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Gaming and strategic opacity in incentive provision

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We study the benefits and costs of "opacity" (deliberate lack of transparency) of incentive schemes as a strategy to combat gaming by better informed agents. In a two-task moral hazard model in which only the agent knows which task is less costly, the agent has an incentive to focus his effort on the less costly task. Opaque schemes, which make a risk-averse agent uncertain about which task will be more highly rewarded, mitigate such gaming but impose more risk. We identify environments in which opaque schemes not only dominate transparent ones, but also eliminate the costs of the agent's hidden information.

1. Introduction

■ A fundamental consideration in designing incentive schemes is the possibility of *gaming*: exploitation of an incentive scheme by an agent for his own self-interest to the detriment of the objectives of the incentive designer. Gaming can take numerous forms, among them (i) diversion of effort away from activities which are socially valuable but difficult to measure and reward, toward activities that are easily measured and rewarded; (ii) exploitation of the rules of classification to improve apparent, though not actual, performance; and (iii) distortion of choices

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about timing to exploit temporarily high monetary rewards even when socially efficient choices have not changed. Evidence of the first type of gaming is provided by Burgess, Propper, Ratto, and Tominey (2017) and Carrell and West (2010), of the second type by Gravelle, Sutton, and Ma (2010), and of the third type by Oyer (1998), Larkin (2014), and Forbes, Lederman, and Tombe (2015).[1] The costs of gaming are exacerbated when the agent has superior knowledge of the environment: this makes the form and extent of gaming harder to predict and hence, harder to deter.

It has been suggested that lack of transparency—deliberate opacity about the criteria upon which rewards will be based and/or how heavily these criteria will be weighted—can help deter gaming. This idea has a long intellectual history. It dates back at least to Bentham (1830) who argued that deliberate opacity about the content of civil service selection tests would lead to the "maximization of the inducement afforded to exertion on the part of learners, by impossibilizing the knowledge as to what part the field of exercise the trial will be applied to, and thence making aptitude of equal necessity in relation to every part."[2]

More recently, responding to documented gaming of the highly transparent incentive schemes which score National Health Service organizations in England according to published lists of precisely defined performance indicators, Bevan and Hood (2004) argued in the *British Medical Journal*, "What is needed are ways of limiting gaming. And one way of doing so is to introduce more randomness in the assessment of performance, at the expense of transparency." They invoke the "analogy [. . .] with the use of unseen examinations, where the unpredictability of what the questions will be means that it is safest for students to cover the syllabus." They reason that making it harder for hospitals to predict what performance measures will be used and how they will be weighted, coupled with hospitals' risk aversion, will reduce the hospitals' incentives for gaming. Similarly, Dranove, Kessler, McClellan, and Satterthwaite (2003) document that in the United States, report cards for hospitals "encourage providers to 'game' the system by avoiding sick patients or seeking healthy patients or both" and they argue that such gaming is facilitated by "risk-averse providers having better information about patients' conditions" than do the analysts who compile the report cards. They present evidence that the increased transparency of incentive schemes for physicians and hospitals provided by report cards increased gaming and even decreased patient and social welfare.[3]

The costs of transparency have also been discussed in the context of gaming, by law school deans, of the performance indicators used by *U.S. News* to produce its influential law school rankings. The ranking methodology is transparent and employs a *linear* scoring rule incorporating multiple performance indicators.[4] There is significant evidence that law schools deploy a range of strategies that exploit their informational advantage over *U.S. News* to increase their measured performance. Examples include cutting the number of full-time students to boost median LSAT scores and GPAs, creating make-work jobs for their own graduates to inflate the number in

[1] Burgess et al. (2017) and Gravelle, Sutton, and Ma (2010) study United Kingdom public sector organizations (an employment agency and the National Health Service, respectively), Carrell and West (2010) use data from post-secondary education, whereas Oyer (1998), Larkin (2014), and Forbes, Lederman, and Tombe (2015) examine private sector organizations (salespeople and executives across various industries, enterprise software vendors, and airlines, respectively).

[2] Bentham, 1830/2005, Ch. IX, §16, Art 60.1.

