(a)$ is more informative than survival until $T^*(a)$, that is, $\mathscr{I}(T_{\min}|a) > \mathscr{I}(T^*(a)|a)$, shareholders optimally respond to the deferral requirement by making the bonus contingent on survival by date $T_{\min}$. With slack (PC), this increase in informativeness strictly reduces the manager's total compensation value, so the agent is strictly worse off for any given action a. In contrast, if (PC) binds, the value of the bonus to the agent, $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}(T_{\min}|a)}$, alone would be insufficient to satisfy (PC). It is now optimal for bank shareholders to supplement the bonus package with fixed pay at date 0, $w > 0$, as noncontingent (salary) pay is not subject to deferral requirements. The latter switch from bonus to fixed pay (in response to regulation) is consistent with empirical evidence, for example, Colonnello, Koetter, and Wagner (2018), suggesting the relevance of the participation constraint.

Second, regardless of these optimal adjustments in response to regulatory deferral requirements, shareholders must be strictly worse off when facing binding deferral regulation, $W(a|T_{\min}) > W(a)$. The tax function $\Delta W(a|T_{\min})$, the difference between (12) and (9), measures the extent to which shareholders are worse off for each action a.

B.2. Tax Function: Which Actions Become More Expensive to Implement?

Facing a given deferral requirement $T_{\min}$, the tax function tells us economically which actions a become more expensive for shareholders to implement. Understanding its structure is crucial since it is sufficient to evaluate the effect of deferral requirements on the equilibrium action (see the principal's objective in (6)). For ease of exposition, it is instructive to focus on the case for which marginally binding deferral regulation robustly works, that is, $\frac{dT^*(a)}{da} > 0$ (see Lemma 1), which is always ensured for binding (PC).

LEMMA 4 (Properties of the tax function): *Suppose that $T^*(a)$ is strictly increasing in a. Then $\Delta W(a)$ is zero for $a = 0$ and $a \geq \underline{a}(T_{\min})$, where $\underline{a}(T_{\min})$ is the action whose unregulated optimal payout time satisfies*

$$T^*\big(\underline{a}(T_{\min})\big) = T_{\min}. \tag{13}$$

For all other actions, $\Delta W(a) > 0$. For $a \in (0, \underline{a}(T_{\min}))$, $\Delta W(a)$ is strictly increasing in a for a sufficiently small and is strictly decreasing in a for a sufficiently close to $\underline{a}(T_{\min})$.

The nonmonotonicity of the tax function implies that intermediate levels of effort are taxed the most (see left panel of Figure 2). The nonmonotonicity results from the interaction of two countervailing forces, which govern the tax rate and tax base, respectively. First, given that $\frac{dT^*(a)}{da} > 0$, the *timing-of-pay* force implies that low effort levels are taxed at the highest "tax rate" since the regulatory deferral requirement $T_{\min}$ is furthest away from the associated unconstrained optimal payout time $T^*(a)$. In contrast, sufficiently high effort levels $a \geq \underline{a}(T_{\min})$ are "tax-exempt" because these actions have unconstrained payout times exceeding $T_{\min}$ (see Figure B.1 in Appendix B).

However, there is an opposing effect, which we label the *size-of-pay* force. Ceteris paribus, implementing higher effort requires shareholders to pay a larger bonus package. The size of this incentive pay package can be interpreted as the "tax base." This tax base is zero in the extreme case in which no incentive pay needs to be provided, as $a = 0$, and is strictly increasing in a. Taken together,

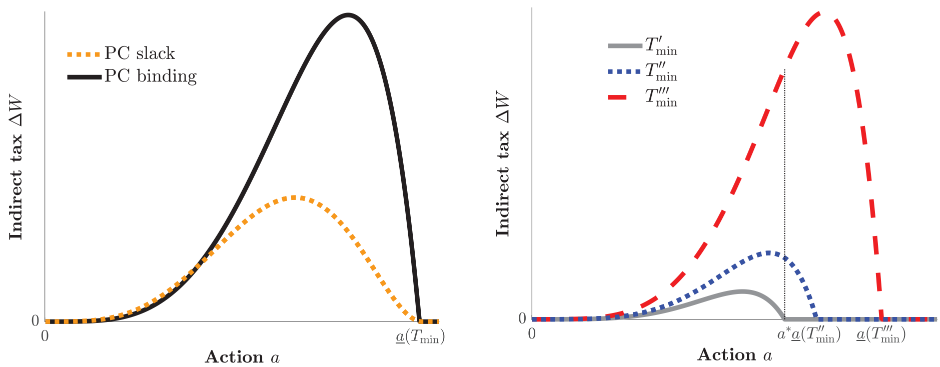

Figure 2. Nonmonotonicity of tax function and its comparative statics in $T_{\min}$. The left panel plots the tax function, $\Delta W(a|T_{\min})$, for a given deferral requirement for both slack and binding (PC). For slack (PC), we use the Gamma distribution (see Example 1) with $\beta > 1$ so that $dT^*(a)/da > 0$. The right panel plots the tax function for binding (PC) for different values of the deferral requirement $T^{'}_{\min} = T^*(a^*) < T^{''}_{\min} < T^{'''}_{\min}$. (Color figure can be viewed at wileyonlinelibrary.com)

the properties of $\Delta W(a) = 0$ at the corners and $\Delta W(a) > 0$ in the interior imply a nonmonotonic tax in the interesting case in which $\frac{dT^*(a)}{da} > 0$.[23]

While in this interesting case the nonmonotonicity result is shared between (PC) binding and slack, there is one important difference: a marginal deviation from the unconstrained optimal payout time—which, for given $T_{\min}$, is required to implement effort marginally below $\underline{a}(T_{\min})$—imposes second-order losses from taxation only if (PC) is slack, $\Delta W_a(\underline{a}(T_{\min})|T_{\min}) = 0$, while these losses are first-order in the limit if (PC) binds, $\Delta W_a(a|T_{\min})|_{a\uparrow\underline{a}(T_{\min})} < 0$. (Compare the smooth orange line in the left panel of Figure 2 with the black line that has a kink at $\underline{a}(T_{\min})$). This follows directly from unregulated optimal compensation design by noting that the optimal payout time with slack (PC) is chosen according to the first-order condition (10), while it is pinned down by the binding constraints (PC) and (IC) otherwise; see (11). This difference in the order of losses arising from the need to adjust compensation contracts in response to regulation (contracting distortion) will be important for the characterization of the equilibrium action, which we turn to next.

B.3. Equilibrium Effort Choice under Binding Deferral Requirements

Intuitively, binding deferral requirements affect the equilibrium contract because (i) shareholders have to adjust the contract to implement a given action a so that $\Delta W > 0$ (*contracting distortions*) and/or (ii) shareholders

[23] If $\frac{dT^*(a)}{da} < 0$, which from Lemma 3 can arise only if (PC) is slack and $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{F}(t|a)}{\partial t} \leq 0$, the timing-of-pay force reinforces the size-of-pay force, so that the tax function is globally increasing in a (see Figure B.2 in Appendix B). In this trivial case, deferral regulation backfires globally; see the left panel of Figure 1.

adjust the implemented equilibrium action choice (*action distortions*). The equilibrium contract trades off these two levers.

LEMMA 5 (Equilibrium effort with binding deferral regulation): *Suppose $T_{\min} > T^*(a^*)$. If (PC) binds, there exists $\tilde{T} > T^*(a^*)$ such that for $T_{\min} \in (T^*(a^*), \tilde{T})$, the equilibrium action is given by $a^*(T_{\min}) = \underline{a}(T_{\min})$ so that $\Delta W(a^*(T_{\min})) = 0$. If (PC) binds and $T_{\min} > \tilde{T}$ or (PC) is slack, $a^*(T_{\min})$ satisfies the first-order condition*

$$\Pi'(a) - W'(a) = \Delta W_a(a|T_{\min}), \tag{14}$$

implying contracting distortions in equilibrium, that is, $\Delta W(a^*(T_{\min})) > 0$.

If (PC) is slack, both levers are balanced via an intuitive first-order condition: the marginal loss from distorting the action relative to the unconstrained action choice a^*, $\Pi'(a) - W'(a)$, has to be equal to the marginal tax imposed by deferral regulation, $\Delta W_a(a|T_{\min})$.

If, instead, (PC) binds and the difference $T_{\min} - T^*(a^*)$ is sufficiently small, shareholders choose to avoid taxation completely by increasing the implemented action to $a^*(T_{\min}) = \underline{a}(T_{\min})$, the lowest action for which an unregulated optimal contract is still feasible (see (13) and Figure B.1 in Appendix B). Implementing even just marginally lower actions would result in first-order taxation costs from contracting distortions (see the kink in the black line at $\underline{a}(T_{\min})$ in the left panel of Figure 2), while small distortions in the action around a^* produce only second-order losses since a^* is pinned down by first-order condition $\Pi'(a) - W'(a) = 0$. As $T_{\min}$ rises (and with it $\underline{a}(T_{\min})$), the marginal losses from further distorting the action become larger until they match the marginal tax $\Delta W_a(a|T_{\min})|_{a\uparrow\underline{a}(T_{\min})}$ at $T_{\min} = \tilde{T}$. For $T_{\min} > \tilde{T}$, the first-order condition (14) again applies.

B.4. Comparative Statics Effects of Deferral Regulation

We are now ready to extend the result on the effect of marginally binding deferral regulation on equilibrium effort from Lemma 1 to nonmarginal interventions. From Lemma 5, it is sufficient to understand the effect that increasing $T_{\min}$ has on the (marginal) tax function, which is shaped, in turn, by the interaction of the timing-of-pay and size-of-pay forces. To build intuition, we first consider an illustrative example with binding (PC) in which these forces are in conflict, resulting in a nonmonotonic tax function (see Lemma 4). The right panel of Figure 2 shows how the tax function shifts in response to three increasingly stringent deferral requirements starting from marginally binding deferral regulation $T^{'}_{\min} = T^*(a^*) < T^{''}_{\min} < T^{'''}_{\min}$. For reference, we also plot the laissez-faire action a^* satisfying $\Pi'(a^*) = W'(a^*)$. For $T^{'}_{\min} = T^*(a^*)$, we illustrate (gray line) the intuition behind marginally binding regulation (Lemma 1). In this case, only the timing-of-pay force matters: since $\frac{dT^*(a)}{da} > 0$, the tax is positive to the left of $a^* = \underline{a}(T^{'}_{\min})$ and zero to the right, pushing toward higher effort. As $T_{\min}$ increases further to $T^{''}_{\min}$ (blue dotted line),

$\underline{a}(T_{\min})$ moves upward as well. The key difference relative to marginal regulation is that all effort levels in the neighborhood of a^* are now subject to taxation. However, shareholders are still taxed more to the left of a^* than to the right of a^*, so that the marginal tax $\Delta W_a(a^*|T_{\min})$ is still negative. As a consequence, shareholders optimally induce a strict increase in equilibrium effort compared to the laissez-faire action a^*. As $T_{\min}$ increases further to $T_{\min}^{'''}$ (red dashed line), $\underline{a}(T_{\min})$ moves even more to the right. However, at this point the size-of-pay force dominates and deferral regulation has overshot: the marginal tax at the original laissez-faire action, a^*, is *positive*, which makes it more expensive to induce effort and thus leads to backfiring.

The following proposition generalizes the intuition built in the previous example and highlights the crucial role of the manager's outside option.

