DISCUSSION PAPER SERIES

DP15081

THE ECONOMICS OF DEFERRAL AND CLAWBACK REQUIREMENTS

Florian Hoffmann, Roman Inderst and Marcus Opp

FINANCIAL ECONOMICS

ISSN 0265-8003

THE ECONOMICS OF DEFERRAL AND CLAWBACK REQUIREMENTS

Florian Hoffmann, Roman Inderst and Marcus Opp

Discussion Paper DP15081
Published 22 July 2020
Submitted 20 July 2020

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

THE ECONOMICS OF DEFERRAL AND CLAWBACK REQUIREMENTS

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 equilibrium risk-management effort only if the bank manager's outside option is sufficiently high, else, their effectiveness depends on the dynamics of information arrival. Stringent deferral requirements unambiguously backfire. We characterize when regulators should not impose any deferral regulation at all, when it can achieve second-best welfare, when additional clawback requirements are of value, and highlight the interaction with capital regulation.

JEL Classification: D86, G28, G21

Keywords: compensation regulation, clawbacks, bonus deferral, Short-termism, moral hazard, principal-agent models with externalities

Florian Hoffmann - hoffmann@ese.eur.nl
Erasmus University Rotterdam, KU Leuven

Roman Inderst - inderst@finance.uni-frankfurt.de
Goethe University Frankfurt and CEPR

Marcus Opp - marcus.opp@hhs.se
Stockholm School of Economics and CEPR

Acknowledgements
This revision benefited significantly from comments by the co-editor Philip Bond, an anonymous associate editor, and, two anonymous referees. We also thank Vish Viswanathan, Elu von Thadden, and Mark Westerfield for excellent discussions, as well as Yakov Amihud, Peter DeMarzo, Alex Edmans, Sivan Frenkel, Willie Fuchs, Ben Hébert, Andrzej (Andy) Skrzypacz, Jan Starmans, and Jeffrey Zwiebel for valuable insights. We are also grateful for comments from seminar participants at Stanford, University of Washington (Seattle), Tel Aviv University, Washington University Corporate Finance conference, FTG Madrid, Barcelona GSE, the Paul Woolley Centre Conference at LSE, the conference in honor of Doug Diamond at the University of Chicago, and the Stockholm School of Economics. Inderst gratefully acknowledges financial support from the ERC (Advanced Grant "Regulating Retail Finance." Opp gratefully acknowledges financial support from the Marianne & Marcus Wallenberg Foundation.

The economics of deferral and clawback requirements*

Florian Hoffmann† Roman Inderst‡ Marcus Opp§

June 26, 2020

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 equilibrium risk-management effort only if the bank manager's outside option is sufficiently high, else, their effectiveness depends on the dynamics of information arrival. Stringent deferral requirements unambiguously backfire. We characterize when regulators should not impose any deferral regulation at all, when it can achieve second-best welfare, when additional clawback requirements are of value, and highlight the interaction with capital regulation.

Keywords: compensation regulation, clawbacks, bonus deferral, short-termism, moral hazard, principal-agent models with externalities.

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

---

*This revision benefited significantly from comments by the co-editor Philip Bond, an anonymous associate editor, and, two anonymous referees. We also thank Vish Viswanathan, Elu von Thadden, and Mark Westerfield for excellent discussions, as well as Yakov Amihud, Peter DeMarzo, Alex Edmans, Sivan Frenkel, Willie Fuchs, Ben Hébert, Andrzej (Andy) Skrzypacz, Jan Starmans, and Jeffrey Zwiebel for valuable insights. We are also grateful for comments from seminar participants at Stanford, University of Washington (Seattle), Tel Aviv University, Washington University Corporate Finance conference, FTG Madrid, Barcelona GSE, the Paul Woolley Centre Conference at LSE, the conference in honor of Doug Diamond at the University of Chicago, and the Stockholm School of Economics. Inderst gratefully acknowledges financial support from the ERC (Advanced Grant "Regulating Retail Finance").

†Erasmus University Rotterdam. E-mail: hoffmann@ese.eur.nl.

‡Johann Wolfgang Goethe University Frankfurt and CEPR. E-mail: inderst@finance.uni-frankfurt.de.

§Stockholm School of Economics and CEPR. E-mail: marcus.opp@hhs.se.

1 Introduction

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

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 UK now mandates deferral periods of 3 to 7 years with the respective incentive pay being 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 B). One may paraphrase regulators' rationale for these interventions as follows: "Short-termist" compensation packages have caused short-termist actions of bank managers. If compensation packages paid out later in the future, so the heuristic argument goes, managers would take a more long-term perspective, reduce excessive risks, and, hence, make banks, ultimately, safer.

What this "silver bullet" view of compensation regulation fails to account for is that compensation packages are not primitives of the economy, but an endogenous outcome (a symptom rather than a cause). The heuristic argument above is, hence, subject to the Lucas-critique. In particular, adopting the standard optimal contracting view of compensation in the tradition of Grossman and Hart (1983), it is not the agent, but the principal that "chooses" the *equilibrium* action by designing the incentive contract. Hence, whichever distortion has led bank shareholders (the principal) to incentivize excessively risky actions in the first place, it is still present when they face regulatory constraints on how to incentivize their key employees (the agent). Thus, to analyze the positive implications of compensation regulation for equilibrium risk choices, the real question is how shareholders choose to restructure incentives by adjusting the entire compensation package, both along regulated and unregulated dimensions.

To this end, we develop a tractable principal-agent framework in which bank shareholders' preferences differ from those of society due to failure externalities on the taxpayer. The resulting "laissez-faire" compensation contract incentivizes the manager to exert too little risk-management effort, which implies socially excessive bank failure rates and scope for regulatory intervention. Our positive analysis shows that moderate deferral regulation has a robustly positive effect on bank stability only if competition for

[1] For Barclays alone, this regulation affected 1641 material risk-takers in 2017 (see its Pillar 3 report).

managerial talent is sufficiently high, so that the value of the manager's compensation package is determined by her outside option. Else, the effectiveness of moderate deferral requirements depends on the dynamics of information arrival. In contrast, stringent deferral regulation unambiguously backfires. Additional clawback requirements may prevent backfiring only if the manager's outside option is sufficiently high and these clawbacks not only pertain to bonuses, but also to fixed pay (wages). We characterize conditions under which the optimal use of these ad hoc tools can achieve second-best welfare.

To illustrate the channel through which compensation regulation operates we rely on a tax analogy. The basic idea is that any (regulatory) constraint on compensation design must (weakly) raise the *level* of compensation costs to incentivize a given action as binding regulation requires deviating from the cost-minimizing contract.[2] The induced increase in compensation costs after optimal restructuring (post vs. pre regulation) then acts akin to an *indirect tax* levied on the principal when incentivizing this action.[3] It is via this tax channel only that the principal may be induced to change actions in equilibrium. The efficacy of any restriction on compensation design, thus, boils down to whether actions that the regulator wants to promote are taxed relatively less than actions that the regulator wants to deter, i.e., to the *marginal tax*.

The tax function implied by a given minimum deferral requirement is typically non-monotonic in risk management effort. In particular, the implementation of both very low (socially undesirable) and high (socially desirable) risk management levels is taxed relatively little. This non-monotonicity is governed by the interaction of two robust forces, the "*timing-of-pay*" force and the "*size-of-pay*" force and responsible for why small interventions may work and large interventions always backfire.

When the imposed deferral period marginally exceeds the laissez-faire payout time, only the *timing-of-pay* force is at play. This timing-of pay force captures that ceteris paribus (c.p.) actions associated with longer deferral periods in *unconstrained optimal* compensation contracts are taxed less. In particular, actions for which this unconstrained optimal vesting period exceeds the regulatory minimum, are not taxed at all as regulation simply does not bind. For marginal interventions, deferral regulation, thus, has the (desired) positive effect on equilibrium risk-management effort if and only if unconstrained optimal contracts indeed incentivize higher effort with later payouts, which, in our model, only holds robustly if the manager's participation constraint binds. When the participation constraint is slack, the sign of this comparative statics is sensitive to

[2] See Murphy and Jensen (2018) for a related observation. Clearly, this result is based on the standard assumption that the principal can commit to a contract (see discussion in Section 4).

[3] It is irrelevant for the principal that this "tax" does not result in revenue to the regulator (even though equilibrium contracting inefficiencies will matter from a welfare perspective).

the dynamics for information arrival such that the timing-of-pay force may push towards higher or lower effort. However, even if the timing-of-pay force promotes higher effort, it is counteracted by the *size-of-pay* force for non-marginal interventions: Actions which c.p. require more incentive pay are taxed more, as it is more costly to defer a larger compensation package. These are actions with higher (marginal) costs, i.e., higher risk management effort. For sufficiently large deferral requirements, this size-of-pay force dominates, which causes unambiguous backfiring.

The just described forces are the ones relevant for gauging the effects of deferral regulation in any principal-agent model as long as the agent has to be incentivized to take on a privately costly action.[4] A concrete model is needed to endogenize the optimal timing of pay and sign the timing-of pay force, i.e., to link the comparative statics of unconstrained optimal payout times to the primitives of the contracting environment, as well as to understand when and why an additional clawback clause has a bite. To this end, we study a parsimonious principal-agent setting that aims to capture three relevant frictions in the financial sector. First, the bank manager (the agent) is a "relevant" employee, as targeted by the regulation, in the sense that she is a "key risk-taker" able to affect the survival of the entire institution. Second, to capture the concern of regulators that "Bad bets by financial-services firms take longer than three years to show up." (WSJ, 2015), we assume that the bank manager's unobservable action, which we interpret as "risk management" effort, has *persistent* effects on the bank's failure rate, so that relevant information about the quality of risk management is gradually revealed through the absence of "disasters." Third, scope for regulatory intervention arises as bailout expectations allow bank shareholders to finance risky projects with effectively subsidized debt (see Atkeson, d'Avernas, Eisfeldt, and Weill (2018) and Duffie (2018) for empirical evidence), such that they do not fully internalize the social cost of bank failure.[5]

In the absence of compensation regulation, shareholders incentivize the manager to exert too little risk-management effort compared to the social optimum (due to bailout distortions). By virtue of universal risk-neutrality and relative impatience of the manager, the unconstrained compensation contract features a unique payout date that is pinned down by the trade-off between better information and impatience costs. If the bank has not failed by this date, the manager receives an appropriately calibrated bonus ensuring incentive compatibility and participation. Interestingly, even within this simple model the

[4] See discussion in Section 4 for how to incorporate an additional explicit risk-taking dimension.

[5] Our main insights do not depend on the precise friction motivating regulatory interference, e.g., our analysis can be easily modified to capture corporate governance problems instead (see Section 4 for a discussion). Regardless of whether the board chooses what shareholders want, it is key that the contract designer does not choose what society wants.

timing-of-pay force does not unambiguously support the rationale for minimum deferral regulation: Higher effort is optimally incentivized with early payout dates if the speed of learning across is higher for lower effort levels and the manager's participation constraint is slack. It is, thus, of essence that the regulator correctly diagnoses these primitives governing the comparative statics of optimal contracts. In turn, when there is substantial competition for managerial talent in the financial sector, the timing-of-pay force pushes unambiguously in the right direction, providing a case at least for mild deferral regulation.

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 contractual 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, 3 years), they optimally exploit the additional information arriving between year 3 and year 4 to provide incentives by conditioning the bonus payout on survival until year 4. Now, when competition for talent is high so that the agent's participation constraint binds, shareholders, in addition, partly convert fully-contingent bonuses to up-front wages to be still able to meet the manager's outside option. Since such conversion of bonuses to wages is not prohibited under current regulation (see concerns by regulators reported by Binham (2015)), banks can effectively circumvent the 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 moderately 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 then go a step further and characterize the optimal deferral period and when 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, e.g., 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 which doesn't target the source but 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 this also requires imposing a clawback requirement that extends to wages.

Literature Our paper contributes to the literature on regulation of incentive contracts, in particular, within the context of financial sector regulation. Within this branch, one can distinguish between structural constraints on compensation contracts, like the timing and contingency of pay, as is the focus of our paper, or constraints on the size of pay (see, e.g., Thanassoulis (2012)).[6]

For firms outside the financial sector, regulatory intervention in executive compensation contracts is typically motivated by a perceived corporate governance problem (see e.g., Bebchuk and Fried (2010) or Kuhnen and Zwiebel (2009)). According to this view, compensation regulation should, thus, benefit shareholders and trigger positive market valuation responses.

An alternative view is that the board may indeed pursue the maximization of shareholder value, which, however, may not be fully aligned with societal goals, justifying regulatory intervention. This view is particularly relevant in the financial sector, and, hence, adopted in our concrete financial sector application. In particular, as is standard in the literature on banking regulation (Dewatripont, Tirole, et al. (1994), Hellmann, Murdock, and Stiglitz (2000), Matutes and Vives (2000), Repullo and Suarez (2004)), we assume that shareholders can externalize part of the default risk to society via bailouts/deposit insurance.[7]

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 (Dewatripont, Tirole, et al. (1994), Admati, DeMarzo, Hellwig, and Pfleiderer (2011)) has, thus, pointed out that a key role of capital requirements is to increase the loss-absorbing capacity ex post and reduce risk-taking incentives ex ante.[8] Our paper contributes to this literature by providing a novel analysis of the

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

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

[8] To tame risk taking, Bolton, Mehran, and Shapiro (2015) propose making CEO compensation a

interaction between capital regulation and compensation regulation, in particular the role of deferral periods and clawbacks.[9] We find that such compensation regulation can work as a substitute to 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, Forthcoming). The particular modeling of a (potentially rare) negative event is shared with Biais, Mariotti, Rochet, and Villeneuve (2010) and notably Hartman-Glaser, Piskorski, and Tchistyi (2012) as well as Malamud, Rui, and Whinston (2013). All these four papers focus purely on optimal compensation design absent regulation. They, thus, neither analyze optimal contracts under regulatory constraints, nor do they study the effect of regulation on the implemented action, nor the welfare implications of such regulatory intervention.

2 Model

We develop a tractable principal-agent model that aims to speak to the effects of compensation regulation in the banking sector. As such, our framework features a bank (the principal) and a bank manager (the agent) as the two contracting parties, and a regulator ("society") that imposes constraints on 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, as well as 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.[10]

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

function of a bank's CDS spreads. In a setting not specific to the financial sector, Edmans and Liu (2010) advocate combining equity stakes with debt-like instruments such as uninsured pension schemes.