[3] Relatedly, Google has experienced manipulation of its search results by some retailers. Although many retailers have been seeking greater transparency from Google about its search algorithm, Google has responded by moving in the direction of greater opacity to prevent manipulation (Structural Search Engine Optimization, Google Penalty Solutions, November 4, 2011, www.re1y.com/blog/occupy-google-blog.html). Motivated in part by this debate, Frankel and Kartik (2014) develop a signalling model of gaming in which the information conveyed by signals (e.g., prominence in search results) about agents' hidden characteristics (e.g., intrinsic relevance to the query) is "muddled" because agents are also privately informed about their gaming ability. Other theoretical treatments of gaming of incentive schemes include Jehiel and Newman (2011) and Barron, Georgiadis, and Swinkels (2017).

[4] The weights in the scoring rule are quality perception (40%), selectivity (25%), placement success (20%), and faculty resources (15%) (*U.S. News*, March 11, 2013, www.usnews.com/education/best-graduate-schools/top-law-schools/articles/2013/03/11/methodology-best-law-schools-rankings).

employment, and heavily advertising their faculty's scholarship to *U.S. News*.[5] Law scholars (e.g., Osler, 2010) have argued that greater opacity in the ranking methodology could mitigate gaming, and *U.S. News* has itself signalled its intention to move away from being "totally transparent about key methodology details."[6]

Finally, one view as to why courts often prefer standards—which are somewhat vague—to specific rules is that standards mitigate incentives for gaming. For example, Weisbach (2000) argues that vagueness can reduce gaming of taxation rules, and Scott and Triantis (2006) argue that vague standards in contracts can improve parties' incentives to fulfill the spirit of the contract rather than focusing on satisfying only the narrowly defined stipulations.

The examples discussed above suggest that "opacity" (i.e., lack of transparency) of incentive schemes can be beneficial in reducing gaming, especially when agents have superior knowledge of the environment, when incentive designers care about multiple aspects of performance, and when gaming takes the form of agents' focusing efforts on easily manipulable indicators. This line of argument is, however, incomplete. If agents are risk-averse, then the additional risk imposed by opaque schemes is per se unattractive to them. Understanding when and why opaque schemes are used thus requires analyzing the trade-off between their incentive benefits and their risk costs. The present article provides such an analysis.

Our analysis incorporates three vital ingredients that are featured in all of our motivating examples: (i) the agent's superior information about the environment, (ii) the agent's risk aversion, and (iii) the incentive designer's need for the agent to choose a relatively balanced allocation of efforts across activities. This suite of ingredients (along with a contractual restriction to incentive schemes that are *ex post* linear) delivers two main messages. First, transparent incentive schemes, even when they involve menus, suffer dramatically from the problem of gaming by the agent. Second, opaque incentive schemes not only mitigate the problem of gaming but can generate a higher payoff for the principal.[7]

In our model, "opacity" corresponds to a lack of transparency about the weights on performance indicators that are used to determine rewards. Motivated by the examples discussed above, we build on Holmstrom and Milgrom's (1991) multitask principal-agent model in which a risk-averse agent performs two tasks, which are substitutes in his cost-of-effort function, and receives compensation that is linear in his performance on each of the tasks. These linear contracts (which have been widely studied) are "transparent" in that the agent faces no uncertainty about the rate at which performance on each of the tasks is rewarded. The principal's benefit function is complementary in the agent's efforts on the two tasks; other things equal, she prefers to induce both types of agent to choose balanced efforts.[8] Into this familiar setup, we introduce superior knowledge of the environment on the part of the agent. There are two types of agent, and only the agent knows which type he is. One type has a lower cost of effort on task 1, and the other has a lower cost of effort on task 2.[9]

The privately informed agent games transparent incentive schemes by choosing effort allocations that are excessively (from an efficiency perspective) sensitive to his private information.

[5] Law School Rankings Reviewed to Deter "Gaming," *Wall Street Journal,* August 26, 2008.

[6] *U.S. News*, May 20, 2010, www.usnews.com/education/blogs/college-rankings-blog/2010/05/20/us-news-takes-steps-to-stop-law-schools-from-manipulating-the-rankings.

[7] The terms "opaque" and "transparent" may have alternative definitions in other contexts, but here, where we confine attention to compensation schedules that are *ex post* linear, an "opaque" incentive scheme will always be one that leaves the agent, when choosing efforts, uncertain about the incentive coefficients he will face, whereas a "transparent" scheme will be one under which the agent faces no such uncertainty.