PROPOSITION 2 (Comparative statics in deferral period $T_{\min}$): *The effect of moderate deferral requirements is characterized as follows:*

(i) If $U \geq \hat{U}$, (PC) already binds in the absence of regulation. Binding deferral requirements $T_{\min}$ below $\tilde{T}$ have an unambiguously positive effect on equilibrium effort with $a^*(T_{\min}) = \underline{a}(T_{\min})$ strictly increasing in $T_{\min}$.

(ii) If $U < \hat{U}$, (PC) is slack in the absence of regulation and marginally binding deferral regulation raises equilibrium effort if and only if $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}|_{(t,a)=(\hat{T}(a^*),a^*)} > 0$. For $U = 0$, (PC) is slack for all $T_{\min}$, while for any $U > 0$, it binds if $T_{\min}$ exceeds a finite threshold (after which (i) applies)).

Stringent deferral requirements backfire independent of the value of U:

$$\lim_{T_{\min}\to\infty} a^*(T_{\min}) = 0.$$

Proposition 2 highlights that stringent deferral regulation unambiguously backfires for general information structures and outside options. If $T_{\min}$ is sufficiently large, the size-of-pay force dominates and pushes toward lower effort. We note that this result arises endogenously from the solution to Problem 2 without any restrictions on the level of bank profits, that is, it holds even absent a participation constraint requiring shareholders' payoff to be nonnegative.

Case (i) applies to situations in which the manager's outside option is sufficiently high so that (PC) already binds in the absence of regulation. The comparative statics then follow directly from Lemma 5. Initially, equilibrium effort is given by $\underline{a}(T_{\min})$, and hence is strictly increasing in $T_{\min}$ until it reaches $T_{\min} = \tilde{T}$. From that point onwards, the action is pinned down by first-order condition (14) so that $a^*(T_{\min}) < \underline{a}(T_{\min})$ (see left panel of Figure 3).[24]

Case (ii) shows that with slack (PC), the success of marginally binding deferral regulation depends from Lemma 1 on the information structure, that

[24] A sufficient (not necessary) condition for the equilibrium action to strictly decrease for all $T_{\min} > \tilde{T}$ is that the growth rate of informativeness is weakly decreasing in a, as is the case in Figure 3.

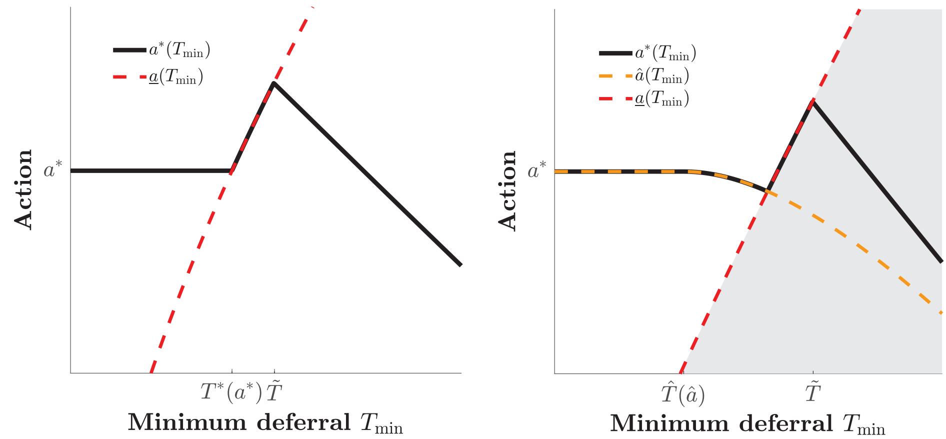

Figure 3. Effect of deferral regulation as a function of outside option U. We plot the equilibrium action $a^*(T_{\min})$ for the case of the exponential distribution; see solid black line. In the left (right) panel, we set $U > \hat{U}$ ($U < \hat{U}$), so that (PC) is binding (slack) in the absence of regulation. The orange dotted line corresponds to the optimal action $\hat{a}(T_{\min})$ disregarding (PC). The red dotted line depicts the cutoff action $\underline{a}(T_{\min})$ below which (PC) has to bind (gray-shaded region). (Color figure can be viewed at wileyonlinelibrary.com)

is, on the stochastic process governing bank failure (see Figure 1). It further highlights a novel effect of more stringent deferral regulation. By inducing shareholders to condition incentive compensation on more informative performance signals, deferral requirements cause the equilibrium agency rent to decline. Thus, for any positive manager outside option, the rent extraction contract, which disregards (PC), would eventually violate the manager's participation constraint for sufficiently high $T_{\min}$.

The right panel of Figure 3 illustrates this second case. For $T_{\min} > \hat{T}(a^*)$ but sufficiently close to $\hat{T}(a^*)$, the equilibrium action $a^*(T_{\min})$ (indicated by solid black line) is given by the equilibrium response for slack (PC), $\hat{a}(T_{\min})$ (see orange dotted line). Since Figure 3 is based on the exponential survival distribution, the equilibrium action is initially constant and then falls in this region in response to larger deferral periods $T_{\min}$ (see center panel Figure 1, $\beta = 1$). Now, as soon as $\hat{a}(T_{\min})$ enters the gray-shaded region, that is, $\hat{a}(T_{\min}) < \underline{a}(T_{\min})$, the agent's participation constraint would be violated under the rent-extraction contract and (PC) must start to bind. From that point onward, the familiar result with binding (PC) applies, namely, that the equilibrium action is initially given by the cutoff action $\underline{a}(T_{\min})$ and is strictly increasing before eventually declining (see left panel of Figure 3).

In sum, (moderate) deferral regulation is more likely to be effective at raising equilibrium risk-management effort if the agent's participation constraint binds. This happens if competition for talent is high, for example, due to employment opportunities in the unregulated shadow banking sector. Large interventions unambiguously backfire. We now examine the welfare aspects of such regulation.

C. Implications for Regulation Design

C.1. Welfare Effects of Deferral Regulation

Our positive analysis above focuses solely on the impact of deferral regulation on equilibrium risk-management effort—it does not consider whether such regulation is socially desirable. To examine such welfare implications, we need to evaluate regulatory intervention according to a welfare criterion. Let κ_A refer to the welfare weight that is attached to the agent. Then welfare Ω can be written as

$$\begin{aligned}\Omega = &- (1 - k_{\min})\left(1 - r\int_0^{\infty} e^{-rt} S(t|a)\, dt\right) \\ &+ \Pi(a) - W(a) - \Delta W(a|T_{\min}) \\ &+ \kappa_A[w + B(a|T_{\min}) - c(a) - U],\end{aligned} \tag{15}$$

accounting for the tax-payer externality, bank profits, and the manager's agency rent.[25]

Welfare Effects of Marginal Interventions: Before turning to the question of how to calibrate welfare-maximizing deferral periods, it is of interest to analyze the welfare effect of small regulatory interventions, as in practice most interventions are small, for example, with deferral requirements that exceed laissez-faire industry practice by a year.

PROPOSITION 3 (Welfare effects of marginal interventions): *A minimum deferral period marginally exceeding the unconstrained optimal payout date is welfare-enhancing if and only if either of the following holds:*

- *(i) (PC) is slack ($U < \hat{U}$), with $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}|_{(t,a)=(T^*(a^*),a^*)} > 0$ and κ_A below a threshold.*
- *(ii) (PC) binds ($U \geq \hat{U}$).*

Thus, if (PC) is slack, the regulator needs to be cautious and ensure that two conditions are satisfied. First, the information environment must be such that the growth rate of informativeness is (locally) increasing in a. This requirement is restrictive and not necessarily satisfied; see Example 1. Second, intuitively, the welfare weight attached to the manager cannot be too large since longer deferral pushes toward a smaller agency rent. Given the regulator's rationale for intervening in bankers' pay, this second restriction is likely satisfied as such regulation has been motivated by failure externalities on the tax payer and not by concerns for rents accruing to bank managers.[26] The main idea of the proof then is that only in the specified information environments do

[25] Normalizing one of the welfare weights to one is without loss of generality. Our results easily generalize to the case in which, for example, the welfare weight on the tax payer exceeds that of the bank, which could reflect dead-weight taxation costs resulting from financing the bailout subsidy.

[26] If anything, regulators were concerned by "excessive" pay for bank employees. See, for example, Plantin and Tirole (2018) for a welfare function with $\kappa_A = 0$.

small interventions trigger an increase in equilibrium effort (see right panel of Figure 1), leading to a *first-order* decrease in the tax-payer externality, while deadweight costs from contracting inefficiencies remain *second-order* and welfare effects of changes in the agency rent are via κ_A sufficiently small.

In contrast, if (PC) binds, the effect of marginally binding deferral regulation on welfare is unambiguously positive. Here the welfare weight κ_A is irrelevant since the manager is kept at her outside option. Hence, the welfare criterion in (15) can be simplified to

$$\Omega = V(a) - W(a) - \Delta W(a|T_{\min}), \tag{16}$$

where we use (5). That marginally binding deferral regulation unambiguously increases welfare in this case and then follows from observing that it induces an increase in effort (see case (i) of Proposition 2)—thereby leading to a decrease in the tax-payer externality—without incurring any contracting distortions in equilibrium, that is, $\Delta W = 0$ (see Lemma 5).

The Optimum Deferral Period: We now go a step further and determine the calibration of the *optimum* deferral period. To avoid additional case distinctions, we focus on the case with binding (PC), that is, the case in which moderate minimum deferral regulation robustly increases risk-management effort. It is then of interest to analyze whether this "ad hoc" regulatory tool can achieve second-best welfare,[27]

$$\Omega^{SB} = \max_{a\in\mathscr{A}} V(a) - W(a),$$

and we consider the relevant case in which bank operations can generate social value, that is, $\Omega^{SB} > 0$.[28] From (16), we observe that achieving second-best welfare requires that both the efficient action is incentivized (action efficiency), $a^*(T_{\min}) = a^{SB}$, and the associated compensation contract is unconstrained optimal (contracting efficiency), that is, $\Delta W(a^*(T_{\min})|T_{\min}) = 0$.

LEMMA 6 (Second-best welfare under deferral regulation): *Second-best welfare can be attained if and only if $T^*(a^{SB}) \leq \tilde{T}$ and $U \geq \overline{U}^{SB} := \frac{c'(a^{SB})}{\mathscr{I}(T^*(a^{SB})|a^{SB})} - c(a^{SB})$. The optimal deferral period is then $T^*_{\min} = T^*(a^{SB})$.*

The intuition for Lemma 6 is as follows. As long as $T^*(a^{SB}) \leq \tilde{T}$ (see left panel of Figure 4), shareholders facing a deferral requirement of $T^*_{\min} = T^*(a^{SB})$ incentivize the action $\underline{a}(T_{\min}) = a^{SB}$ (see Lemma 5) with an unconstrained optimal compensation contract (i.e., case (i) of Proposition 2 applies). In this case, second-best welfare is attained (see green dot in Figure 4).

[27] Second-best welfare refers to the maximal welfare subject to the moral hazard problem, which could be achieved, for example, if the regulator could write compensation contracts directly. However, 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.

[28] Therefore, a PC on the part of shareholders ($\Pi - W > 0$) would never bind under optimal regulation since bank profits exceed social welfare creation due to bailout guarantees.