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

[10] See, e.g., 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 will discuss robustness with respect to alternative costs of deferral arising from the agent's risk aversion in Section 4.

strictly increasing and strictly convex with $c(0) = c'(0) = 0$ as well as $\lim_{a\to\infty} c'(a) = \infty$. In line with the regulator's concern (cf., quote in introduction), the manager's action has persistent effects such that relevant outcomes are only observed over time, providing a rationale for the timing of pay. Concretely, the manager's one-time action reduces the bank's failure rate $\lambda(t|a)$ for all $t \geq 0$:[11]

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

where λ is a twice continuously differentiable function and $\lambda_a := \frac{\partial \lambda}{\partial a}$ denotes the partial derivative with respect to a (similarly for all other functions used below). When the hazard rate is constant over time, e.g., $\lambda(t|a) = \frac{1}{a}$, we obtain the standard exponentially distributed failure time with mean a. One may best interpret the managerial action as an investment in the unobservable quality of the bank's risk-management model.[12]

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:

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

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: The date-t cash flows, Y_t, are constant at $y > 0$ as long as the bank has not failed:

$$Y_t = \begin{cases} y & X_t = 0, \\ 0 & X_t = 1. \end{cases} \tag{2}$$

The cash flow process governed by (1) and (2) captures two features that have been considered relevant in the (regulation of the) financial sector in the simplest possible fashion. First, by construction, we focus on actions that affect the survival of the entire institution, which is in line with regulators targeting the compensation of material risk-takers (see Introduction). Second, information about their actions arrives gradually over time only through the absence of "rare" crisis events. This modeling captures

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

[12] 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 4).

environments in which prudent actions (high a) and imprudent actions often deliver similar performance in the short-run and can only be told apart better in the long run, e.g., as bank managers can replicate the costly generation of true alpha in good states by writing out-of-the money put options on rare bad states.

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

$$V(a) = y \int_0^\infty e^{-rt} S(t|a)\, dt - 1. \quad (3)$$

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

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 which results in wage costs, $W(a)$, that exceed the manager's effort cost, $W(a) > c(a)$. This 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 we, for concreteness, 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, e.g., Hellmann, Murdock, and Stiglitz (2000) or Repullo and Suarez (2013)).[13] 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

$$\Pi(a) = V(a) + (1 - k_{\min}) \left(1 - r \int_0^\infty e^{-rt} S(t|a)\, dt\right). \quad (4)$$

The positive wedge between $\Pi(a)$ and $V(a)$ can be interpreted as the value of the bailout financing subsidy to bank equity holders.[14] 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 $S(t|a)$ and, thus, lowers the financing subsidy by Condition (1), bank shareholders do not fully internalize the benefits of im-

[13] Our main results would remain unchanged, if regulatory intervention was instead motivated by negative externalities of bank failure on other banks, borrowers or depositors (see Section 4 for a discussion).

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

proved risk-management, i.e., $0 < \Pi'(a) < V'(a)$. 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 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. Since current real-world regulation mandates a minimum deferral period, $T_{\min}$, applying to bonus payments but not fixed wages, we decompose the compensation contract as follows: Compensation consists of a date-0 unconditional (wage) payment w 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).[15] In particular, db_t 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). The formal compensation design problem of implementing action a at lowest expected discounted cost to bank shareholders – the first problem in the structure of Grossman and Hart (1983) – can then be stated as:

Problem 1 (Compensation design)

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

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

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

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

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

We now comment on the various constraints. Except for the final constraint (DEF), all constraints are standard and also apply for the derivation of the optimal laissez-faire contract. In particular, the first constraint is the bank manager's time-0 participation constraint (PC). The present value of compensation discounted at the manager's rate

[15] 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.

net of effort costs, must at least match the manager's outside option U.[16] Incentive compatibility (IC) requires that it is optimal for the manager to choose action a given the contract. As is common in the analysis of moral hazard problems with continuous actions (see, e.g., Holmstrom (1979) and Shavell (1979)) we 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).[17]

We now turn to the deferral constraint (DEF), which is motivated by real-world regulation. It prevents bank shareholders from making any bonus payout to the bank manager before date $T_{\min}$, i.e., $db_t = 0 \; \forall t < T_{\min}$. For expositional reasons, we initially abstract away from clawback requirements, which are additional restrictions on the contingency of pay. As we will show in Section 3.3.2, such additional constraints will only have a bite if clawbacks also extend to wages.[18]

Overall objective. Given the solution to the compensation design problem, shareholders induce the action that maximizes gross profits net of compensation costs:

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

For reference we denote the laissez-faire action by $a^* = a^*(0)$, which is obtained by setting $T_{\min} = 0$ with associated wage costs of $W(a) := W(a|0)$. For the subsequent analysis, it is now useful to decompose bank shareholders' overall objective as follows

$$a^*(T_{\min}) = \arg\max_{a \in \mathscr{A}} \Pi(a) - W(a) - \Delta W(a|T_{\min}), \tag{5}$$

where $\Pi(a) - W(a)$ is the unconstrained objective and $\Delta W(a|T_{\min}) := W(a|T_{\min}) - W(a)$ measures the change in wage costs due to deferral regulation.

Since, deferral regulation, as any type of compensation regulation, constrains the space of feasible contracts, we generically obtain that $\Delta W(a|T_{\min}) \geq 0$, akin to an indirect tax on the principal. Importantly, while this *indirect* tax does not constitute a direct transfer from the principal to the government, the deferral constraint affects the equilibrium action choice in (5) "*as if*" the government could observe the action

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

[17] For the formal argument see the proof of Lemma 1 below. This condition is essentially the same (restrictive) sufficient condition as the convexity of the distribution function condition (CDFC) in static moral hazard environments (see Rogerson (1985)). Building on an example by Holmstrom (1979), this restriction is always satisfied for the mixed exponential distribution $S(t|a) = ae^{-\lambda_1 t} + (1-a)e^{-\lambda_2 t}$ for any $\lambda_2 > \lambda_1$. See Bond and Gomes (2009) for an analysis when the first-order approach breaks down.

[18] Such extended clawback requirements are discussed among regulators, but not yet implemented.

a and imposes an action-contingent tax $\Delta W(a|T_{\min})$. Understanding the properties of the tax function $\Delta W(a|T_{\min})$ is, thus, both necessary and sufficient to make predictions regarding the effect of (deferral) regulation on equilibrium actions.[19]

3 Analysis

Our positive analysis of the effects of compensation regulation on equilibrium contract design follows the standard two-step structure of Grossman and Hart (1983). First, we analyze how shareholders design cost-minimizing compensation contracts to implement any given action a (with and without deferral regulation). We then analyze the implemented action choice as a function of the deferral period.

For illustrative purposes, we initially consider the case where the manager does not have a *relevant* participation constraint. This case applies, for instance, whenever the manager's outside option U equals zero or when, for a given $U > 0$, the agency problem is sufficiently severe, so that the manager earns an agency rent. As a result, bank shareholders' action and contract choice reflect a rent-extraction motive. We subsequently turn to the case where the outside option is sufficiently high so that the manager's participation constraint binds. In fact, as the human capital of key decision makers and risk takers in the financial industry is quite fungible, there may indeed be considerable competition for talent driving up the manager's outside option. For ease of exposition, we first consider the two extreme cases (PC always slack vs. PC always binds) before bringing the results together in Proposition 5 which provides a characterization for the full range of U.

3.1 The rent-extraction case

3.1.1 Compensation design

Unregulated optimal rent-extraction 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 only rewarded with a positive bonus for those outcomes that are most "informative" about the incentivized action (in a likelihood ratio sense), and obtains zero otherwise due to limited liability. Intuitively, such contracts provide the strongest incentives per unit of expected pay.[20] In our concrete setting, outcomes are histories of bank survival and failure and,

[19] Notably this insight applies to any form of regulatory intervention in compensation design, such that our approach is applicable beyond the concrete setting of deferral regulation (see Section 4).

[20] See, e.g., Innes (1990). The formal argument in our setting is contained in the Appendix.

for all (t, a), the history "bank survival by 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

$$\mathscr{I}(t|a) := \frac{\partial \log S(t|a)}{\partial a} = t\left|\bar{\lambda}_a(t|a)\right|, \tag{6}$$

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 will refer to $\mathscr{I}(t|a)$, which captures the quality of date-t information, as the date-t *informativeness*. From (6), we observe that informativeness is higher if, for a given t, the (average) failure rate is more sensitive to the action a and the higher t.

What differentiates our compensation-design 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. Concretely, the costs of deferring pay are measured 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, and the information benefit of deferral then is completely captured by the increase in informativeness $\mathscr{I}(t|a)$ over time.[21] For instance, when the arrival time distribution is exponential (with a time-invariant hazard rate of $\frac{1}{a}$), informativeness grows linearly over time with $\mathscr{I}(t|a) = t/a^2$.

To focus on economically relevant dynamics of "learning" about effort, ensuring finite payout dates, we impose the mild technical condition that informativeness $\mathscr{I}(t|a)$ is less convex than the exponentially growing impatience cost $e^{\Delta rt}$ for t sufficiently large.

$$\frac{\partial^2 \mathscr{I}/\partial t^2}{\partial \mathscr{I}/\partial t} = \frac{\lambda_{at}(t|a)}{\lambda_a(t|a)} < \Delta r \qquad \forall a > 0. \tag{7}$$

Given this condition, optimal contracts – as characterized in the following Lemma – exist:

Lemma 1 (Unregulated compensation contract under slack PC) *The manager receives zero fixed pay, $w = 0$, and a positive bonus if and only if the bank has survived by date $\hat{T}(a) = \arg\max_t e^{-\Delta rt}\mathscr{I}(t|a)$. Ex ante, the manager values the bonus package at*

[21] In fact, informativeness is weakly increasing in t for any information process (see Hoffmann, Inderst, and Opp, Forthcoming). Intuitively, with persistent effort, additional signals arriving over time can only improve informativeness. Let us point out that, even though the information structure in our framework is parsimonious — with binary signals "success/failure" in each instant — it imposes only very few restrictions on the relevant dynamics of "learning" about effort, as captured by $\mathscr{I}(t|a)$. In particular, our assumptions on the stochastic process governing bank failure only imply that $\mathscr{I}(t|a)$ is differentiable in both arguments and *strictly* increasing in t.

$B(a) = \frac{c'(a)}{\mathscr{I}(\hat{T}(a)|a)}$ *whereas the cost to bank shareholders satisfies* $W(a) = B(a)\, e^{\Delta r \hat{T}(a)}$.

By maximizing the impatience-discounted informativeness, the chosen deferral period optimally trades off the gain in informativeness, which allows bank shareholders to reduce the manager's rent $B(a) - [U + c(a)]$, with the deadweight costs resulting from the manager's impatience. The associated (necessary) first-order condition implies that bank shareholders optimally defer until the (log) growth rate of impatience costs, Δr, equals the (log) growth rate of informativeness, i.e., $\hat{T}(a)$ solves

$$\frac{\partial \log \mathscr{I}(t|a)}{\partial t} = \Delta r, \tag{8}$$

where $\frac{\partial \log \mathscr{I}(t|a)}{\partial t} = \frac{1}{t}\frac{\lambda_a(t|a)}{\bar{\lambda}_a(t|a)}$. Intuitively, this growth rate is higher if the informativeness of the *marginal* performance signal at date t, $\lambda_a(t|a)$, is high compared to the *accumulated* informativeness encoded in the survival history up to date t, $t\bar{\lambda}_a(t|a)$. One can use the characterization in (8) to obtain closed-form expressions for many common survival distributions. E.g., for the exponential arrival time distribution, we obtain $\hat{T}(a) = \frac{1}{\Delta r}$.

Further, by implicit differentiation of (8) we obtain the comparative statics of optimal payout times in a, which will be key in determining the effects of deferral regulation: $\hat{T}(a)$ is locally increasing (decreasing) in a if and only if the growth rate of informativeness is locally increasing (decreasing) in a. The exponential example, where informativeness grows at rate $1/t$, thus, represents a knife-edge case in the sense that $\hat{T}(a)$ is constant for all a. The following Lemma illustrates that all comparative statics are generically possible even within a common parametric family of survival distributions and implies that observing earlier payouts is, hence, not necessarily indicative of poor incentives.

Lemma 2 *Consider the Gamma survival time distribution with* $S(t|a) := \frac{\Gamma\left(\beta, \frac{t}{a}\right)}{\Gamma(\beta, 0)}$ *where* $\Gamma(\beta, x) := \int_x^\infty s^{\beta-1} e^{-s} ds$ *denotes the upper incomplete Gamma function.*[22] *Then, the payout date* $\hat{T}(a)$ *of the optimal compensation contract is strictly increasing in* a *if* $\beta > 1$, *independent of* a *if* $\beta = 1$, *and decreasing in* a *if* $\beta < 1$.

Optimal rent-extraction contracts under compensation regulation. We will now analyze how shareholders optimally restructure compensation contracts for a given action a if compensation regulation prohibits the implementation of the unregulated

[22] In terms of hazard rate fundamentals, the parameter β implies that 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 $\beta > 1$. In some of the numerical examples below, we scale the effect of the action on $S(t|a)$ via an additional parameter $\kappa > 0$ with $S(t|a) := \Gamma\left(\beta, \kappa \frac{t}{a}\right) / \Gamma(\beta, 0)$.

optimal contract. To streamline notation in the main text, we suppose that the convexity condition (7) holds for all $t > \hat{T}(a)$.[23] We then obtain the following characterization of constrained-optimal compensation contracts:

Proposition 1 *Suppose that (PC) is slack and the minimum deferral period satisfies* $T_{\min} > \hat{T}(a)$. *Then, the agent receives zero fixed pay,* $w = 0$*, and a positive bonus if and only if the bank has survived by date* $T_{\min}$. *For any given* a*, the manager's valuation of the compensation package decreases relative to the unregulated contract,* $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}(T_{\min}|a)} < B(a)$ *whereas compensation costs for bank shareholders increase*

$$W(a|T_{\min}) = c'(a) \frac{e^{\Delta r T_{\min}}}{\mathscr{I}(T_{\min}|a)} > W(a). \tag{9}$$

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 in order to implement the same action – here the bonus size and the contingency of pay. In particular, given that survival until $T_{\min} > \hat{T}(a)$ is more informative than survival until $\hat{T}(a)$, i.e., $\mathscr{I}(T_{\min}|a) > \mathscr{I}\left(\hat{T}(a)|a\right)$, shareholders optimally make use of this additional information when forced to pay bonuses after $T_{\min}$ in order to reduce the manager's rent.[24] Yet, by revealed preference, these optimal adjustments in response to the additional regulatory constraint must lead to higher compensation costs compared to the laissez-faire costs $W(a)$.

While compensation costs, thus, strictly increase for any action for which deferral regulation binds, the key element determining whether it is effective in increasing the equilibrium action – thereby lowering the risk of bank failure – is whether compensation costs increase more for low than for high actions. We turn to this analysis next.