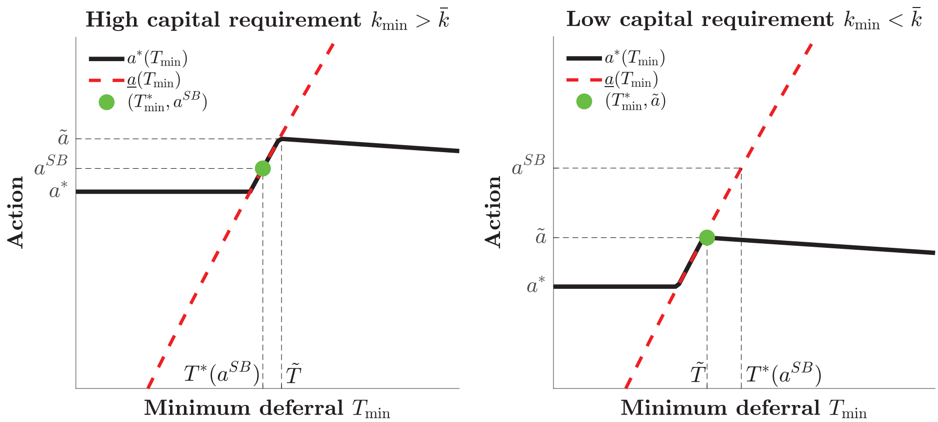

Figure 4. Outcome under welfare-maximizing deferral. We plot the equilibrium action as a function of the minimum deferral period $a^*(T_{\min})$—see solid black line—as well as the outcome under the welfare-maximizing deferral regulation—see green dot—for two different levels of the minimum capital requirement $k_{\min}$ ($k_{\min} = 0.8$ in the left panel and $k_{\min} = 0.01$ in the right panel). The arrival time distribution is exponential and the remaining parameter values are $r = 8$, $\Delta r = 4$, $\kappa = 5$, $y = 100$, and $U = 5$, with $c(a) = a^3/3$. (Color figure can be viewed at wileyonlinelibrary.com)

In contrast, if $T^*(a^{SB}) > \tilde{T}$ (see right panel of Figure 4), shareholders implement an action strictly lower than a^{SB} and additionally sacrifice contracting efficiency (see Lemma 5). In this case, second-best welfare cannot be achieved. As can be easily seen, the optimal deferral period here is given by $T^*_{\min} = \tilde{T}$, so that $a^*(T_{\min}) = \tilde{a}$ (see green dot in figure). A higher $T_{\min}$ would reduce welfare by lowering equilibrium effort and by inducing contracting inefficiencies. Since the contracting inefficiencies manifest themselves in increased wages (see Proposition 1), one could identify excessive regulation upon observing an increase in upfront wages in response to regulation.

It is now useful to link the technical condition $T^*(a^{SB}) \leq \tilde{T}$ to the economic environment. As is intuitive, this condition is satisfied if the privately optimal choice a^* and a^{SB} are not too far apart, that is, if the magnitude of shareholders' preference distortion is small. In our setup, a key driver of this distortion is the amount of leverage as influenced by the minimum capital requirement $k_{\min}$, which, in order to keep the paper focused on deferral regulation, we treat as an exogenous parameter. Proposition 4 now highlights the interaction of capital and compensation regulation.

PROPOSITION 4 (Interaction of compensation and capital regulation): *Second-best welfare can be attained with a minimum deferral requirement of* $T^*_{\min} = T^*(a^{SB})$ *if and only if* $k_{\min}$ *exceeds a threshold* $\bar{k} < 1$ *and* $U \geq \overline{U}^{SB}$.

Qualitatively, Proposition 4 implies substitutability of the intensity of capital regulation and the degree of optimal intervention in compensation contracts: lower capital regulation leads to larger differences between a^* and a^{SB} (compare the vertical distance between a^* and a^{SB} in left and right panels of Figure 4), and hence implies larger differences between optimally imposed minimum deferral periods and payout times of laissez-faire compensation contracts $T^{*}(a^{*})$.

We conclude by highlighting the distinct mechanism of capital regulation and compensation regulation. In our setting, capital regulation operates by reducing the wedge between private (bank) profits and societal welfare $\Pi(a|k_{\min}) - V(a)$, and thus directly addresses the root of shareholders' preference distortion.[29] In contrast, compensation regulation does not target the root of the distortion, that is, it does not lead bank shareholders to internalize tax-payer losses upon bank failure. Yet, by acting as an indirect tax on the implementation of actions, ΔW, it may still be effective in inducing shareholders to incentivize higher risk-management effort. However, the nonmonotonicity of the tax function limits its effectiveness in generating large, positive action changes.

C.2. The Role of Clawback Requirements

So far we have focused on compensation regulation that targets the *timing* dimension of bonus payments. Regulators have also imposed additional restrictions on the *contingency* of bonus payments in the form of clawback requirements. Such clawbacks are usually triggered upon revelation of major negative outcomes or scandals, as, for example, after the uncovering of Wells Fargo's fraud related to checking account applications between 2002 and 2016. In practice, there are two types of clawbacks: (1) pure clawbacks of already paid-out bonuses and (2) clawbacks from nonvested bonus escrow accounts. The latter type of clawback is technically referred to as a malus and is more relevant in practice due to obvious enforcement problems with pure clawbacks (see Arnold (2014)).[30] Accordingly, we focus our attention on clawback requirements in the form of a malus. Since banks may voluntarily include malus clauses in their contracts with managers, as did Wells Fargo, it is of interest whether *regulatory* malus requirements have additional bite.

In practice, regulation usually requires that bonuses be subject to clawback for a period of length T_{claw}. To illustrate the novel effects of a regulation targeting the contingency of pay, we set $T_{claw} = T_{\min}$. In our simple binary information environment, it is most natural to interpret the bank failure event as the relevant contingency triggering a clawback. Thus, we formalize the clawback clause as effectively requiring all incentive pay to be contingent on bank survival until $T_{\min}$. Accordingly, given a minimum deferral requirement of $T_{\min}$, shareholders face the additional constraint

$$b_t = 0 \quad \forall t \geq T_{\min} \text{ if } X_{T_{\min}} = 1. \tag{CLAW}$$

[29] Capital regulation is not the only regulation that leads the principal to (partially) internalize the negative welfare externality. For instance, in our setting, restrictions on dividend payouts to bank shareholders would work in a similar way by increasing shareholders' loss in the case of (early) default. We thank discussant Vish Viswanathan for this insight.

[30] In terms of our model, the impatient agent has already consumed all fully vested pay.

As is now easy to see, in our setting, such additional clawback requirements do not affect equilibrium outcomes. The reason is that, regardless of whether (PC) is slack or binding, (deferred) bonuses are endogenously contingent on survival (see Proposition 1) and hence automatically satisfy (CLAW).[31] More specifically, with slack (PC) the entire pay is always contingent on survival, while with binding (PC) the bank-optimal restructuring of contracts in response to pure deferral regulation involves a shift from fully contingent bonus pay to upfront wages, which—under current regulation—are not subject to clawback requirements. Within the context of our model, such a shift from incentive pay to fixed pay is clearly not in the regulator's interest. Indeed, real-world regulators, for example, Martin Wheatley of the UK Financial Conduct Authority, have become concerned by this practice of contracting "around the regulation" and, as a result, have considered extending the applicability of clawbacks to fixed pay (see Binham (2015)).

Our framework can also inform the debate about this more stringent policy. Recall that in our setting, unconditional wages are paid in equilibrium if and only if (PC) binds and $T_{\min} > \tilde{T}$ (see Lemma 5 and Proposition 1). In this case, a clawback requirement extending to wages would bind, requiring that *all* pay be contingent on bank survival until (at least) the end of the clawback period $T_{\min}$. The following proposition now shows the equilibrium effects of this more stringent regulation.

PROPOSITION 5 (The added value of clawbacks): *If $U > \overline{U}^{SB}$ and clawbacks extend to wages, second-best welfare can always be achieved by imposing a deferral/clawback period of $T^*_{\min} = T_{PC}(a^{SB})$. Such a clawback requirement is necessary to achieve second-best welfare whenever $k < \bar{k}$ or, equivalently, $T_{PC}(a^{SB}) > \tilde{T}$.*

The intuition for this result is simple. The more (regulatory) constraints bank shareholders face, the fewer margins of the compensation contract they can adjust. In this case, (PC) fixes the compensation value to the manager, the minimum deferral requirement (DEF) effectively fixes the timing of pay, and the clawback requirement for bonuses (CLAW) and wages fixes the contingency of pay. Together these constraints make it impossible to incentivize any effort level below $\underline{a}(T_{\min})$, that is, low effort is subject to an infinite tax, $\Delta W(a|T_{\min}) = \infty$ for all $a < \underline{a}(T_{\min})$. Regulation therefore becomes more powerful by effectively imposing a minimum effort constraint $a \geq \underline{a}(T_{\min})$. While Proposition 5 shows that second-best welfare can now be achieved for a larger set of parameters, it has to be noted that the exact calibration of the welfare-maximizing deferral period still requires a highly sophisticated regulator, as it

[31] Note that this result follows from optimality. In particular, it does not hold simply for the trivial reason that the bank may not have the resources to pay the agent in the case of failure. In practice, such bonus payouts could be implemented by funding a bonus escrow account that is separate from bank assets to guarantee payments to the agent even upon bankruptcy of the institution.

hinges on the ability to discern the learning dynamics of the specific information environment.

III. Robustness

In this section, we examine robustness of our model implications with regard to various simplifying assumptions.

Effect of Deferral Regulation on Outside Options: Our model considers the direct effect of deferral regulation on individual contracts, which is in line with regulators' partial-equilibrium rationale that further backloading of payments would lead to more prudent behavior of individual managers. However, even if unintended, this type of regulation may also have general equilibrium effects via its effect on managers' outside options. While a full-fledged general equilibrium analysis is beyond the scope of this paper, we next lay out a conceptual framework that allows us to endogenize the manager's outside option $U(T_{\min})$ and makes its dependence on deferral regulation explicit.

Consider a setting in which two banks GS and DB compete for the services of a bank manager who also has access to an outside employment opportunity in the unregulated shadow banking sector worth $\bar{U}$. To (realistically) ensure that the manager does not extract all rents, we suppose that banks are differentiated, in that the agent perceives a cost of K conditional on accepting the DB offer. This cost K may be interpreted as a switching cost of leaving GS or as the (monetized) difference in status attached to the banks. It is then easy to see that in the equilibrium of the contract offer game, DB just breaks-even. Formally, the manager's gross utility derived from DB's contract offer solves

$$U^{DB}_{gross}(T_{\min}) = \max U \text{ subject to } \Pi(a) - W(a|U, T_{\min}) \geq 0,$$

where the dependence of wage costs on U is now made explicit. Viewed from the (relevant) bank GS's perspective, the manager's outside option then is given by

$$U(T_{\min}) = \max\left\{U^{DB}_{gross}(T_{\min}) - K, \bar{U}\right\}.$$

It is then immediate that, as long as the cost K or the value of working in the shadow banking sector $\bar{U}$ is sufficiently large, our original analysis applies one-to-one. That is, bank GS will offer a contract in which either (PC) is slack or (PC) binds with an exogenous outside option $\bar{U}$. The interesting and novel case is when $U(T_{\min}) = U^{DB}_{gross}(T_{\min}) - K$ and K is sufficiently small such that (PC) binds. In this case, an increase in $T_{\min}$ will affect GS not only directly by constraining the contracting space, but also indirectly via its (negative) effect on the manager's outside option (as long as the within-industry outside option is relevant). Overall, the relevance of such general equilibrium effects is likely to differ across the various groups affected by the regulation (executives, traders, etc.) depending on the relative importance of within—versus across—

industry outside options in the respective line of work.[32] Future work could build on this toy model to explore, for example, the equilibrium implications of compensation regulation on the creation of systemic risk (see Albuquerque, Cabral, and Correia Guedes (2016)).

Nature of Action (Risk-Taking): As in any meaningful moral hazard model, our framework considers a setting in which the agent must be incentivized to take on a privately costly action. For reasons of tractability, the effort dimension (first moment) and volatility/risk (second moment) are directly linked. More generally, it may be interesting to consider a multitask setting that disentangles the effort and risk-taking components. One may then think of the "action" $a = (\mu, \sigma)$ as a vector consisting of the manager's choice of mean cash flow μ and cash flow volatility σ. While the action set is now richer, the "size-of-pay" effect is still relevant as actions that are (ceteris paribus) less costly to the agent (lower effort) require smaller compensation packages. This effect is responsible for the robust result that sufficiently stringent deferral regulation will always lead to backfiring on the (costly) effort dimension. To capture the "timing-of-pay" effect in this richer environment, we now need to consider whether a given action vector a is implemented with longer or earlier payout dates. For example, if $a_1 = (1, 0.3)$ is optimally incentivized with a payout after $T^*(a_1) = 1$ years whereas $a_2 = (2, 0.1)$ is optimally implemented with a payout after $T^*(a_2) = 3$ years, then only action a_1 is taxed under a minimum deferral period of $T_{\min} = 3$. In sum, even with multidimensional (or potentially sequential) actions, it is the interaction of the "size-of-pay" and "timing-of-pay" effects that shapes the indirect tax and thus the regulation's effects on equilibrium actions.

Risk-Aversion of the Agent/Relative Impatience: For the timing of pay to play to have a meaningful role in optimal contracts, one requires the assumption that the manager be risk averse, relatively impatient, or both. Without either of these ingredients, it would always be weakly optimal to wait until all information is revealed (the end of time). For tractability reasons, we favored the assumption of relative impatience, as introducing agent risk aversion in our setting would imply that optimal contracts stipulate payments for a larger set of states and times (see Propositions 2 and 3 in Hoffmann, Inderst, and Opp (2021)) rather than a single payout time and state (survival). However, this additional richness in optimal unconstrained contracts produces no new economic insights regarding the qualitative effects of deferral regulation on the equilibrium action choice, which is the focus of this paper. That is, the tax resulting from regulatory deferral constraints is still driven by the same "size-of-pay" and "timing-of-pay" effects.

[32] In particular, traders' outside job opportunities are likely in the unregulated (shadow) banking sector, such as at hedge funds or mutual funds, that is, $U = \bar{U}$, whereas traditional private banking executives' outside options are more likely to be determined by opportunities within the regulated banking sector.

In particular, the implementation of low-cost "shirking" actions is still less costly to defer. In the extreme case, if the principal wants to implement zero effort, mandatory deferral is costless. For all other actions, binding deferral regulation now constrains desired consumption smoothing, which implies a positive indirect tax levied on the principal (even under equal discounting). To illustrate the importance of "timing-of-pay" and its comparative statics, suppose that the optimal contract for action a_1 (a_2) implies that 30% (50%) of the compensation package value is paid out after year 2. Then, if regulation requires that at least 50% of incentive pay has to be paid out after year 2, only action a_1 is taxed, $\Delta W(a_1) > 0$, whereas action a_2 is tax-exempt. Understanding the comparative statics of the duration of pay is thus still crucial to determine the effects of deferral regulation (analogous to Lemma 1).

Regulatory Motivation: In our main analysis, we take the stance that regulation is motivated by externalities on the tax payer, as this friction has been considered particularly relevant in the financial sector. More generally, as long as bank shareholders do not fully internalize externalities on other parties, such as the payment system, other banks, borrowers, or depositors, there is scope for regulatory intervention. Still, as deferral regulation operates via compensation costs, the exact motivation would not matter qualitatively for its effects on equilibrium actions. Moving beyond the banking sector, one could even motivate regulatory interference via a corporate governance problem, for example, when the principal—the board—has different preferences than shareholders. Different from our setup, shareholders should then applaud regulatory interference. Related, the board may be unable to commit to long-term contracts (as in Hermalin and Katz (1991)). Regulation could then act as a commitment device allowing the principal to achieve *lower* wage costs for some actions. Formally, this would correspond to a negative indirect tax, akin to a *subsidy* that promotes some actions more than others.

Alternative or Additional Regulatory Constraints: Finally, our taxation analogy can be readily extended to allow for additional contracting constraints, as even multidimensional constraints operate as a single-valued indirect tax. In particular, one could analyze the effects of additional bonus caps as introduced in Europe in 2016 (see Appendix C), which put an upper bound on the ratio of bonus to wage compensation. Such a regulation would ceteris paribus imply higher taxes for actions that require higher bonus pay. Since higher effort generally requires higher bonuses, such caps work against promoting higher effort and hence backfire in our setting. Instead, our model points to potential benefits of restricting unconditional wage payments, for example, by extending clawback clauses to wages or by specifying a lower bound on the ratio of bonus to wage compensation.

IV. Conclusion

Our analysis is motivated by recent regulatory initiatives imposing deferral requirements and clawback clauses on compensation contracts in the financial sector. Calls for similar regulatory interventions to combat compensation-induced short-termism have also been frequently made outside the financial sector. Analyzing the real effects of such interventions is, however, of not only applied but also theoretical interest. How does a principal reshuffle incentives when facing such regulatory constraints on compensation design? In particular, how will such constraints affect the equilibrium action and ultimately risk?

To answer these questions accounting for the Lucas critique, our paper relies on a tractable model that endogenizes the timing of optimal compensation with and without regulatory constraints. Mandatory deferral makes it (relatively) more costly to induce actions that (*i*) absent regulation are optimally implemented with short-term contracts (*timing-of-pay channel*), and (*ii*) require large bonus packages (*size-of-pay channel*). We show that for marginal regulatory interventions, only the timing-of-pay force is at play. Deferral regulation then leads to an increase in equilibrium risk-management effort if and only if higher effort is implemented with later payouts in unconstrained optimal contracts. Our analysis reveals that this comparative statics restriction holds robustly only when the agent's outside option is sufficiently high. For large deferral requirements, the size-of-pay force dominates and, since implementing higher effort ceteris paribus requires larger bonuses, the quality of risk management unambiguously decreases in equilibrium.

Our normative analysis sheds light on the welfare effects of such compensation regulation and its interaction with capital regulation in a setting in which shareholders do not internalize failure externalities on the tax payer. We show that the case for (additional) compensation regulation is subtle. In contrast to capital regulation, compensation regulation does not target the root of shareholders' distortion toward excessive risk tolerance, but rather a symptom in the form of the compensation contracts they write to incentivize their key risk-takers. Yet, our analysis reveals that if the regulator correctly understands the economic primitives driving unconstrained optimal compensation design, appropriately calibrated deferral and clawback requirements can be effective in steering bank shareholders to incentivize welfare-superior actions from their employees, and may even allow them to achieve the second-best outcome.

Turned on its head, our results imply that if regulators lack such detailed knowledge of the primitives that govern optimal unconstrained incentive contracts, these interventions may backfire. In particular, the crucial dependence of optimal regulation on the information environment and on the agents' outside options suggests that "one-size-fits-all" regulation applying to traders, managers, and CEOs alike is suboptimal and leads to backfiring for at least some group of risk-takers. Building on these observations, future work may consider imposing realistic information 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. When is it optimal to micromanage the agency problem by interfering in the compensation contract? When is it optimal to directly target the externality? Our analysis of the interaction between capital regulation and deferral/clawback regulation can be thought of as a first step in this direction.

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Appendix A: Proofs

PROOF OF LEMMA 1: Suppose that $\frac{dT^*(a)}{da}|_{a=a^*} > 0$. Then, by continuity, there exist $a_1 < a^* < a_2$ such that $\frac{dT^*(a)}{da} > 0$ for all $a \in [a_1, a_2]$.[33] Hence, for any $T_{\min} \in (T^*(a_1), T^*(a_2))$, there exists a cutoff action $\underline{a}(T_{\min}) \in (a_1, a_2)$ such that the regulatory constraint (DEF) is slack for all $a \in [\underline{a}(T_{\min}), a_2]$, so that $\Delta W(a|T_{\min}) = 0$, and the regulatory constraint binds for all $a \in [a_1, \underline{a}(T_{\min}))$, so that $\Delta W(a|T_{\min}) > 0$ (see Figure B.1 in Appendix B for a case in which $T^*(a)$ is globally increasing in a). The cutoff $\underline{a}(T_{\min})$ solves $T^*(\underline{a}(T_{\min})) = T_{\min}$ and, from $\frac{dT^*(a)}{da}|_{a=a^*} > 0$, satisfies $\frac{d}{dT_{\min}}\underline{a}(T_{\min}) > 0$ for $T_{\min} \in (T^*(a_1), T^*(a_2))$. So, set $T_{\min} = T^*(a^*)$, which implies that $\underline{a}(T_{\min}) = a^*$. We now show that following a marginal increase in $T_{\min}$, the optimal action solving (6) satisfies $a^*(T_{\min}) \in (a^*, \underline{a}(T_{\min})]$.

We first note that the optimal action choice under binding deferral regulation, $a^*(T_{\min})$, is bounded above by $\underline{a}(T_{\min})$. This follows from strict concavity of the unconstrained objective function $\Pi(a) - W(a)$ and the fact that for $T_{\min}$ marginally exceeding $T^*(a^*)$, the cutoff action $\underline{a}(T_{\min})$, the smallest action for which $\Delta W(a|T_{\min}) = 0$, exceeds a^*, that is, $\underline{a}(T_{\min}) > a^*$.

Next note that our assumptions imply that the unconstrained optimal action choice a^* is interior and uniquely characterized by the first-order condition $\Pi'(a^*) - W'(a^*) = 0$. Hence, by the envelope theorem, a marginal change in the action around a^* has no first-order effect on the unconstrained optimal profit $\Pi(a) - W(a)$. We now distinguish two cases depending on whether $\Delta W(a|T_{\min})$ is differentiable.

First, assume that $\Delta W(a|T_{\min})$ is differentiable in the relevant region such that $\frac{\partial}{\partial a}\Delta W(\underline{a}(T_{\min})|T_{\min}) = 0$. Then, following a marginal increase in $T_{\min}$ above $T^*(a^*)$, the marginal tax $\frac{\partial}{\partial a}\Delta W(a|T_{\min})$ at $(a^*, T^*(a^*))$ is positive and of the same order of magnitude as marginal laissez-faire profit $\Pi'(a) - W'(a)$. The first-order condition of the optimal action choice problem in (6) together with strict concavity of the unconstrained objective function then directly implies that $a^*(T_{\min}) \in (a^*, \underline{a}(T_{\min}))$.

Now suppose that $\Delta W(a|T_{\min})$ is not differentiable in the relevant region. We still have that $\Delta W(a|T_{\min}) > 0$ for $a \in [a_1, \underline{a}(T_{\min}))$ and $\Delta W(a|T_{\min}) = 0$ for $a \in [\underline{a}(T_{\min}), a_2]$. In this case, following a marginal increase in $T_{\min}$ above $T^*(a^*)$, the increase in the regulatory tax $\Delta W(a|T_{\min})$ in a neighborhood around a^* and to the left of $\underline{a}(T_{\min})$ is of higher order than marginal laissez-faire profit $\Pi'(a) - W'(a)$. It then directly follows from (6) that $a^*(T_{\min}) = \underline{a}(T_{\min}) > a^*$.