3.1.2 Optimal action choice and the effects of deferral regulation

We now analyze which action shareholders induce in equilibrium and how it is affected by the minimum deferral period. To abstract from technical details, we omit a possible participation constraint on the side of shareholders, i.e., weakly positive profits, and

[23] The proofs of Propositions 1 and 2 do not impose this assumption and reveal that the main results of this Section continue to hold.

[24] When (7) does not hold for all $t > \hat{T}(a)$, it is theoretically possible that shareholders choose a payout time that strictly exceeds the minimum deferral period, $\hat{T}(a|T_{\min}) > T_{\min}$, even if they were to choose $\hat{T}(a|0) < T_{\min}$ in the absence of regulation. See Jewitt, Kadan, and Swinkels (2008) for a related point when the principal is subject to a minimum wage constraint.

suppose that their problem in (5) is strictly concave.[25] Hence, the induced equilibrium effort $a^*(T_{\min})$ is uniquely determined by the associated first-order condition

$$\Pi'(a) - W'(a) = \Delta W_a(a|T_{\min}). \tag{10}$$

Denote the equilibrium action for the benchmark case without regulation, i.e., $\Delta W(a|0) = 0$ for all a, by a^*. From (10) shareholders underinvest in risk-management in this case since $\Pi'(a) < V'(a)$. When facing binding deferral regulation, so that $\Delta W(a^*|T_{\min}) > 0$, from (10) shareholders optimally balance the marginal inefficiency of deviating from the *unconstrained,* privately optimal action choice, $\Pi' - W'$, with the marginal taxation costs arising from having to write inefficient compensation contracts, ΔW_a.

Whether a mandatory deferral period $T_{\min} > \hat{T}(a^*)$ leads shareholders to induce higher or lower risk management effort is then determined by the indirect tax function

$$\Delta W(a|T_{\min}) = c'(a)\left[\frac{e^{\Delta r T_{\min}}}{\mathscr{I}(T_{\min}|a)} - \frac{e^{\Delta r \hat{T}(a)}}{\mathscr{I}\left(\hat{T}(a)|a\right)}\right]\mathbb{1}_{T_{\min}>\hat{T}(a)}. \tag{11}$$

In particular, while the indirect tax is unambiguously positive when deferral regulation binds, $T_{\min} > \hat{T}(a)$, the effects on the equilibrium action depend, from (10), on the marginal tax ΔW_a: If the marginal tax evaluated at the optimal laissez-faire effort level a^* is negative, $\Delta W_a(a^*|T_{\min}) < 0$, shareholders indeed incentivize higher effort in equilibrium when facing the minimum deferral requirement. Otherwise, deferral regulation will lead to lower equilibrium effort and backfire.

In order to understand the differential taxation across effort levels note first that those effort levels that are optimally implemented with unconstrained payout dates exceeding the regulatory minimum, $\hat{T}(a) > T_{\min}$, are "tax-exempt." Whether this is high or low effort in turn depends on the sign of the comparative statics of $\hat{T}(a)$ in a. A priori, our model is flexible enough to generate comparative statics of either sign (see Lemma 2 for an illustration).[26] However, for expositional reasons, it is instructive to initially focus on environments in which the growth rate of informativeness is strictly increasing in a, $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t} > 0$, such that $\frac{d\hat{T}(a)}{da} > 0$ and it is high effort levels that are tax-exempt.

[25] While sufficiently stringent deferral regulation may indeed lead to negative bank profits, we abstract from this additional constraint for expositional reasons and since it will never bind under optimal deferral regulation (see Section 3.3.1). 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, cf., relatedly 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.

[26] In full generality, these comparative statics need not even be monotonic in a.

As this case gives deferral regulation the "*best possible shot*," one can think of it as illustrating an upper bound on the effectiveness of deferral regulation. After highlighting the key effects shaping the regulatory tax in this special information environment, we summarize the robust insights for general information environments in Proposition 2.

Best-case information environment for deferral regulation. When the payout time is strictly increasing in a, there exists a cut-off action $\underline{\hat{a}}(T_{\min})$, solving $T_{\min} = \hat{T}(a)$, above which shareholders can write unconstrained optimal compensation contracts. This cutoff action is a strictly increasing function of the minimum deferral period $T_{\min}$. Now, while $\Delta W(a|T_{\min}) = 0$ for sufficiently high effort $a \geq \underline{\hat{a}}(T_{\min})$, over the domain of effort levels for which deferral regulation binds, $a \in (0, \underline{\hat{a}}(T_{\min}))$, the indirect tax function is, in fact, non-monotonic:

Lemma 3 *Suppose that* $\frac{\partial \log \mathscr{I}(t|a)}{\partial t}$ *is strictly increasing in* a *for all* t *and that* $T_{\min} \in \left(\hat{T}(0), \lim_{a\to\infty} \hat{T}(a)\right)$. *Then* $\Delta W(a)$ *is zero for* $a = 0$ *and* $a \geq \underline{\hat{a}}(T_{\min})$ *and strictly positive, otherwise. For* $a \in (0, \underline{\hat{a}}(T_{\min}))$, $\Delta W(a)$ *is strictly increasing in* a *for a sufficiently small and strictly decreasing for* a *sufficiently close to* $\underline{\hat{a}}(T_{\min})$ *with* $\lim_{a\uparrow\underline{\hat{a}}(T_{\min})} \Delta W_a(a|T_{\min}) = 0$.

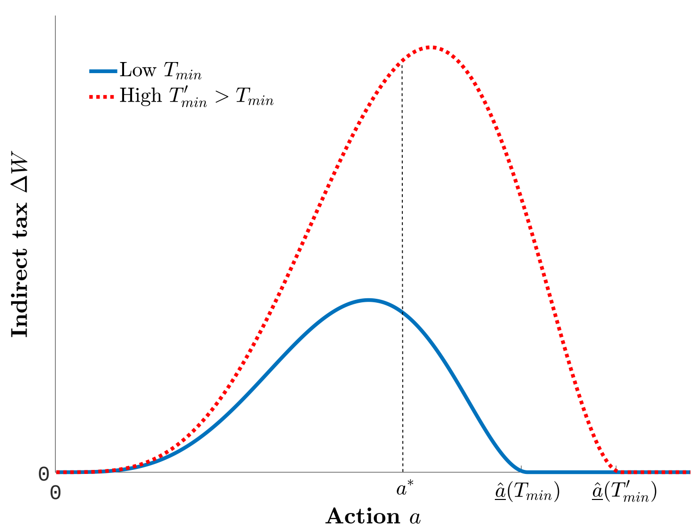

Figure 1. Properties of the indirect tax function: The figure plots the regulatory tax, $\Delta W(a|T_{\min}) = W(a|T_{\min}) - W(a)$, as a function of a for two levels of $T_{\min} > \hat{T}(a^*)$, with a gamma arrival time distribution as specified in Lemma 2. The chosen parameter values are $\Delta r = 0.75$, $\beta = 3$, $\kappa = 5$, $T_{\min} = 2.3$ and $T'_{\min} = 2.4$, with $c(a) = a^3/3$.

The non-monotonicity of the indirect tax (see Figure 1) intuitively results from the interaction of two countervailing effects that jointly determine how deferral regulation operates. First, since in this case $\hat{T}(a)$ is increasing in a, minimum deferral regulation forces banks to adjust the payout time most severely for low actions (relative to the unregulated choice of $\hat{T}(a)$). We label this effect the "*timing-of-pay*" effect. It is good news for regulation aiming at increasing a as low effort levels are taxed with the highest "tax rate" whereas high effort levels, $a \geq \underline{\hat{a}}(T_{\min})$ are "tax-exempt."

However, there is a countervailing effect since the total tax burden $\Delta W(a)$ in (11) is also a function of the "tax base" $c'(a)$. Mandatory deferral of the compensation package is more costly to bank shareholders if the size of the overall compensation package is larger. This "*size-of-pay*" effect is bad news for deferral regulation since the required incentive pay increases in effort. In particular, in the extreme case when no incentive pay needs to be provided, as $a = 0$, the tax base is zero as $c'(0) = 0$ (see (11)). Since deferring a payout of zero is not costly to the shareholders we obtain that $\Delta W(0) = 0$. Taken together, the properties of $\Delta W(a) = 0$ at the corners and $\Delta W(a) > 0$ in the interior imply the non-monotonicity of the indirect tax function.

In short, even in this best possible case for deferral regulation, the tax function features a region where the marginal tax is positive. Whether binding deferral regulation then raises or lowers equilibrium effort relative to the laissez-faire level of a^* depends on how stringent it is. If the minimum deferral period is sufficiently close to the unconstrained optimal payout time $\hat{T}(a^*)$ the unregulated choice $a^* < \underline{\hat{a}}(T_{\min})$ is close to $\underline{\hat{a}}(T_{\min})$ (see blue-colored tax function associated with deferral period $T_{\min}$ in Figure 1). Lemma 3 then implies that the marginal regulatory tax is negative in a neighborhood of a^*. From (10) it is, thus, strictly beneficial for bank shareholders to incentivize higher effort. In contrast, for sufficiently stringent minimum deferral periods, the implied outwards shift in the indirect tax function always results in a positive marginal tax at a^* inducing shareholders to implement lower effort (see red-colored tax function associated with $T'_{\min}$ in Figure 1), regulation "backfires."

General information environments. We now discuss the general case, where we put no restrictions on how the growth rate of informativeness $\frac{\partial \log \mathscr{I}(t|a)}{\partial t}$ changes in a. The tax function is then still shaped by the timing-of-pay-effect and the size-of-pay effect. However, while the size-of-pay effect unambiguously pushes towards "backfiring," the timing-of-pay effect can either oppose the size-of-pay effect (when $\hat{T}(a)$ is increasing in a as in the just considered case) or reinforce it (when $\hat{T}(a)$ is decreasing in a). In general, the effects of deferral regulation on equilibrium effort can then be summarized as follows:

Proposition 2 *A sufficiently small regulatory intervention $T_{\min} > \hat{T}(a^*)$, induces a strict increase in equilibrium effort compared to the laissez-faire outcome, $a^*(T_{\min}) > a^*$,* *if and only if* $\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}\Big|_{(t,a)=\left(\hat{T}(a^*),a^*\right)} > 0$, *and lower equilibrium effort otherwise. Regardless of the information environment, sufficiently large regulatory interventions unambiguously reduce equilibrium effort with* $\lim_{T_{\min}\to\infty} a^*(T_{\min}) = 0$.

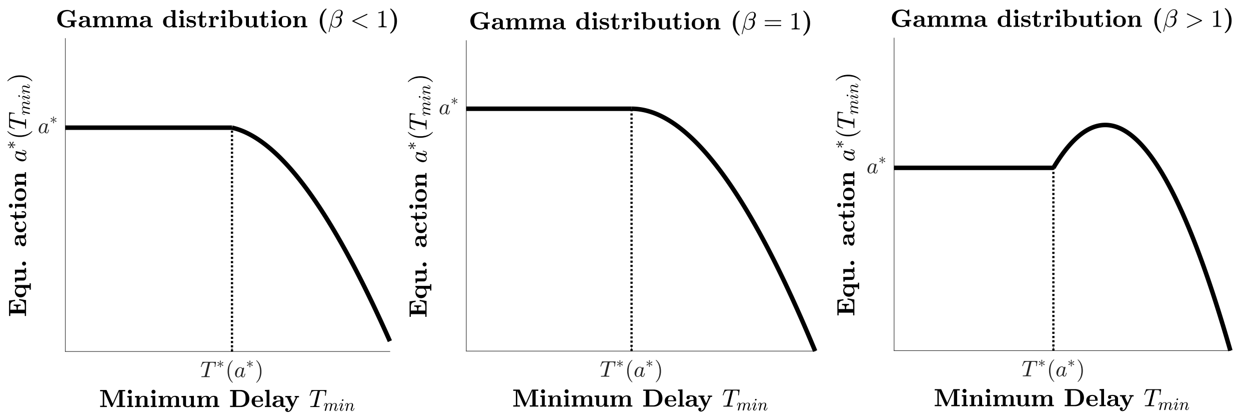

Figure 2. Effect of deferral regulation on equilibrium effort (PC slack): We plot the equilibrium action as a function of the minimum deferral period $T_{\min}$ for three different information environments, as captured by the parameter β of the Gamma survival distribution as introduced in Lemma 2 with $\beta = 0.5$, $\beta = 1$ and $\beta = 3$ in the respective panels. The remaining parameter values are $r = 0.05$, $\Delta r = 3$,$\kappa = 5$, $y = 100$, $k_{\min} = 0.1$ and $U = 0$, with $c(a) = a^3/3$.

This Proposition highlights two robust insights: For small interventions, the effect of deferral regulation is entirely determined by the local comparative statics of the payout time $\frac{d\hat{T}(a)}{da}\Big|_{a=a^*} > 0$, i.e., the timing-of-pay effect. E.g., with a Gamma survival distribution (see Lemma 2), marginally binding deferral regulation immediately backfires when $\beta < 1$ (see left panel of Figure 2), has zero effect when $\beta = 1$ (see middle panel) and initially raises effort for $\beta > 1$ (see right panel). In contrast, large interventions unambiguously backfire due to the size-of-pay effect (see all panels of Figure 2).[27] As the mandated deferral period becomes "large," the *marginal* cost of implementing any positive effort level grows without bound such that equilibrium effort approaches zero. Let us stress that, since we do not (exogenously) restrict shareholder profits to be positive for expositional clarity, this result is purely driven by action optimality, not by a violation of the shareholders' participation constraint.

Our analysis reveals that the effectiveness of deferral regulation in raising equilibrium effort, thus, requires the regulator to both correctly assess (local) comparative statics of

[27] In information environments for which the monotonicity condition $\frac{\partial^2 \log \mathscr{I}(t|a)}{\partial a \partial t} \leq 0$ holds globally (see left and middle panel of Figure 2), binding regulation always backfires, $a^*(T_{\min}) < a^*$, and equilibrium effort is strictly decreasing in the mandatory deferral period for all $T_{\min} > \hat{T}(a^*)$.

unconstrained optimal payout times and to calibrate the deferral requirement correctly to avoid overshooting.[28] These insights extend one-to-one to the case with a binding participation constraint to which we turn next. The only difference is that, with binding (PC), comparative statics of unconstrained optimal payout times work unambiguously in favor of deferral regulation via the timing-of-pay effect, so that the results are very similar to the best case scenario for deferral regulation with slack (PC).