[33] The argument of the proof only requires that $T^*(a)$ be strictly monotonic in the neighborhood of a^*. In our model, differentiability of $T^*(a)$ follows from the characterization in Lemma 2.

Above we show that $\frac{dT^*(a)}{da}|_{a=a^*} > 0$ is sufficient for marginally binding regulation to have a strictly positive effect on equilibrium effort. To show that it is also necessary, assume that $\frac{dT^*(a)}{da}|_{a=a^*} \leq 0$. Then the same line of argument implies that $a^*(T_{\min}) \leq a^*$ if $T_{\min}$ marginally exceeds the laissez-faire payout time $T^*(a^*)$. □

PROOF OF LEMMA 2: We first characterize the optimal contingency of pay, before turning to the optimal timing of pay. The optimal payments as well as the agent's valuation and the principal's compensation cost then follow immediately.

Optimal Contingency of Pay. A solution to Problem 1 has the following property.[34] □

LEMMA A.1: *An optimal contract never stipulates rewards following failure.*

PROOF OF LEMMA A.1: Note first that the unconditional upfront payment w is equivalent to a survival-contingent date-0 bonus since $S(0|a) = 1$. The result then follows from the fact that for each $t > 0$, survival is the performance history with the highest log-likelihood ratio (score).[35] To see this, denote the failure density by $f(t|a) = S(t|a)\lambda(t|a)$, such that the score of the history involving a failure at t satisfies

$$\frac{\partial \log f(t|a)}{\partial a} = \frac{\partial \log S(t|a)}{\partial a} + \frac{\partial \log \lambda(t|a)}{\partial a} < \frac{\partial \log S(t|a)}{\partial a}, \tag{A.1}$$

where we use the assumption on the failure rate in (1). Since (1) further implies that $\frac{\partial \log S(t|a)}{\partial a}$ is a strictly increasing function of t, histories involving a failure at some $s < t$ also have a lower score than date-t survival. Hence, making incentive pay contingent on survival provides the strongest incentives per unit of expected pay at each given t. Having established that in our setting, the survival history has the highest score, the remaining parts of the proof simply adapt the key ideas of the proof of Theorem 1 in Hoffmann, Inderst, and Opp (2021) to our specific setting.

An optimal contract exists (as characterized in Lemma 2) since the maximal likelihood ratio history ("survival") has strictly positive probability mass $S(t|a) > 0$ for all finite t and $a > 0$. Moreover, condition (7) ensures that the optimal payout time is finite.

[34] Note that Lemma A.1 applies independently of the value of $T_{\min}$, that is, to both unregulated contracts ($T_{\min} = 0$) and regulated contracts ($T_{\min} > 0$).

[35] For a formal definition of the score in this setup, recall that the family of probability measures associated with the failure intensities $\lambda(\cdot|a)$ for $a \in \mathscr{A}$ is denoted by $(\mathbb{P}^a)_{a\in\mathscr{A}}$, that is, under $\mathbb{P}^a$, the counting process of bank failure X has intensity $\lambda(\cdot|a)$. Then, denoting by $\mathbb{P}^a_t$ the restriction of $\mathbb{P}^a$ to $\mathcal{F}^X_t$, we can define for each $a > 0$ the likelihood function $\mathcal{L}_t(a|\omega) := \frac{d\mathbb{P}^a_t}{d\mathbb{P}^{a_0}_t}(\omega)$ as the Radon-Nikodym derivative of the measure induced by action a with respect to the base measure for action $a_0 = 0$. The likelihood function exists from the Radon-Nikodym theorem. The log-likelihood ratio is then given as $L_t(a|\omega) := \frac{\partial}{\partial a} \log \mathcal{L}_t(a|\omega)$, which exists and is bounded above as our setup satisfies standard Cramér-Rao regularity conditions.

The remaining proof then is by contradiction. Assume that for some admissible t, the optimal contract stipulates a date-t payment that is not contingent on survival up to date t. Clearly, unconditional payments at $t > 0$ are never optimal given the agent's relative impatience. We therefore restrict attention to date-t payments contingent on a history involving failure at some $s \leq t$. Then there exists another feasible contract with $db_t = 0$ for all histories other than survival that yields lower compensation costs, contradicting optimality of the candidate contract.[36]

To see this, assume first that (PC) is slack and, for all t, make all payments contingent on survival holding $\mathbb{E}^a[e^{-(r+\Delta r)t}db_t]$ and thus total compensation costs constant. However, (IC) will be slack under this alternative contract.[37] To see this, denote the share of expected date-t compensation $\mathbb{E}^a[db_t]$ derived from a survival-contingent bonus by γ_t^S and the cumulative share derived from date-t bonuses contingent on failure up to $s \leq t$ by $\gamma_t^F(s)$. Then from (IC), the incentives provided by these bonus payments are given by

$$\frac{d}{da}\mathbb{E}^a\big[db_t\big] = \left[\frac{\partial \log S(t|a)}{\partial a}\gamma_t^S + \int_0^t \frac{\partial \log f(s|a)}{\partial a} d\gamma_t^F(s)\right]\mathbb{E}^a\big[db_t\big],$$

which, holding $\mathbb{E}^a[db_t]$ constant, is maximized for $\gamma_t^S = 1$ by (A.1). A slack (IC) then allows one to reduce $db_t > 0$ at some t for which $\mathbb{E}^a[db_t] > 0$, reducing compensation costs.

Second, assume that (PC) binds. Then using the same variation in the original contract constructed above, we again arrive at a solution with slack (IC), which now allows one to reduce $db_t > 0$ at some $t > 0$ for which $\mathbb{E}^a[db_t] > 0$ to $(1 - y)db_t$ with $y \in (0, 1)$ and add a lump-sum payment at $t = 0$ of $\mathbb{E}^a[e^{-(r+\Delta r)t}y\,db_t]$ to still satisfy (PC). Compensation costs are again lower, now due to differential discounting. □

Optimal Timing of Pay. We next characterize the optimal timing of pay without the regulatory constraint (DEF). The proof is adapted from Hoffmann, Inderst, and Opp (2021) (see in particular the proof of their Theorem 1 as well as Theorem B.1 in their Internet Appendix). For notational convenience, we subsume the unconditional upfront payment w (which is equivalent to a survival-contingent date-0 bonus since $S(0|a) = 1$) into the bonus process b_t. To solve for the optimal timing of payouts, it is now useful to introduce the following two auxiliary variables capturing the total size of the compensation package and the distribution of payments over time. In particular, denote for any admissible process b_t the agent's time-0 valuation of the compensation contract

[36] Compensation costs can be strictly reduced if payments following failure occur with strictly positive probability under the candidate contract.

[37] That (IC) binds under the optimal contract follows directly from the observation that deferring pay is costly due to the agent's relative impatience but necessary to provide incentives given an information system in which no informative signals are available at $t = 0$.

by

$$B(a) := \mathbb{E}^a\left[\int_0^\infty e^{-(r+\Delta r)\,t}\, db_t\right],$$

and define the fraction of the compensation value B that the agent derives from stipulated payouts up to time s by

$$g_s := \mathbb{E}^a\left[\int_0^s e^{-(r+\Delta r)\,t}\, db_t\right]/B(a).$$

Then using Lemma A.1, we can rewrite Problem 1 for $T_{\min} = 0$ in terms of $(B(a), g)$ as follows.

PROBLEM 1*:

$$W(a|0) := \min_{B(a),g_t} B(a)\int_0^\infty e^{\Delta rt}dg_t \quad s.t.$$

$$B(a) - c(a) \geq U, \tag{PC*}$$

$$B(a)\int_0^\infty \mathscr{I}(t|a)dg_t = c'(a), \tag{IC*}$$

$$dg_t \geq 0 \quad \forall t. \tag{LL*}$$

Here, $g_\infty = \int_0^\infty dg_t = 1$ so that $\int_0^\infty t dg_t$ can be interpreted as the (cash-flow weighted) duration of the contract. We now characterize the optimal timing and size of pay in terms of $(B(a), g)$. We can then recover b via the transformation $\mathbb{E}^a[db_t] = e^{(r+\Delta r)t}B(a)dg_t$ for each $t \geq 0$ together with Lemma A.1.

First, consider the relaxed problem with slack (PC*). Then, substituting out B from the objective function using (IC*), the compensation design problem reduces to

$$W(a) := W(a|0) = \min_{g_t} c'(a)\frac{\int_0^\infty e^{\Delta rt}dg_t}{\int_0^\infty \mathscr{I}(t|a)dg_t}, \tag{A.2}$$

which is solved by $\int_{\hat{T}(a)} dg_t = 1$ for $\hat{T}(a) = \arg\max_t e^{-\Delta rt}\mathscr{I}(t|a)$ and $dg_t = 0$ else. Differentiability of $\mathscr{I}(t|a)$ together with the fact that $\hat{T}(a)$ must be strictly positive, as $\mathscr{I}(t|a)$ is strictly increasing in t from $\mathscr{I}(0|a) = 0$, and finite by condition (7) then implies that (10) characterizes the optimal payout date, which is unique from (7).[38] Hence, there is no upfront bonus in this case ($w = 0$). Substituting the optimal payout time in (IC*), we obtain the agent's time-0 valuation

[38] To see this, note that (7) is equivalent to $\frac{\partial^2\mathscr{I}(t|a)/\partial t^2}{\partial\mathscr{I}(t|a)/\partial t} < \Delta r$ such that $e^{\Delta rt}$ is strictly convex relative to $\mathscr{I}(t|a)$.

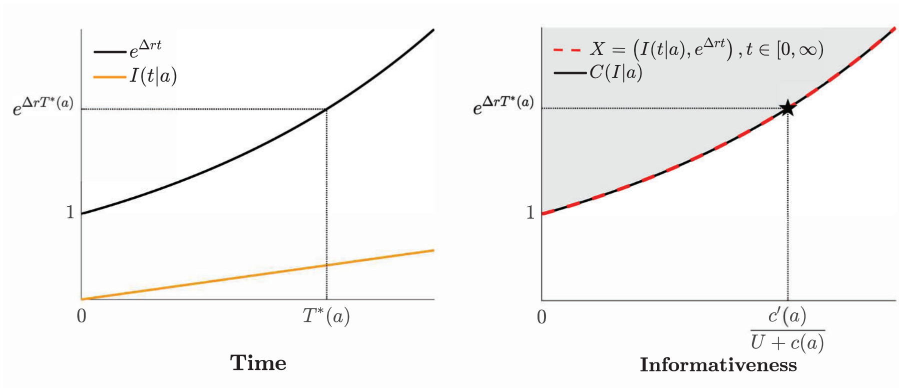

Figure A.1. Optimal payout date with binding (PC). The left panel plots informativeness, $\mathscr{I}(t|a) = \frac{t}{a}$ (exponential arrival time distribution), for given action a and impatience costs $e^{\Delta rt}$ both as functions of time. The right panel plots $e^{\Delta rt}$ against $\mathscr{I}(t|a)$ as a parametric curve X (red dashed line). The gray-shaded area corresponds to the convex hull, $conv(X)$, of this set of points for $t \to \infty$. Finally, the black solid line refers to the lower hull, C, the "cost of informativeness." (Color figure can be viewed at wileyonlinelibrary.com)

of the bonus payment $B(a|T^*(a)) = B(a|\hat{T}(a)) = \frac{c'(a)}{\mathscr{I}(\hat{T}(a)|a)}$, and (PC*) is indeed slack if and only if $U \leq B(a|\hat{T}(a)) - c(a)$.

Next, consider the case with binding (PC*). The optimality of a contract with a single payout date, as characterized by (11), follows directly from the convexity condition (7) and the results in Hoffmann, Inderst, and Opp (2021) (see in particular their Lemma 1 and Theorem B.1 in their Internet Appendix). The essential steps are as follows.

Consider the compensation design Problem 1* with binding (PC*). Then, substituting out B using the binding (PC*), the compensation design problem can be written as

$$W(a|0) := \min_{g_0, dg_t \geq 0} \left(U + c(a)\right) \int_0^{\infty} e^{\Delta rt} dg_t \quad \text{s.t.} \tag{A.3}$$

$$\int_0^{\infty} \mathscr{I}(t|a)\, dg_t = \frac{c'(a)}{U + c(a)}. \tag{A.4}$$

That is, optimal bonus payout times achieve a given *weighted-average* informativeness of $\int_0^{\infty} \mathscr{I}(t|a) dg_t = \frac{c'(a)}{U+c(a)}$ at lowest *weighted-average* impatience costs, $\int_0^{\bar{T}} e^{\Delta rt} dg_t$. The optimal payout times can now be characterized using simple tools of convex analysis. To do so, it is useful to consider the curve $(\mathscr{I}(t|a), e^{\Delta rt})$ parameterized by $t \in [0, \infty)$ and its convex hull tracing out the set of $(\int_0^{\infty} \mathscr{I}(t|a) dg_t, \int_0^{\infty} e^{\Delta rt} dg_t)$ achievable with any admissible weighting $(g_t)_{t=0}^{\infty}$ (see gray-shaded area in right panel of Figure A.1).

Since the objective in (A.3) is to *minimize* weighted-average impatience costs, only the *lower hull* is relevant, which, from condition (7), is for any a a strictly convex function of (weighted-average) informativeness given by $C(x|a) = e^{\Delta r \inf\{t:\mathscr{I}(t|a)\geq x\}} = e^{\Delta r \mathscr{I}^{-1}(x|a)}$ (see solid black line in right panel of Figure A.1). Economically, this function can be interpreted as the *cost of informativeness*—the minimum impatience cost required to achieve a given level of (weighted-average) informativeness. As incentive compatibility in (A.4) requires a weighted-average informativeness of $\frac{c'(a)}{U+c(a)}$, minimum wage costs in (A.3) are thus given by $W = (U + c(a))C(\frac{c'(a)}{U+c(a)}|a)$. Due to strict convexity of $C(\cdot|a)$, it is never optimal to mix between two payout dates. That is, the uniquely optimal payout time satisfies (11) (see star in right panel of Figure A.1). Again, the agent's time-0 valuation of the bonus $B(a|T^*(a))$ then follows from substituting the optimal payout time in (IC*).

From the definition of $C(\cdot|a)$, the expression for $W(a|0)$ follows immediately from substituting the optimal payout time as well as $B(a|T^*(a))$ into the principal's objective. It remains to show that whenever (PC*) binds, $T^*(a)$ solving (11) satisfies $T^*(a) < \hat{T}(a)$. To see this, note first that (PC*) binds if and only if $U > B(a|\hat{T}(a)) - c(a) \Leftrightarrow \mathscr{I}(\hat{T}(a)|a) > \frac{c'(a)}{U+c(a)}$. The result then follows directly from (11) together with the fact that $\mathscr{I}(t|a)$ is increasing in t.

Validity of First-Order Approach. It remains to show the validity of the first-order approach. To do so, it is sufficient to show that, given the optimal contract characterized above, the agent's optimal action choice problem is strictly concave whenever $S(t|a)$ is concave in a at the optimal payout date $T^*(a)$. To see this, note that facing a contract (w, b), the agent chooses action a to maximize expected discounted utility

$$u(a) = w + \int_0^\infty e^{-(r+\Delta r)\,t} S(t|a)\,db_t - c(a),$$

which is twice-differentiable in a under the candidate optimal contract by the assumptions on $S(t|a)$ and $c(a)$. The result then follows directly from $u''(a) = \int_0^\infty e^{-(r+\Delta r)t} \frac{\partial^2}{\partial a^2} S(t|a) db_t - c''(a)$ and the fact that $db_t = 0$ for all $t \in [0, \infty)\backslash T^*(a)$. The first-order condition in (IC) is then both necessary and sufficient for incentive compatibility.

The following auxiliary lemma is used repeatedly in the proofs to follow.

LEMMA A.2: *Assume that a contract stipulates a bonus at a single payout date T if and only if the bank has survived by date T. Then IC implies*

$$\frac{1}{\mathscr{I}(T|a)} \frac{c''(a)}{c'(a)} - \frac{\frac{\partial}{\partial a}\mathscr{I}(T|a)}{\mathscr{I}^2(T|a)} \geq 1. \tag{A.5}$$

PROOF OF LEMMA A.2: Given a contract, the manager maximizes his value $u(\tilde{a}) := \mathbb{E}^{\tilde{a}}[\int_0^\infty e^{-(r+\Delta r)t} db_t] - c(\tilde{a})$ such that incentive compatibility of a contract implementing action a requires that, at $\tilde{a} = a$, the manager's first-order condition $B = c'(a)/\mathscr{I}(T|a)$ as well as the second-order condition $B(\frac{\partial}{\partial a}\mathscr{I}(T|a) + \mathscr{I}^2(T|a)) - c''(a) \leq 0$ are satisfied. Rearranging yields condition (A.5). □

PROOF OF LEMMA 3: We first show the result for binding (PC). To make this explicit, denote the optimal payout time with binding (PC) as characterized in (11) by $T_{PC}(a)$ and the manager's utility from taking action a given an incentive-compatible contract with single survival-contingent payout at date t by $u(a,t) := \frac{c'(a)}{\mathscr{I}(t|a)} - c(a)$, which is differentiable in both arguments. Now $T_{PC}(a)$ is implicitly defined by $u(a, T_{PC}(a)) = U$. Hence, strict monotonicity of $\mathscr{I}(t|a)$ implies that $\partial u(a,t)/\partial t < 0$, while

$$\frac{\partial u(a,t)}{\partial a} = \frac{c''(a)\mathscr{I}(t|a) - c'(a)\frac{\partial}{\partial a}\mathscr{I}(t|a)}{\mathscr{I}^2(t|a)} - c'(a)$$
$$= c'(a)\left(\frac{1}{\mathscr{I}(t|a)}\frac{c''(a)}{c'(a)} - \frac{\frac{\partial}{\partial a}\mathscr{I}(t|a)}{\mathscr{I}^2(t|a)} - 1\right) > 0,$$

where the inequality holds from Lemma A.2. The result then follows from the implicit function theorem as $T'_{PC}(a) = -\frac{\partial u(a,t)/\partial a}{\partial u(a,t)/\partial t} > 0$.

It remains to show the comparative statics results for the case with slack (PC) for which the optimal payout date $T^*(a) = \hat{T}(a)$ is uniquely characterized by (10). A direct application of the implicit function theorem then shows that

$$\operatorname{sgn}\left(\frac{d\hat{T}(a)}{da}\right) = \operatorname{sgn}\left(\frac{\partial}{\partial a}\left.\frac{\partial \log \mathscr{I}(t|a)}{\partial t}\right|_{t=\hat{T}(a)}\right),$$

and the result follows. □

PROOF OF COROLLARY 1: We provide a characterization of the threshold $\hat{U}$. Denote the solution to the action choice problem, if (PC) is disregarded, by $\hat{a}(T_{\min})$, and let $\hat{a} := \hat{a}(0)$ refer to the corresponding laissez-faire action. Then the manager's net utility under the associated laissez-faire contract is given by $\hat{U} := u(\hat{a}, \hat{T}(\hat{a})) = \frac{c'(\hat{a})}{\mathscr{I}(\hat{T}(\hat{a})|\hat{a})} - c(\hat{a})$. As a result, (PC) is indeed slack in the absence of regulation if and only if $U \leq \hat{U}$ (see Lemma 2). □

PROOF OF PROPOSITION 1: That all bonus payments under the optimal contract with deferral regulation (DEF) are still contingent on survival follows from Lemma A.1. Here, we note again that an unconditional upfront payment w is equivalent to a survival-contingent date-0 bonus since $S(0|a) = 1$. To show that with binding deferral regulation bonus payouts optimally occur at $T_{\min} > 0$, consider first the case with slack (PC). Here, inspection of the simplified compensation design problem in (A.2), with the additional constraint that $dg_t = 0$ for $0 < t < T_{\min}$, directly implies $w = 0$ and an optimal bonus payout time of

$$\hat{T}(a, T_{\min}) = \arg\max_{t \geq T_{\min}} e^{-\Delta rt}\mathscr{I}(t|a).$$

This simplifies to $\hat{T}(a, T_{\min}) = \max\{\hat{T}(a), T_{\min}\}$, where we use the convexity condition in (7) (see also footnote 40). Substituting the optimal payout time in (IC*), we obtain the agent's expected compensation value of $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}(T_{\min}|a)}$ and (PC*) is indeed slack if and only if $U \leq B(a|T_{\min}) - c(a)$.

Consider, next, the case with binding (PC), that is, the compensation design problem in (A.3) and (A.4) with the additional constraint that $dg_t = 0$ for $0 < t < T_{\min}$. It then follows directly from $\mathscr{I}(0|a) = 0$ and $\frac{\partial}{\partial t}\mathscr{I}(t|a) > 0$ together with $T_{\min} > T^*(a)$ that (A.4) can only be satisfied with a positive payment at $t = 0$, that is, $w > 0$. The optimality of a single deferred bonus at $T_{\min}$ then follows from the fact that the cost of informativeness $C(\mathscr{I}(t|a)|a)$ is strictly increasing and strictly convex in informativeness by condition (7) together with $\frac{\partial}{\partial t}\mathscr{I}(t|a) > 0$. From (IC*), we then directly obtain, with slight abuse of notation, the agent's valuation of the deferred bonus as $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}(T_{\min}|a)}$. The upfront wage is then obtained from binding (PC*), where $w > 0$ follows from $U > B(a|T_{\min}) - c(a)$.

Finally, the expression for $W(a|T_{\min})$ follows from direct substitution and $W(a|T_{\min}) > W(a) = W(a|0)$ whenever $T_{\min} > T^*(a)$ follows from optimality of the unconstrained optimal payout time. □

PROOF OF LEMMA 4: The regulatory tax $\Delta W(a|T_{\min}) := W(a|T_{\min}) - W(a)$ satisfies $\Delta W(a|T_{\min}) \geq 0$ by optimality of the unregulated optimal contract. Further, $\Delta W(a|T_{\min}) = 0$ if and only if the shadow cost on the regulatory constraint (DEF) is zero. This is the case if no deferred bonus is paid, which from Lemma 2 and Proposition 1 applies if and only if there is no incentive problem as $a = 0$, or if (DEF) is slack, $T_{\min} \leq T^*(a)$. The latter case applies for actions $a \geq \underline{a}(T_{\min})$ as defined in (13), where the inequality and existence of $\underline{a}(T_{\min})$ follow from $dT^*(a)/da > 0$. 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 $\underline{a}(T_{\min})$.