3.2 Positive reservation value

We now consider the case where the manager has a strictly positive reservation value $U > 0$, as, for example, determined by working in the unregulated (shadow) banking sector.[29] For ease of exposition, we initially focus on the interesting (and novel) case where the manager's outside option is sufficiently high such that the participation constraint always binds. At the end of this section we then bring together the cases of slack and binding (PC) providing a characterization for the full range of U.

3.2.1 Compensation design with binding PC

Unregulated optimal compensation contracts (PC binds). If the manager's participation constraint (PC) binds, her valuation of the compensation package associated with action a is pinned down at $U + c(a)$. In this case, the timing of payouts under the optimal contract does not reflect a rent-extraction motive, but aims at minimizing deadweight impatience costs subject to incentive compatibility. To abstract from additional technical details, we suppose in this section that the convexity condition (7) holds for all t.[30] The optimal compensation contract is then characterized as follows:

Lemma 4 *Suppose (PC) binds and (DEF) is slack. Then, the manager receives zero fixed pay, $w = 0$, and a bonus if and only if the bank has survived by date $T_{PC}(a)$, solving*

$$\mathscr{I}(t|a) = \frac{c'(a)}{U + c(a)}. \tag{12}$$

[28] Of course, maximizing welfare is not equivalent to "maximizing effort," but, as is intuitive, the overshooting region can never be optimal (cf., section 3.3.1).

[29] We presently abstract from the possibility that this outside option is itself affected by compensation regulation. See Section 4 for further discussion.

[30] If the convexity condition (7) does not hold, optimal unconstrained contracts with a binding participation constraint may otherwise require two payout dates (cf., Lemma 1 in Hoffmann, Inderst, and Opp, Forthcoming). While this analysis brings out novel insights for optimal compensation design, it does not generate additional insights regarding the effects of compensation regulation.

The manager's ex-ante valuation of the compensation package is $B(a) = U + c(a)$ *and shareholders' compensation costs are* $W(a) = (U + c(a))\, e^{\Delta r T_{PC}(a)}$.

Optimal contracts with and without binding (PC) share the feature that bonus payments are only made conditional on bank survival at a single payout date. However, the trade-offs determining the optimal timing of pay are fundamentally different: With slack (PC), the optimal timing of pay reflects a rent-extraction motive, which implies that the bonus is deferred as long as informativeness *growth* exceeds the growth rate of impatience costs Δr (see (8)). In contrast, when (PC) binds, the optimal payout time minimizes deadweight impatience costs subject to incentive compatibility. Hence, it is optimal to pay at the earliest date at which the *level* of informativeness in (12), $\frac{c'(a)}{U+c(a)}$, is reached. This level ensures incentive compatibility of a compensation package that the manager values at $B(a) = U + c(a)$. In the special case of an exponential survival distribution, we obtain $T_{PC}(a) = a^2 \frac{c'(a)}{U+c(a)}$. Since the value of the bonus package is fixed at $B(a)$ by (PC), deferring pay beyond $T_{PC}(a)$ would only increase deadweight impatience costs.

The efficiency rationale with binding (PC) implies that it is optimal to pay out earlier than in the case disregarding (PC), i.e., $T_{PC}(a) < \hat{T}(a)$, and that pay is more front-loaded the higher the manager's outside option. In contrast to the rent-extraction case, this payout date now exhibits unambiguous comparative statics with respect to a.

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

Intuitively, as the value of the manager's total compensation package is fixed by (PC), implementing higher effort now unambiguously requires longer deferral periods to condition pay on more informative performance signals in order to satisfy (IC).

Constrained optimal compensation contracts (PC binds). We now study the optimal restructuring of contracts when the minimum deferral requirement binds.

Proposition 3 *Suppose (PC) binds. If* $T_{\min} > T_{PC}(a)$, *the optimal contract stipulates a bonus contingent on survival by date* $T_{\min}$ *and a fixed up-front wage* $w > 0$. *The manager values the bonus package at* $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}(T_{\min}|a)}$ *and the up-front wage is given by*

$$w = U + c(a) - B(a|T_{\min}) > 0.$$

With binding deferral regulation part of pay is now provided unconditionally (without incentive effects) as reflected in the base pay $w > 0$.[31] Intuitively, in order to provide

[31] That banks raise fixed compensation in response to regulatory intervention restricting incentive compensation is consistent with empirical evidence, see, e.g., Colonnello, Koetter, and Wagner (2018).

incentives at lowest impatience costs, incentive compensation is still fully contingent on survival and paid out at the earliest possible date $T_{\min}$. However, since a survival-contingent bonus at $T_{\min} > T_{PC}(a)$ provides stronger incentives as more information is available, i.e., $\mathscr{I}(T_{\min}|a) > \mathscr{I}(T_{PC}(a)|a) = \frac{c'(a)}{U+c(a)}$, the value of the bonus package $B(a|T_{\min})$ required by (IC) is smaller and, hence, insufficient to satisfy (PC). Due to differential discounting, it is then optimal to ensure the manager's participation by paying the remaining amount $U + c(a) - B(a|T_{\min})$ as an up-front wage. The next section analyzes when shareholders indeed switch from fully contingent pay to a contract with unconditional base pay in equilibrium, i.e., for the optimally chosen action.

3.2.2 Optimal action choice and the effects of deferral regulation with $U > 0$

We now analyze shareholders' optimal action choice with binding (PC) and how it is affected by changes in the deferral period. Since unconstrained optimal payout times are unambiguously increasing in a (by Lemma 5), we obtain a non-monotonic tax function as in the best case scenario for deferral regulation with slack (PC). Denoting the cutoff action of the taxation domain by $\underline{a}(T_{\min})$, solving $T_{\min} = T_{PC}(a)$, we obtain:

Lemma 6 *Suppose (PC) binds and $T_{\min} \in \left(T_{PC}(0), \lim_{a\to\infty} T_{PC}(a)\right)$. Then regardless of the information environment, the indirect regulatory tax $\Delta W(a|T_{\min})$ is zero for $a = 0$ and $a \geq \underline{a}(T_{\min})$ and strictly positive, otherwise with*

$$\Delta W(a|T_{\min}) = c'(a)\left(\frac{e^{\Delta r T_{\min}} - 1}{\mathscr{I}(T_{\min}|a)} - \frac{e^{\Delta r T_{PC}(a)} - 1}{\mathscr{I}(T_{PC}(a)|a)}\right)\mathbb{1}_{T_{\min} > T_{PC}(a)}. \tag{13}$$

For $a \in (0, \underline{a}(T_{\min}))$, $\Delta W(a|T_{\min})$ is strictly increasing in a for a sufficiently small and strictly decreasing for a sufficiently close to $\underline{a}(T_{\min})$ with $\lim_{a\uparrow\underline{a}(T_{\min})} \Delta W_a(a|T_{\min}) < 0$.

Again, the non-monotonicity arises from the interaction of the timing-of-pay effect, which, from $T'_{PC}(a) > 0$, robustly pushes towards a lower tax for higher effort, and the size-of-pay effect, which pushes towards a lower tax for lower effort. Accordingly, the main *directional* effect of deferral regulation on the equilibrium action is akin to the best-case scenario with slack (PC): As soon as regulation binds, i.e., $T_{\min} > T_{PC}(a^*)$, the effect on a^* is initially positive and eventually negative for large deferral periods (see Figure 3). The crucial difference to the case with slack (PC) now is, that this characterization applies generally, i.e., independent of the concrete information environment. When the manager's (PC) binds, there is, thus, a case for deferral regulation even in information environments that would not support its use with slack (PC), e.g., when the process of bank failure is governed by a Gamma arrival time distribution with $\beta \leq 1$ as characterized in Lemma 2 (Figure 3 plots the case of $\beta = 1$). Proposition 4 formalizes these insights.

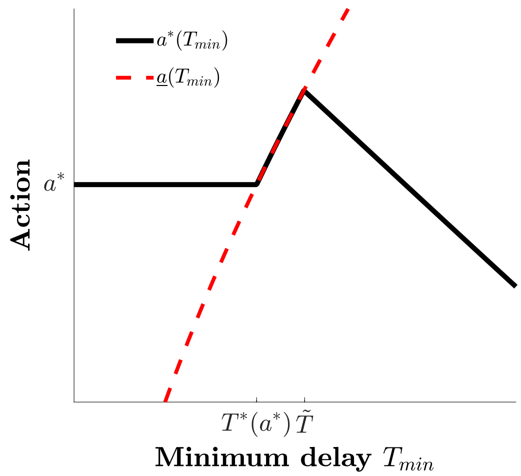

Figure 3. Effect of deferral regulation on equilibrium effort (PC binding): We plot the equilibrium action with binding PC ($U = 3$) as a function of the minimum deferral period $T_{\min}$ for the case of the exponential distribution (Gamma with $\beta = 1$), see solid black line. The red dotted line indicates the cut-off action $\underline{a}(T_{\min})$. The remaining parameter values are as in Figure 2.

Proposition 4 *Suppose U is sufficiently high, so that (PC) binds with and without deferral regulation. Then, there exists $\tilde{T} > T_{PC}(a^*)$ such that*

1. *For any $T_{\min} \in (T_{PC}(a^*), \tilde{T})$, the equilibrium action is given by the cutoff-action $a^*(T_{\min}) = \underline{a}(T_{\min}) > a^*$ and strictly increasing in $T_{\min}$.*

2. *For any $T_{\min} > \tilde{T}$, the equilibrium action solves the first-order condition (10) with $a^*(T_{\min}) < \underline{a}(T_{\min})$. Sufficiently high deferral periods then reduce equilibrium effort with $\lim_{T_{\min}\to\infty} a^*(T_{\min}) = 0$.*

With binding (PC), moderate deferral periods $T_{\min} < \tilde{T}$ generate an additional novel feature, next to their *robustly* positive effect on equilibrium effort: The equilibrium action is not interior, i.e., pinned down by a first-order condition, but instead given by the cutoff-action $\underline{a}(T_{\min})$. This technical result has the following important economic implications:

Corollary 1 *Suppose Proposition 4 applies. Then,*

1. *If $T_{\min} \in (T_{PC}(a^*), \tilde{T})$, the equilibrium action $a^*(T_{\min})$ is incentivized with an unconstrained optimal compensation contract (see Lemma 4). No deadweight costs from inefficient contracting are realized in equilibrium, $\Delta W(a^*(T_{\min})|T_{\min}) = 0$.*

2. *If* $T_{\min} > \tilde{T}$*, deadweight costs from inefficient contracting occur in equilibrium,* $\Delta W\left(a^*\left(T_{\min}\right)|T_{\min}\right) > 0$*. Equilibrium contracts feature unconditional base pay.*

Thus, surprisingly, moderate deferral regulation, $T_{\min} \in \left(T_{PC}\left(a^*\right), \tilde{T}\right)$, has the desired effect of raising equilibrium effort *without sacrificing contracting efficiency*. Heuristically, one can think of marginal deferral regulation imposing a *prohibitive* tax for all actions below $\underline{a}\left(T_{\min}\right)$, so that shareholders optimally choose the corner solution $\underline{a}\left(T_{\min}\right)$. With binding (PC), the tax is deemed prohibitive for all $a < \underline{a}\left(T_{\min}\right)$ as the optimal contracting adjustments required to implement these actions subject to deferral regulation are non-marginal — switching from a contract with fully contingent pay to one featuring unconditional base pay $w > 0$ (cf. Proposition 3 vs. Lemma 4). These non-marginal contract adjustments generate *first-order* deadweight costs even in the limit of a marginal regulatory intervention, i.e., $\lim_{a \uparrow \underline{a}(T_{\min})} \Delta W_a\left(a|T_{\min}\right) < 0$, which are optimally avoided by distorting the optimal action choice to the cut-off action $\underline{a}\left(T_{\min}\right)$, which only generates second-order losses by the envelope theorem.[32]

However, as $T_{\min}$ rises and with it $a^*\left(T_{\min}\right) = \underline{a}\left(T_{\min}\right)$, shareholders are further and further away from their unconstrained optimal action choice a^* generating marginal losses of $\Pi'\left(a^*\left(T_{\min}\right)\right) - W'\left(a^*\left(T_{\min}\right)\right) < 0$. Eventually, at $T_{\min} = \tilde{T}$, these marginal losses from distorting the implemented action just match the marginal taxation costs arising from deviating from unconstrained optimal contracting. For larger deferral periods, $T_{\min} > \tilde{T}$, the implemented action then is again interior, $a^*\left(T_{\min}\right) < \underline{a}\left(T_{\min}\right)$, and pinned down by the first-order condition (10) equalizing marginal action distortions and taxation costs.[33]

Significance of reservation value. Our analysis so far discussed the effects of deferral regulation when the outside option of the agent U is either sufficiently low or sufficiently high such that (PC) was either slack or binding for all values of $T_{\min}$. We now conclude our positive analysis of deferral regulation by characterizing the results for the entire range of U. For this characterization, it is useful to denote the solution to the relaxed problem, when (PC) is disregarded, by $\hat{a}\left(T_{\min}\right)$, with $\hat{a} := \hat{a}\left(0\right)$ referring to the corresponding laissez-faire action, and $\hat{U} := \frac{c'(\hat{a})}{\mathscr{I}\left(\hat{T}(\hat{a})|\hat{a}\right)} - c(\hat{a})$ denoting the manager's net utility under the associated laissez-faire contract. Moreover, we denote by $T^*\left(a\right) = \min\left\{\hat{T}\left(a\right), T_{PC}\left(a\right)\right\}$ the optimal payout time for a given action. We then obtain:

[32] Graphically, the tax function with binding (PC) has a kink at $\underline{a}\left(T_{\min}\right)$, see Appendix Figure A.1. In contrast, the contracting adjustments in response to marginal regulatory interventions under slack (PC) only generate second-order losses by the envelope theorem, since the payout time is pinned down by a first-order condition, implying a smooth tax function (see Figure 1).

[33] 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.

Proposition 5 *For all U, the directional effect of marginally binding deferral regulation on equilibrium effort is determined by the sign of the payout time comparative statics* $\left.\frac{dT^*(a)}{da}\right|_{a=a^*}$. *Stringent minimum deferral requirements unambiguously backfire.*

1. *If $U = 0$, (PC) is slack for all $T_{\min}$ and Proposition 2 applies.*

2. *If $U \in \left(0, \hat{U}\right)$, (PC) is slack without regulation and the effect of marginal interventions is given by Proposition 2. If $T_{\min}$ exceeds a finite threshold, (PC) binds.*

3. *If $U \geq \hat{U}$, (PC) binds already in the absence of regulation. Marginal interventions have an unambiguously positive effect on equilibrium effort (see Proposition 4).*

Thus, case (2) represents the novel case. It reveals that deferral regulation will push towards binding (PC) via an intuitive and robust effect: By effectively nudging shareholders to condition incentive compensation on more informative performance signals ("longer survival"), mandatory deferral of pay causes the equilibrium agency rent to decline. Thus, for any positive manager outside option, the rent extraction contract eventually violates the manager's participation constraint for sufficiently high $T_{\min}$.