We next derive some additional results referred to in the main text. Consider first the case with slack (PC), for which we can write the indirect tax function $\Delta W(a|T_{\min}) := W(a|T_{\min}) - W(a)$ as

$$\Delta W(a) = c'(a)\left(\frac{e^{\Delta r T_{\min}}}{\mathscr{I}(T_{\min}|a)} - \frac{e^{\Delta r \hat{T}(a)}}{\mathscr{I}(\hat{T}(a)|a)}\right)\mathbb{1}_{T_{\min} > \hat{T}(a)}, \tag{A.6}$$

where we use Lemma 2 and Proposition 1. Similarly, for the case with binding (PC), we obtain

$$\Delta W(a|T_{\min}) = c'(a)\left(\frac{e^{\Delta r T_{\min}} - 1}{\mathscr{I}(T_{\min}|a)} - \frac{e^{\Delta r T_{PC}(a)} - 1}{\mathscr{I}(T_{PC}(a)|a)}\right)\mathbb{1}_{T_{\min} > T_{PC}(a)}, \tag{A.7}$$

where for notational convenience, we again denote the optimal bonus payout time as characterized in (11) by $T_{PC}(a)$. Inspection of (A.6) and (A.7) confirms the previously established properties of the tax function.[39]

For our subsequent results, the following difference between the cases with slack and binding (PC) will be crucial: If (PC) is slack, straightforward differentiation of (A.6) together with $\hat{T}(\underline{a}(T_{\min}), T_{\min}) = T_{\min} = \hat{T}(\underline{a}(T_{\min}))$ implies that $\frac{\partial}{\partial a}\Delta W(\underline{a}(T_{\min})|T_{\min}) = 0$. In contrast, with binding (PC), we obtain $\lim_{a\uparrow\underline{a}(T_{\min})}\frac{\partial}{\partial a}\Delta W(a|T_{\min}) < 0$. To see this, differentiate the expression in (A.7) with respect to a and note that $T_{PC}(a) \to T_{\min}$ as a approaches $\underline{a}(T_{\min})$ from below, such that

$$\lim_{a\uparrow\underline{a}(T_{\min})}\frac{\partial}{\partial a}\Delta W(a|T_{\min}) = -c'(a)\underbrace{\frac{\partial}{\partial T_{PC}}\frac{e^{\Delta r T_{PC}(a)}-1}{\mathscr{I}\left(T_{PC}(a)|a\right)}}_{>0}T'_{PC}(a) < 0. \tag{A.8}$$

Here we use the fact that $\frac{\partial}{\partial T_{PC}}\frac{e^{\Delta r T_{PC}(a)}-1}{\mathscr{I}(T_{PC}(a)|a)} > 0$, which follows from strict convexity of the cost of informativeness implied by condition (7).[40] □

PROOF OF LEMMA 5: We first consider the case with binding (PC). To do so, it is convenient to recall from Lemma 4 that the regulatory tax $\Delta W(a)$ is zero for all $a \geq \underline{a}(T_{\min})$. Further, from (13), we have $a^* = \underline{a}(T_{\min})$ at the unregulated optimum $T_{\min} = T_{PC}(a^*)$. Hence, since $\underline{a}(T_{\min})$ is increasing in $T_{\min}$ from Lemma 3, strict concavity of the unconstrained objective function $\Pi(a) - W(a)$ implies that $a^*(T_{\min}) \leq \underline{a}(T_{\min})$ for all $T_{\min} \geq 0$. More specifically, the optimal action choice with binding regulation thus solves

$$a^*(T_{\min}) = \underset{a\leq\underline{a}(T_{\min})}{\arg\max}\,\Pi(a) - W(a) - \Delta W(a|T_{\min}).$$

Now recall that without regulation, a^* solves $\Pi'(a^*) - W'(a^*) = 0$ while $\lim_{a\uparrow\underline{a}(T_{\min})}\frac{\partial}{\partial a}\Delta W(a|T_{\min}) < 0$ (see (A.8)) such that $a^*(T_{\min}) = \underline{a}(T_{\min})$ for $T_{\min}$ sufficiently close to the unconstrained optimal payout date $T_{PC}(a^*)$ (see also the proof of Lemma 1). It immediately follows from the definition of $\underline{a}(T_{\min})$ that $\Delta W(a^*(T_{\min})|T_{\min}) = 0$ in this region.

Now, as $T_{\min}$ increases further, strict concavity of the unconstrained objective function $\Pi(a) - W(a)$ eventually implies that $a^*(T_{\min}) < \underline{a}(T_{\min})$.[41] This is the

[39] More specifically, (A.6) and (A.7) together with $\hat{T}(a) := \arg\min e^{\Delta rt}/\mathscr{I}(t|a)$ and $T_{PC}(a) := \arg\min(e^{\Delta rt} - 1)/\mathscr{I}(t|a)$, respectively, imply that $\Delta W(a) \geq 0$, with equality if and only if either $T_{\min} \leq T^*(a)$ and/or $c'(a) = 0$, which from $dT^*(a)/da > 0$ and the assumption on the effort cost function is equivalent to $a \geq \underline{a}(T_{\min})$ and $a = 0$, respectively.

[40] To see this, consider the curve $(\mathscr{I}(t|a), e^{\Delta rt} - 1)$ parameterized by t, that is, graphically, the plot of $e^{\Delta rt} - 1$ on the vertical axis against $\mathscr{I}(t|a)$ on the horizontal axis. From condition (7), this is strictly convex such that the slope of a ray through the origin and $(\mathscr{I}(t|a), e^{\Delta rt} - 1)$ is strictly increasing in t.

[41] Note that for finite $T_{\min}$, the marginal tax is bounded below for all $a < \underline{a}(T_{\min})$.

case for all $T_{\min} > \tilde{T}$, where the latter solves

$$\Pi'\big(\underline{a}(T_{\min})\big) - W'\big(\underline{a}(T_{\min})\big) = \lim_{a \uparrow \underline{a}(T_{\min})} \frac{\partial}{\partial a} \Delta W(a|T_{\min}). \tag{A.9}$$

Then for all $T_{\min} > \tilde{T}$, the optimal action choice is characterized by the first-order condition in (14).[42] From $a^*(T_{\min}) < \underline{a}(T_{\min})$, which is equivalent to $T_{\min} > T_{PC}(a^*(T_{\min}))$, it immediately follows from Proposition 1 that $w > 0$ and $\Delta W(a^*(T_{\min}|T_{\min}) > 0$ for $T_{\min} > \tilde{T}$.

The result for slack (PC) follows directly from the definition of the optimal action choice problem in (6) by observing that $a^*(T_{\min}) < \underline{a}(T_{\min})$ for $T_{\min} > \hat{T}(a)$ due to strict concavity of the shareholders' action choice problem and the fact that $\frac{\partial}{\partial a}\Delta W(\underline{a}(T_{\min})|T_{\min}) = 0$ as shown in Lemma 4. $\square$

PROOF OF PROPOSITION 2: We first show that $\lim_{T_{\min}\to\infty} a^*(T_{\min}) = 0$. To do so, consider first the case where (PC) is slack for all $T_{\min}$. Then differentiating (12) with respect to a and noting that $w = 0$ in this case, we obtain

$$\frac{\partial W(a|T_{\min})}{\partial a} = \left[\frac{1}{\mathscr{I}(T_{\min}|a)} \frac{c''(a)}{c'(a)} - \frac{\frac{\partial}{\partial a}\mathscr{I}(T_{\min}|a)}{\mathscr{I}^2(T_{\min}|a)}\right] e^{\Delta r T_{\min}} c'(a). \tag{A.10}$$

Lemma A.2 then implies that the term in brackets is greater than unity, so that marginal costs as expressed in (A.10)—and the marginal tax—go to infinity as $T_{\min} \to \infty$ for any $a > 0$. The result then follows from strict concavity of the unconstrained objective. Next, consider the case in which (PC) is binding for $T_{\min}$ sufficiently large. Here, substituting the respective expressions for B and w into (12) and differentiating with respect to a, we similarly obtain

$$\frac{\partial W(a|T_{\min})}{\partial a} = c'(a) + \left[\frac{1}{\mathscr{I}(T_{\min}|a)} \frac{c''(a)}{c'(a)} - \frac{\frac{\partial}{\partial a}\mathscr{I}(T_{\min}|a)}{\mathscr{I}^2(T_{\min}|a)}\right] \big(e^{\Delta r T_{\min}} - 1\big) c'(a).$$

The result then follows from the same arguments as before.

To show the results for moderate deferral requirements, note that the comparative statics in statement (i) follow directly from Corollary 1. Further, $u_a(a,t) > 0$ and $u_t(a,t) < 0$ (see proof of Lemma 3) together with $\lim_{T_{\min}\to\infty} a^*(T_{\min}) = 0$ imply that (PC) must bind for $T_{\min}$ sufficiently high for any $U > 0$.[43] Finally, statement (ii) follows directly from Lemmas 3 and 5. $\square$

PROOF OF PROPOSITION 3: First, consider the case in which $U < \hat{U}$, such that from Proposition 2 (PC) is slack for $T_{\min} = 0$. We now show that, in this case, a marginal increase in the deferral period $T_{\min}$ strictly increases welfare if and

[42] For notational simplicity, we assume here that $\tilde{T}$ is unique. A sufficient condition for this to hold is that the growth rate of informativeness does not increase too much with a. Still, if there are multiple solutions to (A.9), the result continues to hold in that $a^*(T_{\min}) = \underline{a}(T_{\min})$ for $T_{\min} \in (T^*(a^*), \min\{\tilde{T}\})$ while $a^*(T_{\min})$ satisfies the first-order condition in (14) for all $T \geq \tilde{T}_{\max} = \max\{\tilde{T}\}$.

[43] Incentive compatibility and limited liability imply that the manager's net utility under the optimal rent extraction contract is positive for all $T_{\min}$ such that (PC) is always slack if $U \leq 0$.

only if $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}|_{(t,a)=(\hat{T}(a^*),a^*)} > 0$. To do so, consider the regulator's problem of choosing $T_{\min}$ to maximize (15), which can be conveniently rewritten as

$$\begin{aligned}\Omega(T_{\min}) = \Pi\big(a^*(T_{\min})\big) - W\big(a^*(T_{\min})|T_{\min}\big)\\ - (1-k_{\min})\left(1 - r\int_0^\infty e^{-rt}S\big(t|a^*(T_{\min})\big)dt\right)\\ + \kappa_A\big[u(a^*(T_{\min}), T_{\min}) - U\big],\end{aligned}$$

where u is the manager's derived utility as defined in Lemma 3. We then obtain

$$\begin{aligned}\left.\frac{d\Omega(T_{\min})}{dT_{\min}}\right|_{T_{\min}=\hat{T}(a^*)} =&(1-k_{\min})\left(r\int_0^\infty e^{-rt}\left.\frac{\partial S(t|a)}{\partial a}\right|_{a=a^*}dt\right)\left.\frac{\partial a^*(T_{\min})}{\partial T_{\min}}\right|_{T_{\min}=\hat{T}(a^*)} \\ &+ \kappa_A \left.\frac{du(a^*(T_{\min}), T_{\min})}{dT_{\min}}\right|_{T_{\min}=\hat{T}(a^*)},\end{aligned} \tag{A.11}$$

where we use the envelope theorem, which implies that

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

The result then follows since the first term on the right-hand side in (A.11) is strictly positive if and only if $\partial a^*(T_{\min})/\partial T_{\min} > 0$ for $T_{\min} = \hat{T}(a^*)$, which from Proposition 2 requires that $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}|_{(t,a)=(\hat{T}(a^*),a^*)} > 0$, while the second term is from $\kappa_A < \bar{\kappa}_A$ (where $\bar{\kappa}_A$ might be infinite) bounded below by $\min\{0, \bar{\kappa}_A \frac{du(a^*(T_{\min}),T_{\min})}{dT_{\min}}|_{T_{\min}=\hat{T}(a^*)}\}$.