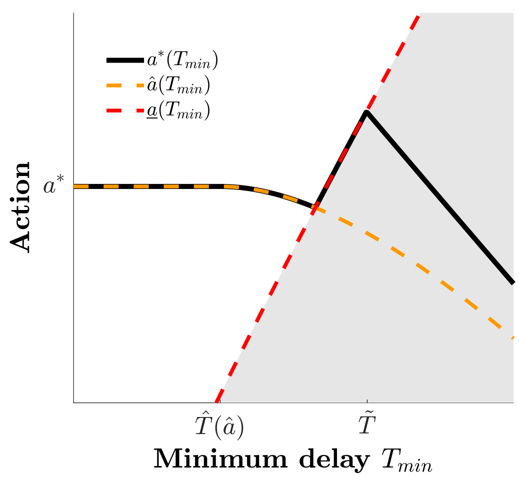

Figure 4. Effect of deferral regulation on equilibrium effort for intermediate $U \in \left(0, \hat{U}\right)$: We plot the equilibrium action $a^*(T_{\min})$ for the case of the exponential distribution ($\beta = 1$), see solid black line. Since $U < \hat{U}$, (PC) is slack in the absence of regulation. The orange dotted line refers to the optimal action $\hat{a}(T_{\min})$ given a rent extraction contract. The red dotted line indicates the cut-off action $\underline{a}(T_{\min})$, below which, i.e., in the grey-shaded region, (PC) has to bind. The parameter values are as in Figure 3 with the only difference that $U = 1$.

Figure 4 illustrates this insight, and reveals that, with an intermediate value of the manager's outside option, the effect of deferral regulation on the equilibrium action can be thought of as merging Figures 2 and 3. For $T_{\min} > \hat{T}(\hat{a})$ but sufficiently close to

$\hat{T}(\hat{a})$, the equilibrium action $a^*(T_{\min})$ (indicated by solid black line) is given by the equilibrium response under slack (PC), $\hat{a}(T_{\min})$ (see orange dotted line). Since Figure 4 plots the case of an exponential survival distribution, which features $\left.\frac{d\hat{T}(a)}{da}\right|_{a=\hat{a}} = 0$, the equilibrium action is initially constant and then falls in this region in response to larger deferral periods $T_{\min}$ (cf. Figure 2, $\beta = 1$). Now, as soon as $\hat{a}(T_{\min})$ enters the grey-shaded region, i.e., $\hat{a}(T_{\min}) < \underline{a}(T_{\min})$, the agent's participation constraint would be violated under the rent-extraction contract and (PC) must start to bind. We then obtain the familiar result with binding (PC) that the equilibrium action is initially given by the cut-off action $\underline{a}(T_{\min})$ and strictly increasing, before eventually declining (cf., Figure 3).

In sum, (moderate) deferral regulation is more likely to be effective at raising equilibrium risk-management effort when the participation constraint binds. Large interventions unambiguously backfire. We now examine the welfare aspects of such regulation.

3.3 Implications for regulation design

3.3.1 Welfare effects of deferral regulation

Our positive analysis focused solely on the impact of deferral regulation on equilibrium risk-management effort, but did 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:

$$\begin{aligned}\Omega = &-(1-k_{\min})\left(1 - r\int_0^\infty e^{-rt} S(t|a)\,dt\right) \\ &+ \Pi(a) - W(a) - \Delta W(a|T_{\min}) \\ &+ \kappa_A\left[w + B(a|T_{\min}) - c(a) - U\right],\end{aligned} \tag{14}$$

accounting for the tax payer externality, bank profits, and the manager's agency rent.[34]

Welfare effects of marginal interventions. Before turning to the question of how to calibrate welfare maximizing deferral periods, it is of particular interest to analyze the welfare effect of small regulatory interventions, as most interventions in practice are small, e.g., with deferral requirements exceeding laissez-faire industry practice by a year.

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

Proposition 6 (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*

1. *(PC) slack* ($U < \hat{U}$) *with* $\frac{\partial}{\partial a} \frac{\partial \log \mathscr{I}(t|a)}{\partial t}\Big|_{(t,a)=\left(\hat{T}(a^*),a^*\right)} > 0$ *and* κ_A *below a threshold.*

2. *(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, so that (locally) higher effort is optimally implemented with later pay. This requirement is restrictive and not necessarily satisfied, see Lemma 2. Ultimately, whether this restriction holds in reality is an empirical question and determined by the information environment of the various groups affected by the regulation. Second, and, intuitively, the welfare weight attached to the manager cannot be too large since longer deferral pushes towards 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.[35] The main idea of the proof then is that only in the specified information environments, do small interventions trigger an increase in equilibrium effort (see right panel of Figure 2), 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, moderate deferral regulation unambiguously increase welfare. The effect is robust since higher effort is optimally implemented with later payouts, $T'_{PC}(a) > 0$, regardless of the information environment (see Lemma 5). Moreover, the welfare weight κ_A is irrelevant since the manager is kept at her outside option. Hence, the welfare criterion in (14) can be simplified to

$$\Omega = V(a) - W(a) - \Delta W(a|T_{\min}), \tag{15}$$

where we used (4). Marginal regulation with binding (PC) unambiguously increases welfare since the induced increase in effort leads to a decrease in the tax payer externality without incurring any contracting distortions, i.e., $\Delta W = 0$ (Corollary 1).

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

The optimum deferral period. We can 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), i.e., the case where moderate "minimum deferral regulation" robustly increases risk-management effort. It is then of particular interest to analyze whether this "ad hoc" regulatory tool can achieve second-best welfare,[36]

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

where we consider the relevant case where bank operations can generate social value, i.e., $\Omega^{SB} > 0$.[37] From (15), we observe that achieving second-best welfare requires both that the efficient action be incentivized (action efficiency), $a^*(T_{\min}) = a^{SB}$, and that the associated compensation contract be unconstrained optimal (contracting efficiency), i.e., $W(a^*(T_{\min})|T_{\min}) = 0$.

Lemma 7 *Second-best welfare can be attained if and only if $T_{PC}(a^{SB}) \leq \tilde{T}$ and $U \geq \overline{U}^{SB} := \frac{c'(a^{SB})}{\mathscr{I}(T^*(a^{SB})|a^{SB})} - c(a^{SB})$. The optimal deferral period then is $T^*_{\min} = T_{PC}(a^{SB})$.*

The intuition for this Lemma is as follows: As long as $T_{PC}(a^{SB}) \leq \tilde{T}$, see left panel of Figure 5, shareholders facing a deferral requirement of $T^*_{\min} = T_{PC}(a^{SB})$ view all actions $a < a^{SB}$ as prohibitively taxed, and, hence incentivize the cut-off action $\underline{a}(T_{\min}) = a^{SB}$ with an unconstrained optimal compensation contract (i.e., case (1) of Proposition 4 and Corollary 1 applies). Second-best welfare is attained (see green dot in Figure 5).

In contrast, if $T_{PC}(a^{SB}) > \tilde{T}$, see right panel of Figure 5, shareholders subject to a deferral requirement of $T_{\min} = T_{PC}(a^{SB})$ would implement an action strictly lower than a^{SB} and, from Corollary 1, sacrifice contracting efficiency. Second-best welfare cannot be achieved. As is 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 both by lowering equilibrium effort and by inducing contracting inefficiencies via the payment of an unconditional up-front wage. Put differently, observing an increase in up-front pay would, thus, indicate excessive regulation.

It is now useful to link the technical condition $T_{PC}(a^{SB}) \leq \tilde{T}$ to the economic environment. As is intuitive, this condition is satisfied if the privately optimal choice

[36] Second-best welfare refers to the maximal welfare subject to the moral hazard problem, which could be achieved, e.g., if the regulator could write compensation contracts directly. 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.

[37] Therefore, a participation constraint 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.

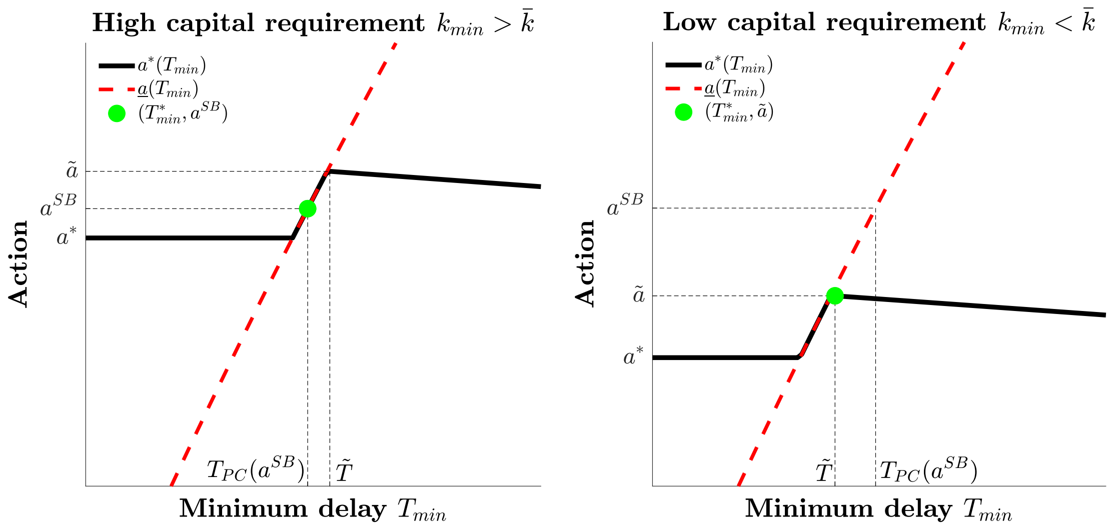

Figure 5. Outcome under welfare maximizing deferral: We plot the equilibrium action as a function of the minimum deferral period $a^*(T_{\min})$ – see solid black line – as well as the outcome under the welfare maximizing deferral regulation – see green point – for two different levels of the minimum capital requirement $k_{\min}$ ($k_{\min} = 0.8$ in the left 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 $c(a) = a^3/3$.

a^* and a^{SB} are not too far apart, or, put differently, 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 short and focused on deferral regulation, we treat as an exogenous parameter. Proposition 7 now highlights the interaction of capital and compensation regulation.

Proposition 7 *Second-best welfare can be attained with a deferral requirement of* $T^*_{\min} = T_{PC}\left(a^{SB}\right)$ *if and only if* $k_{\min}$ *exceeds a threshold* $\bar{k} < 1$ *and* $U \geq \overline{U}^{SB}$.

Qualitatively, Proposition 7 also 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 panel of Figure 5), and, hence, implies larger differences between optimally imposed minimum deferral periods and payout times of laissez-faire compensation contracts $T_{PC}\left(a^*\right)$.

We conclude by highlighting the distinct mechanism of capital regulation and compensation regulation. In our setting, capital regulation operates via reducing the wedge between private (bank) profits and societal welfare $\Pi\left(a|k_{\min}\right) - V(a)$, and, thus, directly addresses the root of shareholders' preference distortion. In terms of the tax analogy, an increase in $k_{\min}$ implies a monotonic tax (on profits) $\Delta\Pi$, with larger taxes for lower actions.[38] In contrast, compensation regulation does not target the root of the distortion, i.e., it does not cause bank shareholders to internalize tax payer losses upon bank failure. Yet, by acting as an indirect tax on compensation costs, ΔW, it may still be effective in inducing shareholders to adjust actions. However, the non-monotonicity of the tax function limits its effectiveness in generating large positive action changes.

3.3.2 The role of clawback requirements

So far, we only considered compensation regulation targeting 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, e.g., 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 non-vested bonus escrow accounts. The latter type of clawback is technically referred to as a malus and more relevant in practice due to obvious enforcement problems with pure clawbacks (see Arnold (2014)).[39] We, hence, 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 an additional bite.

In practice, regulation usually requires bonuses to be subject to clawback for a period of given length T_{claw}, where, in order to illustrate the novel effects of a regulation targeting the contingency of pay, we set $T_{claw} = T_{\min}$. Now, in our simple, binary information environment, it is most natural to interpret the event "bank failure" as the relevant contingency triggering a clawback and we, hence, 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

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

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 Propositions 1

[38] Formally, $\frac{\partial^2 \Pi}{\partial k_{\min} \partial a} = r \int_0^\infty e^{-rt} S_a(t|a)\, dt > 0$. 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 case of (early) default. We thank our discussant Vish Viswanathan for this insight.

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

and 3), and, hence automatically satisfy (CLAW).[40] Concretely, 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 up-front 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. Also real-world regulators, such as Martin Wheatley (UK Financial Conduct Authority), have become concerned by this practice of contracting "around the regulation" and, hence, have considered extending the applicability of clawbacks to fixed pay (see Binham (2015)).

Our framework can inform the debate about this more stringent policy, too. Recall that in our setting unconditional wages are paid in equilibrium if and only if (PC) binds and $T_{\min} > \tilde{T}$ (see Corollary 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 8 *If $U > \overline{U}^{SB}$ and clawbacks extend to wages, second-best welfare can always be achieved by imposing a deferral / clawback period of $T^*_{\min} = T_{PC}\left(a^{SB}\right)$. Such a clawback requirement is necessary to achieve second-best welfare whenever $k < \bar{k}$ or, equivalently, $T_{PC}\left(a^{SB}\right) > \tilde{T}$.*

The intuition for this result is fairly simple. The more (regulatory) constraints bank shareholders are facing, the fewer margins of the compensation contract they can adjust. In this case, (PC) fixes the value of the pay package 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. Taken together these constraints make it impossible to incentivize any effort level below $\underline{a}\left(T_{\min}\right)$, i.e., low effort is subject to an infinite tax, $W\left(a|T_{\min}\right) = \infty$ for all $a < \underline{a}\left(T_{\min}\right)$. Regulation, thus, becomes more powerful by effectively imposing a minimum effort constraint $a \geq \underline{a}\left(T_{\min}\right)$. While Proposition 8 highlights 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 hinges on the ability to discern the learning dynamics of the concrete information environment.

[40] Note that this result follows from optimality. In particular, it does not just hold for the trivial reason that the bank may not have the resources to pay the agent in 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.

4 Robustness

In this section, we aim to show robustness of our model implications with regards 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 to endogenize the manager's outside option $U(T_{\min})$ making explicit its dependence on deferral regulation.

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 simply the (monetized) difference in status attached to the banks. As is easy to see, in equilibrium of the contract offer game, DB just breaks-even. Formally, the manager's gross utility derived from DB's contract offer solves

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

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

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

It is then immediate that, as long as the cost K or the value of working in the shadow banking sector $\bar{U}$ are sufficiently large, our original analysis applies one-to-one. That is, bank GS will either offer a contract in which (PC) is slack or (PC) binds with an exogenous outside option $\bar{U}$. The interesting and novel case is when $U(T_{\min}) = U_{gross}^{DB}(T_{\min}) - K$ and K is sufficiently small such that (PC) binds. In this case, an increase in $T_{\min}$ will not only affect GS directly by constraining the contracting space, but also via its (negative) effect on the manager's outside option (at least as long as the within-industry outside option is relevant). Overall, the relevance of such general equilibrium effects are, hence, likely to differ across the various groups affected by the regulation (executives, traders, etc.) depending on the relative importance of within vs. across industry outside options in the respective line of work.[41] Future work could build on this toy model to explore, e.g., the equilibrium implications of compensation regulation on the creation of systemic risk (cf., 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 its volatility σ. While the action set is now richer, the "size-of-pay" effect is still relevant as actions that are (c.p.) 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. E.g., 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 shape 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 a meaningful role in optimal contracts, one either requires the assumption that the manager be risk averse or 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 only, we favored the assumption of relative impatience, as introducing agent risk-aversion in our setting implies that optimal contracts stipulate payments both for a larger set of states and times (cf., Propositions 2 and 3 in Hoffmann, Inderst, and Opp, Forthcoming) rather than a single payout time and state (survival). However, this additional richness in optimal unconstrained contracts produces no new

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

economic insights regarding the qualitative effects of deferral regulation on the equilibrium action choice, which is the focus of this paper. I.e., the tax resulting from regulatory deferral constraints is still driven by the same "size-of-pay" and "timing-of-pay" effects.

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 (and the agent has no outside option), 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 the "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.

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, e.g., when the principal, the board, has different preferences than shareholders. Different from our setup, shareholders should, then, applaud regulatory interference. Relatedly, 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 multi-dimensional 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 B), which put an upper bound on the ratio of bonus to wage compensation. Such a regulation would c.p. 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, e.g., by extending clawback clauses to wages, or by specifying a lower bound on the ratio of bonus to wage compensation.[42]

5 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, not only of applied, but also of theoretical interest. How does a principal reshuffle incentives when facing such regulatory constraints on compensation design? In particular, how will it affect the equilibrium action, and, ultimately risk?

To answer these questions accounting for the Lucas-critique, our paper has relied 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 for which (i) bank shareholders would write short-term contracts (*timing-of-pay channel*), and that (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: Then, deferral regulation 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 only holds robustly when the agent's outside option is sufficiently high. For large deferral requirements, the size-of-pay force dominates and, since implementing higher effort c.p. requires larger bonuses, the quality of risk management unambiguously decreases in equilibrium.

Our *normative* analysis shed light on the welfare effects of such compensation regulation and its interaction with capital regulation in a setting where 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 towards excessive risk tolerance, but merely 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, in certain envi-

[42] We thank an anonymous referee for suggesting this implication.

ronments, be effective in steering bank shareholders to incentivize welfare-superior actions from their employees, and may even allow 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 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 thoughts, future work may consider imposing realistic informational constraints on the regulator and analyze optimal regulation as a solution to the implied mechanism design problem rather than restricting the analysis to specific regulatory tools observed in practice.[43] When is it optimal to micromanage the agency problem via interfering in the compensation contract? When is it optimal to directly target the externality? Our analysis of the interaction of capital regulation and deferral/clawback regulation can be thought of as a first, modest step in this direction.

Appendix A Proofs

Proof of Lemma 1 We will first derive the optimal contingency of pay and second the optimal timing of pay. The optimal size of payments then follows immediately.

Lemma A.1 *An optimal unregulated contract never stipulates rewards following failure.*

Proof of Lemma A.1 The result follows from the fact that for each $t > 0$, survival is the performance history with the highest log-likelihood ratio (score).[44] 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

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

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

[44] 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 $a \in [0, \bar{a}]$ is denoted by $(\mathbb{P}^a)_{a \in [0,\bar{a}]}$, i.e., 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.

where we have used the assumption on the failure rate in (1). Since (1) further implies that $\frac{\partial \log S(t|a)}{\partial a}$ is an increasing function of t, also histories involving a failure at some $s < t$ have a lower score than date-t survival. Hence, making incentive pay contingent on survival provides strongest incentives per unit of expected pay at each given t. Having established that in our concrete 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 (Forthcoming) to our concrete setting.

The proof is by contradiction. Assume that for some 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. Hence, we 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.[45]

To see this, assume, first, that (PC) is slack and make, for all t, all payments contingent on survival holding $\mathbb{E}^a\left[e^{-(r+\Delta r)t}db_t\right]$ and, thus, total compensation costs constant. However, (IC) will be slack under this alternative contract.[46] To see this denote the share of expected date-t compensation $\mathbb{E}^a\left[db_t\right]$ 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

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

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

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

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

[46] 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 $t = 0$.

Optimal timing of pay. We now characterize the optimal *timing* of pay, which is adapted from the proof of Theorem 1 and B.1 in Hoffmann, Inderst, and Opp (Forthcoming). Here, we note that the unconditional up-front payment w is equivalent to a survival-contingent date-0 bonus since $S(0|a) = 1$ and will, hence, be subsumed by 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 how to spread out payments over time. In particular, denote for any admissible process b_t the agent's time-0 valuation of the compensation contract 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*

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

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

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

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

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 will 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

$$W(a) = W(a|0) = \min_{g_t} c'(a) \frac{\int_0^\infty e^{\Delta r t} dg_t}{\int_0^\infty \mathscr{I}(t|a)\, dg_t}, \tag{16}$$

which is solved by $\int_{\hat{T}(a)} dg_t = 1$ for $\hat{T}(a) = \arg\max_t e^{-\Delta r t}\mathscr{I}(t|a)$ 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 with $\mathscr{I}(0|a) = 0$ and finite by condition (7) then implies that (8) characterizes the optimal payout date.[47] Hence, there is no up-front bonus in this case ($w = 0$). The remaining results then follow immediately from substituting the optimal payout time in (IC) and the shareholders' objective.

Validity of first-order approach. It remains to show the validity of the first-order approach. For this 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 $\hat{T}(a)$. To see this, note that, facing a contract (w, b), the agent chooses the action a to maximize expected discounted utility

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

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 $t \in [0, \infty) \setminus \hat{T}(a)$. Hence, the first-order condition in (IC) is both necessary and sufficient for incentive compatibility. **Q.E.D.**

Proof of Lemma 2 For this proof we will assume for convenience that $\hat{T}(a)$ as characterized by (8) is unique.[48] Then, a direct application of the implicit function theorem to (8) shows that

$$\text{sgn}\left(\frac{d\hat{T}(a)}{da}\right) = \text{sgn}\left(\frac{\partial}{\partial a}\left.\frac{\partial \log \mathscr{I}(t|a)}{\partial t}\right|_{t=\hat{T}(a)}\right). \tag{17}$$

For the Gamma survival time distribution direct computation then gives

$$\frac{\partial \log \mathscr{I}(t|a)}{\partial t} = \frac{1}{t}\left(\beta - \frac{t}{a} + \frac{\left(\frac{t}{a}\right)^\beta e^{-\frac{t}{a}}}{\int_{\frac{t}{a}}^\infty s^{\beta-1}e^{-s}ds}\right),$$

such that

$$\frac{\partial^2 \log \mathscr{I}(t|a)}{\partial a \partial t} = \left[\frac{t}{a} - \left(\frac{t}{a}\right)^\beta e^{-\left(\frac{t}{a}\right)} \frac{\left(\beta - \frac{t}{a}\right)\int_{\frac{t}{a}}^\infty s^{\beta-1}e^{-s}ds + \left(\frac{t}{a}\right)^\beta e^{-\frac{t}{a}}}{\left(\int_{\frac{t}{a}}^\infty s^{\beta-1}e^{-s}ds\right)^2}\right]\frac{1}{a}.$$

[47] If there are multiple solutions, the principal can select any payout date (or a combination thereof).
[48] All results continue to hold in the respective monotone comparative statics sense if there are multiple solutions to (8).

Now, define $x := \frac{\hat{T}(a)}{a}$, where $\hat{T}(a)$ solves (8) for given a, then

$$\begin{aligned}\operatorname{sgn}\left(\left.\frac{\partial^2 \log \mathscr{I}(t|a)}{\partial a \partial t}\right|_{t=\hat{T}(a)}\right) &= \operatorname{sgn}\left(x\Gamma^2(\beta,x) - (\beta - x)\, x^{\beta} e^{-x}\Gamma(\beta,x) - \left(x^{\beta}e^{-x}\right)^2\right) \\ &= \operatorname{sgn}\left((\beta-1)\left[x\left(e^{-x}x^{\beta} + \Gamma(\beta,x)\right)\Gamma(\beta-1,x) - \Gamma(\beta,x)\, e^{-x}x^{\beta}\right]\right),\end{aligned}$$

where we have used that $\Gamma(\beta,x) = (\beta-1)\Gamma(\beta-1,x) + e^{-x}x^{\beta-1}$ for all $\beta > 0$. The result then follows as the term in square brackets is strictly positive by properties of the Gamma function. **Q.E.D.**

Proof of Proposition 1 That all payments under the optimal contract with deferral regulation (DEF) are still contingent on survival follows from the same arguments as in the proof of Lemma 1. Similarly, the arguments there, in particular the simplified problem in (16), directly imply that the optimal payout time under (DEF) is given by

$$\hat{T}(a, T_{\min}) = \underset{t \geq T_{\min}}{\arg\max}\, e^{-\Delta r t} \mathscr{I}(t|a). \tag{18}$$

Denoting the maximal optimal payout date absent deferral regulation by $\bar{T}(a)$, the above simplifies to $\hat{T}(a, T_{\min}) = \max\left\{\bar{T}(a), T_{\min}\right\}$ if the convexity condition in (7) holds for all $t > \bar{T}(a)$, as assumed in the main text. That $B(a|T_{\min}) < B(a)$ then follows directly from the fact that $\mathscr{I}(t|a)$ is increasing in t together with $\hat{T}(a, T_{\min}) > \bar{T}(a)$ for the case of binding deferral regulation. That $W(a|T_{\min}) > W(a) = W(a|0)$ whenever $T_{\min} > \bar{T}(a)$ follows from optimality of the unconstrained optimal payout time. **Q.E.D.**

Proof of Lemma 3 Using the definition of the optimal payout date in (18) we can write the indirect tax function in (11) more generally as

$$\Delta W(a) = c'(a)\left[\frac{e^{\Delta r \hat{T}(a,T_{\min})}}{\mathscr{I}\left(\hat{T}(a,T_{\min})|a\right)} - \frac{e^{\Delta r \bar{T}(a)}}{\mathscr{I}\left(\bar{T}(a)|a\right)}\right]\mathbb{1}_{T_{\min} > \bar{T}(a)}. \tag{19}$$

Then, $\bar{T}(a) := \arg\max e^{-\Delta r t}\mathscr{I}(t|a)$ and (18) imply that $\Delta W(a) \geq 0$, with equality if and only if either $T_{\min} \leq \bar{T}(a)$ and/or $c'(a) = 0$. The latter holds if and only if $a = 0$ by the assumptions on the cost function, while the former holds if and only if $a \geq \underline{\hat{a}}(T_{\min})$, where $\underline{\hat{a}}(T_{\min})$ solves $T_{\min} = \bar{T}(a)$. Here we used that $\bar{T}(a)$ is increasing in a from (17) by the assumption on informativeness growth. 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 $\underline{\hat{a}}(T_{\min})$. That $\Delta W_a(\underline{\hat{a}}(T_{\min})|T_{\min}) = 0$ then follows from straightforward differentiation of (19) together with $\hat{T}\left(\underline{\hat{a}}\left(T_{\min}\right), T_{\min}\right) = T_{\min} = \bar{T}\left(\underline{\hat{a}}\left(T_{\min}\right)\right)$. **Q.E.D.**

Lemma A.2 *Assume a contract stipulates a bonus at a single payout date T if and only if the bank has survived by date T. Then, incentive compatibility implies:*

$$\frac{1}{\mathscr{I}\left(T|a\right)}\frac{c''(a)}{c'(a)} - \frac{\frac{\partial}{\partial a}\mathscr{I}(T|a)}{\mathscr{I}^2(T|a)} \geq 1. \tag{20}$$

Proof of Lemma A.2. Given a contract, the manager maximizes his value $u(\tilde{a}) := \mathbb{E}^{\tilde{a}}\left[\int_0^\infty e^{-(r+\Delta r)t} db_t\right] - c\left(\tilde{a}\right)$ such that incentive compatibility requires that, at $\tilde{a} = a$, both the manager's first-order condition $B = c'(a)/\mathscr{I}(T|a)$ as well as the second-order condition $B\left(\frac{\partial}{\partial a}\mathscr{I}(T|a) + \mathscr{I}^2(T|a)\right) - c''(a) \leq 0$ are satisfied. Rearranging yields condition (20). **Q.E.D.**

Proof of Proposition 2 For the sake of notational simplicity set $\hat{T}(a, T_{\min}) = T_{\min}$ for $T_{\min} \geq \bar{T}(a)$, where $\bar{T}(a)$ denotes the maximal optimal payout date absent deferral regulation (see Proof of Proposition 1). This is without loss of generality for the cases covered in the Proposition, i.e., for both $T_{\min}$ marginally larger than $\bar{T}(a^*)$ as well as for $T_{\min} \to \infty$. Then, note first that for all $T_{\min} > \bar{T}(a)$, we must have $a^*(T_{\min}) < \underline{\hat{a}}\left(T_{\min}\right)$ due to strict concavity of the shareholders' action choice problem in (5) together with the fact that $\Delta W_a(\underline{\hat{a}}\left(T_{\min}\right)|T_{\min}) = 0$ as shown in Lemma 3. Hence, $a^*(T_{\min})$ is determined from the first-order condition in (10). Then assuming uniqueness of $\hat{T}(a)$,[49] the implicit function theorem implies that for $T_{\min} = \hat{T}(a^*)$

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

where the last equality follows from the fact that, $\partial \Delta W\left(a|T_{\min}\right)/\partial T_{\min} = 0$, evaluated at the optimal action and timing choice $(a, T_{\min}) = \left(a^*, \hat{T}\left(a^*\right)\right)$. The result for marginal regulation then follows directly from (17).