In the second case, where $U \geq \hat{U}$ such that (PC) is binding at $T_{\min} = 0$, welfare can be conveniently rewritten as in (16). Note that $\Delta W(a^*(T_{\min})|T_{\min}) = 0$ for $T_{\min} \in [T_{PC}(a^*), \tilde{T}]$ (see Lemma 5) and $V'(a) > \Pi'(a)$ (see (5)). Hence, comparing the bank's and the regulator's objectives in (6) and (16) directly implies that marginal deferral regulation, which leads to $\partial a^*(T_{\min})/\partial T_{\min} > 0$ for $T_{\min} \in [T_{PC}(a^*), \tilde{T}]$ (see Lemma 5), must be welfare-increasing by strict (quasi)concavity of the regulator's objective. □

Proof of Lemma 6: Note first that (PC) is slack for a given $T_{\min}$ if and only if $U \leq \overline{U}(T_{\min}) := u(a^*(T_{\min}), T_{\min}) = \frac{c'(a^*(T_{\min}))}{\mathscr{I}(\hat{T}(a^*(T_{\min}))|a^*(T_{\min}))} - c(a^*(T_{\min}))$, where $\overline{U}(T_{\min})$ denotes the agent's rent under the optimal rent-extraction contract. Now, second-best welfare cannot be attained if $U < \overline{U}^{SB} := u(a^{SB}, T^*(a^{SB}))$, since binding deferral regulation and a slack PC (at the relevant second-best action) imply welfare losses due to contracting distortions.

Thus, assume that $U \geq \overline{U}^{SB}$. It remains to show that second-best welfare can be attained if and only if $T_{PC}(a^{SB}) \leq \tilde{T}$. To show sufficiency, assume that the regulator imposes a minimum deferral period of $T^*_{\min} = T_{PC}(a^{SB}) \le \tilde{T}$. Then from Lemma 5, bank shareholders optimally implement $a^*(T_{\min}) = \underline{a}(T_{\min}) = a^{SB}$ with a contract featuring a single payment at $T_{PC}(a^{SB})$ (see Proposition 1), which from $U \ge \overline{U}^{SB}$ is also the unconstrained optimal contract implementing a^{SB}, that is, $\Delta W(a^*(T_{\min})|T_{\min}) = 0$ (see also Lemma 5). Hence, welfare is maximized. Otherwise, that is, if $T_{PC}(a^{SB}) > \tilde{T}$, bank shareholders will optimally implement $a^*(T_{PC}(a^{SB})) < a^{SB} = \underline{a}(T_{PC}(a^{SB}))$ if they face a minimum deferral requirement of $T_{\min} = T_{PC}(a^{SB})$, which implies a contracting inefficiency $\Delta W(a^*(T_{\min})|T_{\min}) > 0$ (see Lemma 5). Necessity then follows from the fact that second-best welfare can only be achieved if a contract with a single bonus at $T_{PC}(a^{SB})$ implements a^{SB}. □

PROOF OF PROPOSITION 4: We need to show that $T_{PC}(a^{SB}) \le \tilde{T}(k_{\min})$ if and only if $k \ge \bar{k}$. Since $U \ge \overline{U}^{SB}$, the result then follows from Lemma 6. Thus, note first that $\tilde{T}(k_{\min})$ is increasing in $k_{\min}$, which directly follows from (A.9) together with $\frac{\partial^2 \Pi(a)}{\partial a \partial k_{\min}} = r\int_0^\infty e^{-rt}\frac{\partial S(t|a)}{\partial a}dt > 0$ and strict concavity of shareholders' unconstrained objective function. It is then sufficient to show that $T_{PC}(a^{SB}) \le \tilde{T}(k_{\min})$ is satisfied for $k_{\min} = 1$, which holds trivially, since in this case $a^{SB} = a^*$ such that $T_{PC}(a^{SB}) = T_{PC}(a^*) < \tilde{T}(k_{\min})$ and the inequality follows from the arguments in the proof of Lemma 5. Existence of a $\bar{k} < 1$ then follows by continuity. More specifically, $\bar{k}$ is interior if $T_{PC}(a^{SB}) > \tilde{T}(0)$; otherwise, we set $\bar{k} = 0$. □

PROOF OF PROPOSITION 5: Suppose clawbacks extend to wages. Then note first that, for a given $T_{\min}$, actions $a < \underline{a}(T_{\min})$ can no longer be implemented. To see this, recall that the utility that the manager receives from an incentive-compatible contract with a single survival-contingent payout at date t is given by $u(a,t) := \frac{c'(a)}{\mathscr{I}(t|a)} - c(a)$, which from the arguments in the proof of Lemma 3 is strictly increasing in a and strictly decreasing in t. Hence, the highest utility the manager can get from a contract satisfying (IC), (DEF), and (CLAW) extended to wages is then $u(a, T_{\min})$. By definition of $\underline{a}(T_{\min})$, it further holds that $u(\underline{a}(T_{\min}), T_{\min}) = U$, and $u_a(a,t) < 0$, thus implies that $u(a, T_{\min}) < U$ for all $a < \underline{a}(T_{\min})$, violating (PC).

So, by setting $T_{\min} = T_{PC}(a^{SB})$, the regulator effectively imposes a minimum action constraint of $a^*(T_{\min}) \ge \underline{a}(T_{\min}) = a^{SB}$. Now, since $a^* < a^{SB}$, it follows from strict concavity of bank shareholders' unconstrained objective together with $\Delta W(a|T_{\min}) = 0$ for all implementable actions that shareholders optimally implement a^{SB} with a single payment at $T_{PC}(a^{SB})$, which from $U > \overline{U}^{SB}$ corresponds to the unconstrained optimal contract. Second-best welfare is attained. From Lemma 6, this outcome can be achieved without a clawback clause if and only if $T_{PC}(a^{SB}) \le \tilde{T}$, which from Proposition 4 is equivalent to $k < \bar{k}$. □

Appendix B: Additional Figures

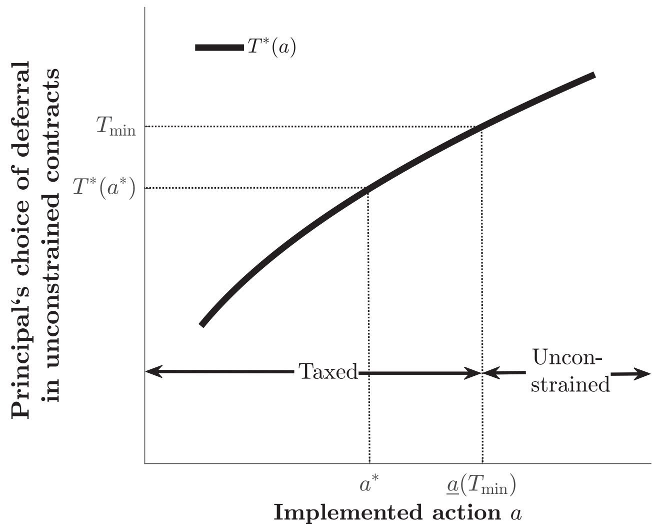

Figure B.1. This graph plots the connection between the principal's choice of deferral times in unconstrained contracts and the constraints imposed by deferral regulation. In this example, the comparative statics are such that $T^*(a)$ is globally increasing in implemented effort a.

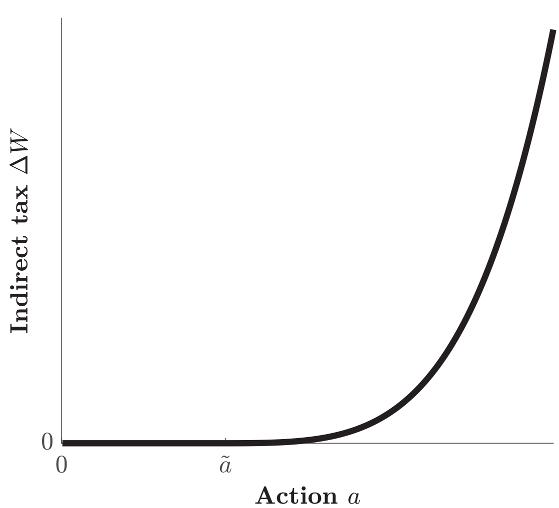

Figure B.2. Example of a monotonically increasing tax function. The figure plots the tax function, $\Delta W(a|T_{\min})$, for a given deferral requirement for a case with slack (PC) in which the growth rate of informativeness is globally, that is, for all a, decreasing in the action, $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t} < 0$, such that $\frac{dT^*(a)}{da} < 0$. The plot shows the case of a Gamma distribution (see Example 1) with $S(t|a) = \Gamma(\beta, \kappa\frac{t}{a})/\Gamma(\beta, 0)$, and parameters set at $\beta = 0.7$, $\Delta r = 0.75$, $\kappa = 5$, and $T_{\min} = 1.254$, with $c(a) = a^3/3$, such that (DEF) binds for all $a > \widetilde{a} = 2$.

Appendix C: 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 supranational level, in 2009 the Financial Services Forum (FSF)—which later became the Financial Stability Board (FSB)—adopted the Principles for Sound Compensation Practices and their Implementation Standards. 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.[44]

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 federal agencies involved[45] 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 four years from the last day of the performance period for short-term arrangements (two years for long-term arrangements with minimum three year performance period). Clawback requirements extend to a minimum of seven years from the end of vesting based on Dodd-Frank §954.[46]

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 at the country level. These include mandatory deferral of bonuses for three to five years, which are further subject to clawback[47] for up to seven years. Additionally, as part of CRD IV

[44] See Financial Stability Board (2017) for a more detailed account.

[45] These six agencies are: 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).

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

[47] 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 labor law, the total 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)

that took effect in 2016, a bonus cap limits 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 that 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.[48] Regulatory requirements for deferral periods for MRTs vary significantly across jurisdictions, ranging from a minimum of around three years (Argentina, Brazil, China, Hong Kong, India, Indonesia, Japan, Korea, Russia, Singapore, Switzerland, and Turkey) to five years or more for selected MRTs (United States, United Kingdom, European Single Supervisory Mechanism—SSM—jurisdictions), with the maximum of seven years applying to the most senior managers in the United Kingdom. Equally, the proportion of variable compensation that has to be deferred is highly country-specific, ranging from 25% to 60% in Canada, 40% in Argentina, Australia, Brazil, and Hong Kong, 33% to 54% in Singapore to more than 40% in China and Turkey, 40% to 55% in India, 40% to 60% in SSM jurisdictions, the United Kingdom, and the United States, 50% to 70% in Korea, and 70% to 75% in Switzerland.[49] Further, some countries impose regulatory restrictions on the proportion of fixed remuneration as a percentage of total remuneration (such as the EU "bonus cap"), ranging from 30% in Switzerland to 35% in Australia and China, 22% to 56% in Singapore, 54% in the United Kingdom, 58% in Hong Kong and the SSM jurisdictions, and 60% in India. Such requirements are not set out in Argentina, Brazil, Canada, Indonesia, Russia, South Africa, and the United States. 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, particularly clawbacks, is subject to legal impediments and enforcement issues such that applications are still rare.

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participated in or was responsible for conduct which resulted in significant losses to the institution and (ii) failed to meet appropriate standards of fitness and propriety."

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

[49] 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 (for example, Indonesia, South Africa).

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