It remains to show that $\lim_{T_{\min}\to\infty} a^*(T_{\min}) = 0$. To do so, note that

$$\frac{\partial W\left(a|T_{\min}\right)}{\partial a} = \left[\frac{1}{\mathscr{I}(T_{\min}|a)}\frac{c''\left(a\right)}{c'\left(a\right)} - \frac{\frac{\partial}{\partial a}\mathscr{I}(T_{\min}|a)}{\mathscr{I}^2(T_{\min}|a)}\right] e^{\Delta r T_{\min}} c'\left(a\right). \tag{21}$$

Lemma A.2 implies that the term in brackets is greater than unity, so that marginal costs

[49] If $\hat{T}(a)$ is not unique, the results continue to hold in the respective monotone comparative statics sense.

(and the marginal tax) as expressed in (21) go to infinity as $T_{\min} \to \infty$ for any $a > 0$. The result then follows from strict concavity of the unconstrained objective. **Q.E.D.**

Proof of Lemma 4. That all payments under the optimal contract are contingent on survival follows from Lemma A.1. The optimality of a contract with a single payout date, as characterized by (12), follows directly from the convexity condition (7) and Lemma 1 and Theorem B.1 in Hoffmann, Inderst, and Opp (Forthcoming). The essential steps are as follows.

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

$$W(a|0) := \min_{g_t, dg_t \geq 0} (U + c(a)) \int_0^\infty e^{\Delta r t} dg_t \quad \text{s.t.} \tag{22}$$

$$\int_0^\infty \mathscr{I}(t|a)\, dg_t = \frac{c'(a)}{U + c(a)}. \tag{23}$$

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, $\int_0^{\bar{T}} e^{\Delta r t} dg_t$. The optimal payout times can now be characterized using simple tools of convex analysis (see Hoffmann, Inderst, and Opp (Forthcoming) for graphical intuition). To do so, it is now useful to consider the curve $\left(\mathscr{I}(t|a), e^{\Delta r t}\right)$ parameterized by $t \in [0, \infty)$ and its convex hull tracing out the set of $\left(\int_0^\infty \mathscr{I}(t|a)\, dg_t, \int_0^\infty e^{\Delta r t} dg_t\right)$ achievable with any admissible weighting $(g_t)_{t=0}^\infty$. Since the objective in (22) is to *minimize* weighted average impatience costs, only the *lower hull* is relevant, which is given by $C(x|a) = e^{\Delta r \inf\{t: \mathscr{I}(t|a) \geq x\}} = e^{\Delta r \mathscr{I}^{-1}(x|a)}$, where we have used condition (7). 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 (23) requires a weighted-average informativeness of $\frac{c'(a)}{U+c(a)}$, minimum wage costs in (22) are, thus, given by $W = (U + c(a))\, C\left(\frac{c'(a)}{U+c(a)} | a\right)$. From the definition of $C(\cdot|a)$, the uniquely optimal payout time, thus, satisfies (12). **Q.E.D.**

Proof of Lemma 5. Denote the manager's utility from taking action a given an incentive compatible contract with single survival-contingent payout at date t by $u(a,t) := \frac{c'(a)}{\mathscr{I}(t|a)} - c(a)$, such that $T_{PC}(a)$ is implicitly defined by $u(a, T_{PC}(a)) = U$. Now note that strict monotonicity of $\mathscr{I}(t|a)$ implies that $\partial u(a,t)/\partial t < 0$, while

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

where the term in parentheses is positive from Lemma A.2. The result then follows as $T'_{PC}(a) = -\frac{\partial u(a,t)/\partial a}{\partial u(a,t)/\partial t} > 0$ and $\frac{dT_{PC}(a)}{dU} = \frac{1}{\partial u(a,t)/\partial t} < 0$. **Q.E.D.**

Proof of Proposition 3. That all payments under the optimal contract with deferral regulation (DEF) are still contingent on survival follows from the same arguments as in the proof of Lemma A.1. Here, we note again that an unconditional up-front payment w is equivalent to a survival-contingent date-0 bonus since $S(0|a) = 1$. So, consider the compensation design problem with binding (PC) in (22) and (23) 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 $T_{\min} > T_{PC}(a)$ that (23) can only be satisfied with a positive payment at $t = 0$, i.e., $w > 0$. 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 convex in informativeness by condition (7) together with $\frac{\partial}{\partial t}\mathscr{I}(t|a) > 0$. From (IC) we then directly obtain, with a slight abuse of notation, $B(a|T_{\min}) = \frac{c'(a)}{\mathscr{I}(T_{\min}|a)}$, such that the up-front wage follows from binding (PC). **Q.E.D.**

Proof of Lemma 6. In order to guide through the proof, consider the graphical illustration in Figure A.1. The regulatory tax $\Delta W(a|T_{\min})$ is zero if the shadow cost on the regulatory constraint (DEF) is zero. This is the case if either no deferred bonus is paid, which applies if and only if there is no incentive problem as $a = 0$, or if $T_{\min} \leq T_{PC}(a)$ which from Lemma 5 holds if and only if $a \geq \underline{a}(T_{\min})$. For all other cases, taking the difference between wage costs with and without the regulatory constraint as derived in Proposition 3 and Lemma 4 we obtain the regulatory tax $\Delta W(a)$ in (13), which for $0 < a < \underline{a}(T_{\min})$ is strictly positive by optimality of the unregulated optimal contract. It then follows by continuity that $\Delta W(a|T_{\min})$ is strictly increasing in a for a sufficiently close to zero and strictly decreasing for a sufficiently close to $\underline{a}(T_{\min})$. It remains to show that $\lim_{a\uparrow\underline{a}(T_{\min})} \Delta W'(a|T_{\min}) < 0$. Differentiating the expression in (13) and noting that $T_{PC}(a) \to T_{\min}$ as a approaches $\underline{a}(T_{\min})$ from below, we obtain

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

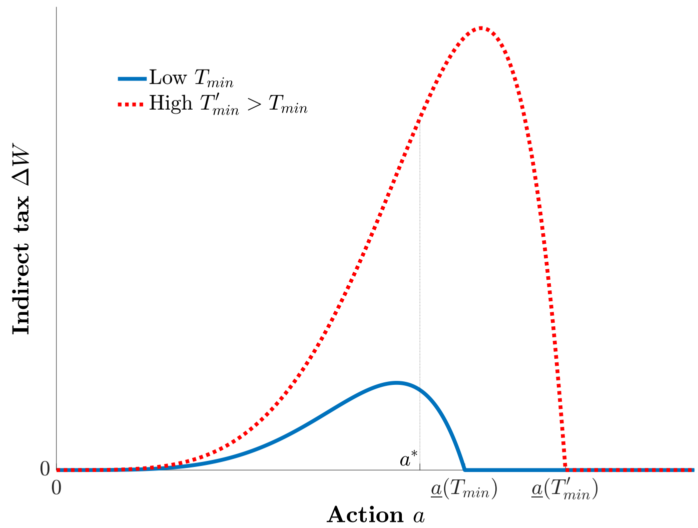

Figure A.1. Properties of the indirect tax function: The figure plots the regulatory tax, $\Delta W\left(a|T_{\min}\right) = W\left(a|T_{\min}\right) - W\left(a\right),$ as a function of a for two levels of $T_{\min} > T_{PC}\left(a^*\right)$, with an exponential arrival time distribution (corresponding to a gamma arrival time distribution as specified in Lemma 2 with $\beta = 1$). The chosen parameter values are $\Delta r = 1.5$, $U = 3$, $T_{\min} = 1$ and $T'_{\min} = 1.5$, with $c(a) = a^3/3$ and $h(a) = 5/a$.

Here we have used 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).[50] **Q.E.D.**

Proof of Proposition 4. We first show that (PC) binds for all $T_{\min}$ whenever U is sufficiently high. To see this, note that (PC) is slack for a given $T_{\min}$ if and only if $U \leq \overline{U}(T_{\min}) = \frac{c'(a^*(T_{\min}))}{\mathscr{I}(\hat{T}(a^*(T_{\min}))|a^*(T_{\min}))} - c\left(a^*(T_{\min})\right)$, where $\overline{U}(T_{\min})$ denotes the agent's rent under the optimal rent-extraction contract. Now, since $\overline{U}(T_{\min})$ is increasing in the implemented action but decreasing in the payout time (see Lemma 5), it is bounded above by $\overline{U}(T_{\min}) < \frac{c'(a^{FB})}{\mathscr{I}(\hat{T}(a^*(0))|a^{FB})} - c\left(a^{FB}\right)$.[51] Hence, a sufficient condition for (PC) to bind for all $T_{\min}$ is that $U \geq \frac{c'(a^{FB})}{\mathscr{I}(\hat{T}(a^*(0))|a^{FB})} - c\left(a^{FB}\right)$.

In order to derive the optimal action choice under deferral regulation with binding (PC) it is then convenient to recall from Lemma 6 that the regulatory tax $\Delta W(a)$ is zero for all $a \geq \underline{a}\left(T_{\min}\right)$. Further, from Lemma 4 we have $a^* = \underline{a}\left(T_{\min}\right)$ at the unregulated optimum $T_{\min} = T_{PC}(a^*)$. Hence, since $\underline{a}\left(T_{\min}\right)$ is increasing in $T_{\min}$ from Lemma 5, strict

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

[51] Here, we have used that under deferral regulation, the constrained optimal payout date is always weakly larger than the equilibrium payout date absent regulation $T^*(a^*)$ as well as the fact that the optimal action under the rent extraction contract is always bounded above by the first-best action solving $V'(a^{FB}) - c'(a^{FB}) = 0$ since $V' > \Pi'$ and $c' < W_a$.

concavity of the unconstrained objective function $\Pi(a) - W(a)$ implies that $a^*(T_{\min}) \leq \underline{a}(T_{\min})$. Concretely, 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 $\Pi'(a^*) - W'(a^*) = 0$. It then follows from the envelope theorem together with $\lim_{a \uparrow \underline{a}(T_{\min})} \frac{\partial}{\partial a} \Delta W(a|T_{\min}) < 0$ that $a^*(T_{\min}) = \underline{a}(T_{\min})$ for $T_{\min}$ sufficiently close to the unconstrained optimal payout date $T_{PC}(a^*)$. It immediately follows from the definition of $\underline{a}(T_{\min})$ that $\Delta W(a^*(T_{\min})|T_{\min}) = 0$, and from strict monotonicity of $\underline{a}(T_{\min})$ that $a^*(T_{\min}) > a^*$ in this region.

Now, as $T_{\min}$ increases further, strict concavity of the unconstrained objective function $\Pi(a) - W(a)$ eventually implies that $a^*(T_{\min}) < \underline{a}(T_{\min})$.[52] This is the case for all $T_{\min} > \tilde{T}$ where the latter solves

$$\Pi'(\underline{a}(T_{\min})) - W'(\underline{a}(T_{\min})) = \lim_{a \uparrow \underline{a}(T_{\min})} \Delta W_a(\underline{a}(T_{\min})|T_{\min}).^{53} \tag{24}$$

Then, for all $T_{\min} > \tilde{T}$ the optimal action choice is characterized by the first-order condition $\Pi'(a) - W'(a) - \frac{\partial}{\partial a}\Delta W(a|T_{\min}) = 0$. From $a^*(T_{\min}) < \underline{a}(T_{\min})$ which is equivalent to $T_{\min} > T_{PC}(a^*(T_{\min}))$ it immediately follows from Proposition 3 that $w > 0$ and $\Delta W(a^*(T_{\min}|T_{\min}) > 0$ for $T_{\min} > \tilde{T}$. It remains to show that $\lim_{T_{\min} \to \infty} a^*(T_{\min}) = 0$. For this it is sufficient to show that marginal compensation costs $\frac{\partial}{\partial a} W(a|T_{\min}) = W'(a) + \frac{\partial}{\partial a}\Delta W(a|T_{\min})$ go to infinity for all $a > 0$ as $T_{\min} \to \infty$. This follows from direct differentiation

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

and Lemma A.2 from which the term in brackets is greater than unity. **Q.E.D.**

Proof of Proposition 5. That $\operatorname{sgn}\left(\left.\frac{da^*(T_{\min})}{dT_{\min}}\right|_{T_{\min} = T^*(a^*)}\right) = \operatorname{sgn}\left(\left.\frac{dT^*(a)}{da}\right|_{a=a^*}\right)$ as well as $\lim_{T_{\min} \to \infty} a^*(T_{\min}) = 0$ follows directly from Propositions 2 and 4. Note next that, in the absence of regulation, the manager's net utility under the optimal rent-extraction

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

[53] For notational simplicity we will assume for the remainder of this paper 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 (24), statement (1) in the Proposition continues to hold replacing $\tilde{T}$ by $\tilde{T}_{\min} = \min\left\{\tilde{T}\right\} > T_{PC}(a^*)$, while statement (2) applies replacing $\tilde{T}$ by $\tilde{T}_{\max} = \max\left\{\tilde{T}\right\}$.

contract is given by $\hat{U} := u(\hat{a}, \hat{T}(\hat{a})) = \frac{c'(\hat{a})}{\mathscr{I}(\hat{T}(\hat{a})|\hat{a})} - c(\hat{a})$, such that (PC) is slack if and only if $U \leq \hat{U}$. As incentive compatibility and limited liability imply that the manager's net utility under the optimal rent extraction contract is positive for all $T_{\min}$, statements (1) and (3) follow. As for statement (2), it follows from $u_a(a,t) > 0$ and $u_t(a,t) < 0$ (see proof of Lemma 5) together with $\lim_{T_{\min}\to\infty} \hat{a}(T_{\min}) = 0$ (see Proposition 2) that (PC) must bind for $T_{\min}$ sufficiently high. **Q.E.D.**

Proof of Proposition 6. First, consider the case where $U < \hat{U}$ such that from Proposition 5 (PC) is slack for $T_{\min} = 0$. We will now show that a marginal increase in the deferral period $T_{\min}$ strictly increases welfare. To do so, consider the regulator's problem of choosing $T_{\min}$ to maximize (14) which can be conveniently rewritten as

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

where u is the manager's derived utility as defined in Lemma 5. Then, we obtain

$$\begin{aligned}\left.\frac{d\Omega(T_{\min})}{dT_{\min}}\right|_{T_{\min}=\hat{T}(a^*)} = {} & \left(1 - k_{\min}\right)\left(r\int_0^\infty e^{-rt} \left.\frac{\partial S\left(t|a\right)}{\partial a}\right|_{a=a^*} dt\right) \left.\frac{\partial a^*\left(T_{\min}\right)}{\partial T_{\min}}\right|_{T_{\min}=\hat{T}(a^*)} \\ & + \kappa_A \left.\frac{du(a^*(T_{\min}), T_{\min})}{dT_{\min}}\right|_{T_{\min}=\hat{T}(a^*)}\end{aligned} \tag{25}$$

where we have used the envelope theorem which implies that

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

The result then follows since the first term on the right-hand side in (25) 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 $\left.\frac{\partial}{\partial a}\frac{\partial \log \mathscr{I}(t|a)}{\partial t}\right|_{(t,a)=\left(\hat{T}(a^*),a^*\right)} > 0$, while the second term is from $\kappa_A < \bar{\kappa}_A$ (where $\bar{\kappa}_A$ might be infinite) bounded below by $\min\left\{0, \bar{\kappa}_A \left.\frac{du(a^*(T_{\min}),T_{\min})}{dT_{\min}}\right|_{T_{\min}=\hat{T}(a^*)}\right\}$.

When (PC) is binding at $T_{\min} = 0$ since $U \geq \hat{U}$, welfare can be conveniently rewritten as in (15). Then, note that $\Delta W\left(a^*\left(T_{\min}\right)|T_{\min}\right) = 0$ for $T_{\min} \in [T_{PC}\left(a^*\right), \tilde{T}]$ (see Proposition 4) and $V'(a) > \Pi'(a)$ (see (4)). Hence, comparing the bank's and the regulator's objectives in (5) and (15) 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 Proposition 4), must be welfare increasing by strict (quasi)concavity of the regulator's objective. **Q.E.D.**

Proof of Lemma 7. Second-best welfare cannot be attained if $U < \overline{U}^{SB}$, since binding deferral regulation and a slack participation constraint (at the relevant second-best action) imply welfare losses due to contracting distortions.

So assume that $U \geq \overline{U}^{SB}$. It remains to show that second-best welfare can be attained if and only if $T_{PC}\left(a^{SB}\right) \leq \tilde{T}$. To show sufficiency, assume the regulator imposes a minimum deferral period of $T^*_{\min} = T_{PC}\left(a^{SB}\right) \leq \tilde{T}$. Then, from Proposition 4 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 3), which from $U \geq \overline{U}^{SB}$ is also the unconstrained optimal contract, i.e., $\Delta W(a^*(T_{\min})|T_{\min}) = 0$ (see also Corollary 1). Thus, welfare is maximized. Else, i.e., if $T_{PC}\left(a^{SB}\right) > \tilde{T}$, bank shareholders will optimally implement $a^*\left(T_{PC}\left(a^{SB}\right)\right) < a^{SB} = \underline{a}\left(T_{PC}\left(a^{SB}\right)\right)$ when faced with a minimum deferral requirement of $T_{\min} = T_{PC}\left(a^{SB}\right)$, which implies a contracting inefficiency $\Delta W(a^*(T_{\min})|T_{\min}) > 0$ (see Corollary 1). Necessity then follows from the fact that second-best welfare can only be achieved when a contract with a single bonus at $T_{PC}(a^{SB})$ implements a^{SB}. **Q.E.D.**

Proof of Proposition 7. We need to show that $T_{PC}\left(a^{SB}\right) \leq \tilde{T}(k_{\min})$ if and only if $k \geq \bar{k}$. Since $U \geq \overline{U}^{SB}$, the result then follows from Lemma 7. So, note first that $\tilde{T}(k_{\min})$ is increasing in $k_{\min}$ which directly follows from (24) 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 the shareholders' unconstrained objective function. It is then sufficient to show that $T_{PC}\left(a^{SB}\right) \leq \tilde{T}(k_{\min})$ is satisfied for $k_{\min} = 1$, which holds trivially, since in this case $a^{SB} = a^*$ such that $T_{PC}\left(a^{SB}\right) = T_{PC}(a^*) < \tilde{T}(k_{\min})$ where the inequality follows from the arguments in the proof of Proposition 4. Existence of a $\bar{k} < 1$ then follows by continuity. Concretely, $\bar{k}$ is interior if $T_{PC}\left(a^{SB}\right) > \tilde{T}(0)$, else we set $\bar{k} = 0$. **Q.E.D.**

Proof of Proposition 8. 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 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 5 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 then is $u(a, T_{\min})$. By definition of $\underline{a}(T_{\min})$, it further holds that $u(\underline{a}(T_{\min}), T_{\min}) = U$, and $u_a(a,t) < 0$, hence, implies that $u(a, T_{\min}) < U$ for all $a < \underline{a}(T_{\min})$ violating (PC).

So, when setting $T_{\min} = T_{PC}\left(a^{SB}\right)$, the regulator imposes a minimum action constraint of $a^*(T_{\min}) \geq \underline{a}\,(T_{\min}) = a^{SB}$. Now, since $a^* < a^{SB}$, it then 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 7 this outcome can be achieved without a clawback clause if and only if $T_{PC}(a^{SB}) \leq \tilde{T}$, which from Proposition 7 is equivalent to $k < \bar{k}$. **Q.E.D.**

Appendix B Compensation regulation in practice

The recent financial crisis triggered regulatory initiatives around the world aiming to align compensation in the financial sector with prudent risk-taking. On a supra-national level the Financial Services Forum (FSF)—which later became the Financial Stability Board (FSB)—adopted the Principles for Sound Compensation Practices and their Implementation Standards in 2009. While these do not prescribe particular designs or levels of individual compensation they do, inter alia, set out detailed proposals on compensation structure, including deferral, vesting and clawback arrangements. In this Appendix we summarize the current state of regulation regarding deferral and clawback/malus in different FSB member jurisdictions.[54]

In the United States Dodd Frank Act §956 prohibits *"any types of incentive-based payment (...) that (...) encourages inappropriate risks by covered financial institutions - by providing an executive officer, employee, director, or principal shareholder of the covered financial institution with excessive compensation, fees, or benefits; or that could lead to material financial loss to the covered financial institution."* The joint implementation proposal by the six involved federal agencies[55] includes the following deferral requirements for incentive compensation paid by covered financial institutions with more than $250 billion in total average consolidated assets: Mandatory deferral of 60% of incentive compensation for senior executive officers (50% for significant risk takers) for at least 4 years from the last day of the performance period for short-term arrangements (2 years for long-term arrangements with minimum 3 year performance period). Clawback requirements extend to a minimum of 7 years from the end of vesting based on Dodd Frank §954.[56]

Similar rules are already in place in the EU based on Directive 2010/76/EU, amending the Capital Requirements Directives (CRDs), which took effect in January 2011, even though implementation varies on country-level. These include mandatory deferral of bonuses for 3-5 years, which are further subject to clawback[57] for up to 7 years. Ad-

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

[55] 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).

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

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

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

More broadly, all FSB member jurisdictions have issued some form of deferral requirements which usually apply to MRTs in the banking sector, including senior executives as well as other employees whose actions have a material impact on the risk exposure of the firm.[58] Regulatory requirements for deferral periods for material risk takers vary significantly across jurisdictions, ranging from a minimum of around 3 years (Argentina, Brazil, China, Hong Kong, India, Indonesia, Japan, Korea, Russia, Singapore, Switzerland, Turkey) up to 5 years or more for selected MRTs (US, UK, European Single Supervisory Mechanism - SSM - jurisdictions), with the maximum of 7 years applying to the most senior managers in the UK. Equally, the proportion of variable compensation that has to be deferred is highly country specific ranging from 25-60% in Canada, 40% in Argentina, Australia, Brazil and Hong Kong, 33-54% in Singapore, to more than 40% in China and Turkey, 40-55% in India, 40%-60% in SSM jurisdictions, the UK and the US, to 50-70% in Korea, and 70%-75% in Switzerland.[59] Further, some countries impose regulatory restrictions on the proportion of fixed remuneration as a percentage of total remuneration (as the EU "bonus cap") ranging from 30% in Switzerland, 35% in Australia, China, 22-56% in Singapore, 54% in the UK, 58% in Hong Kong and SSM jurisdictions, to about 60% in India. Such requirements are not set out in Argentina, Brazil, Canada, Indonesia, Russia, South Africa and the US. Finally, in all FSB member jurisdictions there are regulatory requirements for the use of ex post compensation adjustment tools such as clawback and malus clauses. However, in a number of jurisdictions the application of these ex post tools, in particular clawbacks, is subject to legal impediments and enforcement issues such that applications are still rare.

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

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

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

References

Admati, A. R., P. M. DeMarzo, M. F. Hellwig, and P. C. Pfleiderer (2011): "Fallacies, irrelevant facts, and myths in the discussion of capital regulation: Why bank equity is not expensive," Working paper series, Stanford University.

Albuquerque, R. A., L. M. B. Cabral, and J. F. Correia Guedes (2016): "Incentive Pay and Systemic Risk," Working Paper 490/2016, European Corporate Governance Institute.

Arnold, M. (2014): "Bonus clawback rules unenforceable, say bankers," *Financial Times*.

Atkeson, A. G., A. d'Avernas, A. L. Eisfeldt, and P.-O. Weill (2018): "Government Guarantees and the Valuation of American Banks," Working Paper 24706, National Bureau of Economic Research.

Axelson, U., and P. Bond (2015): "Wall Street Occupations," *The Journal of Finance*, 70(5), 1949–1996.

Bebchuk, L. A., and J. M. Fried (2010): "Paying for Long-Term Performance," *University of Pennsylvania Law Review*, 158, 1915–1960.

Bénabou, R., and J. Tirole (2016): "Bonus Culture: Competitive Pay, Screening, and Multitasking," *Journal of Political Economy*, 124(2), 305–370.

Benmelech, E., E. Kandel, and P. Veronesi (2010): "Stock-Based Compensation and CEO (Dis)Incentives," *The Quarterly Journal of Economics*, 125(4), 1769–1820.

Biais, B., T. Mariotti, J.-C. Rochet, and S. Villeneuve (2010): "Large Risks, Limited Liability, and Dynamic Moral Hazard," *Econometrica*, 78(1), 73–118.

Binham, C. (2015): "Reckless bankers face having to pay back salary," *Financial Times*.

Bolton, P., H. Mehran, and J. Shapiro (2015): "Executive Compensation and Risk Taking," *Review of Finance*, 19(6), 2139–2181.

Bond, P., and A. Gomes (2009): "Multitask principal-agent problems: Optimal contracts, fragility, and effort misallocation," *Journal of Economic Theory*, 144(1), 175–211.

Colonnello, S., M. Koetter, and K. Wagner (2018): "Effectiveness and (in)efficiencies of compensation regulation: Evidence from the EU banker bonus cap," Working Paper 7/2018, Halle Institute for Economic Research (IWH).

Dávila, E., and B. Hébert (2018): "Optimal Corporate Taxation Under Financial Frictions," Discussion paper, Stanford University.

DeMarzo, P., and D. Duffie (1999): "A Liquidity-based Model of Security Design," *Econometrica*, 67(1), 65–99.

DeMarzo, P. M., and Y. Sannikov (2006): "Optimal Security Design and Dynamic Capital Structure in a Continuous-Time Agency Model," *Journal of Finance*, 61(6), 2681–2724.

Dewatripont, M., J. Tirole, et al. (1994): *The prudential regulation of banks*, vol. 1. MIT Press.

Duffie, D. (2018): "Prone to Fail: The Pre-Crisis Financial System," Working paper, Stanford GSB.

Edmans, A., and Q. Liu (2010): "Inside Debt," *Review of Finance*, 15(1), 75–102.

Eufinger, C., and A. Gill (2017): "Incentive-Based Capital Requirements," *Management Science*, 63(12), 4101–4113.

Grossman, S. J., and O. D. Hart (1983): "An Analysis of the Principal-Agent Problem," *Econometrica*, 51(1), 7–45.

Harris, M., C. Opp, and M. M. Opp (2020): "The aggregate demand for bank capital," Unpublished working paper, University of Chicago, University of Rochester, and Stockholm School of Economics.

Hartman-Glaser, B., T. Piskorski, and A. Tchistyi (2012): "Optimal securitization with moral hazard," *Journal of Financial Economics*, 104(1), 186 – 202.

Hellmann, T. F., K. C. Murdock, and J. E. Stiglitz (2000): "Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough?," *American Economic Review*, 90(1), 147–165.

Hermalin, B. E., and M. L. Katz (1991): "Moral Hazard and Verifiability: The Effects of Renegotiation in Agency," *Econometrica*, 59(6), 1735–1753.

Hoffmann, F., R. Inderst, and M. M. Opp (Forthcoming): “Only time will tell - A theory of Deferred Compensation,” *Review of Economic Studies.*

Holmstrom, B. (1979): “Moral Hazard and Observability,” *Bell Journal of Economics*, 10(1), 74–91.

Innes, R. D. (1990): “Limited liability and incentive contracting with ex-ante action choices,” *Journal of Economic Theory*, 52(1), 45–67.

Jewitt, I., O. Kadan, and J. M. Swinkels (2008): “Moral hazard with bounded payments,” *Journal of Economic Theory*, 143(1), 59 – 82.

John, T. A., and K. John (1993): “Top-Management Compensation and Capital Structure,” *The Journal of Finance*, 48(3), 949–974.

Kuhnen, C. M., and J. Zwiebel (2009): “Executive pay, hidden compensation and managerial entrenchment,” Unpublished working paper, Princeton University.

Malamud, S., H. Rui, and A. Whinston (2013): “Optimal incentives and securitization of defaultable assets,” *Journal of Financial Economics*, 107(1), 111 – 135.

Matutes, C., and X. Vives (2000): “Imperfect competition, risk taking, and regulation in banking,” *European Economic Review*, 44(1), 1–34.

Murphy, K. J., and M. C. Jensen (2018): “The Politics of Pay: The Unintended Consequences of Regulating Executive Compensation,” *Journal of Law, Finance, and Accounting*, 3(2), 189–242.

Opp, M. M., and J. Y. Zhu (2015): “Impatience versus Incentives,” *Econometrica*, 83(4), 1601–1617.

Plantin, G., and J. Tirole (2018): “Marking to Market versus Taking to Market,” *American Economic Review*, 108(8), 2246–76.

Repullo, R., and J. Suarez (2004): “Loan pricing under Basel capital requirements,” *Journal of Financial Intermediation*, 13(4), 496–521.

——— (2013): “The procyclical effects of bank capital regulation,” *Review of Financial Studies*, 26(2), 452–490.

Rogerson, W. P. (1985): “The First-Order Approach to Principal-Agent Problems,” *Econometrica*, 53(6), 1357–67.

Shavell, S. (1979): "Risk Sharing and Incentives in the Principal and Agent Relationship," *The Bell Journal of Economics*, 10(1), 55–73.

Thanassoulis, J. (2012): "The Case for Intervening in Bankers Pay," *The Journal of Finance*, 67(3), 849–895.