[8] Our model, like Holmstrom and Milgrom's (1991), incorporates shocks to measured performance. These shocks are not essential for our two main messages, given our focus on contracts that are *ex post* linear. In fact, as shown in Section 6, our findings about the benefits of opaque incentive schemes would be even stronger in the absence of such shocks. Nonetheless, it is natural to include them in the analysis; if the agent's efforts were directly observable by the principal, then the problem of moral hazard could be trivially solved by a so-called "forcing contract."

[9] The analysis would be very similar if the agent types differed with respect to the task on which they were more productive.

In fact, we show that the agent's superior knowledge of his preferences makes it impossible for the principal, with transparent linear schemes, to induce both types of agent to exert positive efforts on both tasks, even when menus of contracts are used as screening devices. This is the sense in which transparent incentive schemes in our model suffer dramatically from the problem of gaming. One approach to mitigating gaming would be for the principal to design general (menus of) nonlinear compensation schedules. However, such schedules can be very complex to describe and difficult for agents to understand. Moreover, optimizing over general nonlinear contracts is difficult, especially when agents have hidden information.

Our approach is instead to explore a class of incentive schemes that is both simple and opaque. This class is simple in that, *ex post*, compensation is determined by one of two possible linear functions of performance measures, differing with respect to which performance measure is more highly rewarded. It is opaque in that, at the time the agent chooses his efforts, he does not know which of these two linear reward functions will be used. In the main body of the article, we focus on one such simple, opaque scheme, which we term *ex ante randomization*. Under *ex ante* randomization, the principal, before the agent makes his effort choices, commits to randomizing uniformly between the two linear compensation schedules. *Ex ante* randomization encourages the risk-averse agent to choose relatively balanced efforts on the tasks in order to partially insure himself against the wage risk generated by the random choice of compensation schedule. The more unequal the weights on the performance measures in the two possible compensation schedules, the stronger the agent's incentive to self-insure and the more balanced his optimal efforts will be.[10]

The benefits of opaque incentive schemes in deterring gaming do, nevertheless, come at a cost: such schemes impose more risk on the agent. Given any incentive scheme involving *ex ante* randomization, there exists a transparent contract that induces the same level of *aggregate* effort on the two tasks and imposes lower overall risk costs. Highlighting the importance of our three key model ingredients, we prove that any opaque contract will be dominated by some transparent contract if (i) the agent has no private information about his preferences, or (ii) the agent's risk aversion is too weak for the opaque contract to induce him to choose positive efforts on both tasks, or (iii) the agents' efforts on the two tasks are not sufficiently complementary for the principal to make balanced efforts socially efficient. In other words, in these situations, the principal is willing to tolerate gaming because the gains from mitigating it with opaque contracts are outweighed by the higher wages that such contracts would require the principal to pay.

Most importantly, we also identify three environments in which our simple opaque incentive schemes, with the relative weights on the performance measures chosen optimally, strictly dominate all transparent incentive schemes. In the first such setting, the agent has private information about his preferences but the magnitude of his preference across tasks is small. The second is the case where the agent's risk aversion is large and the variance of the shocks to measured performance is small. In the final setting, diversification of the risk from the shocks is unimportant, because either their correlation is large or their variance is small. In each of these settings, the strict superiority of *ex ante* randomization over the best transparent scheme follows in the limit from the result that *ex ante* randomization allows the principal to achieve a payoff arbitrarily close to what she could achieve in the absence of the agent's hidden information.

Though the results just described focus on limiting environments to prove analytically the strict dominance of optimally weighted *ex ante* randomization over all transparent menus, we also present more general findings about what features of the environment increase the relative

[10] In Section 7, we briefly discuss two other simple, opaque schemes, *interim randomization* and *ex post discretion*, which differ from *ex ante* randomization in the assumptions on the principal's powers of commitment. *Ex post* discretion is analyzed in detail in an earlier version of our article (Ederer, Holden, and Meyer, 2014). All three such opaque schemes work in very similar ways. In particular, by making the risk-averse agent uncertain *ex ante* about the values of the incentive coefficients in the linear payment rule, they all provide an incentive for balancing efforts. Our findings, from the analysis of *ex ante* randomization, about the pros and cons of opacity are thus robust to alternative assumptions on the principal's commitment powers.

attractiveness of opaque schemes. We prove that as the agent becomes more risk-averse, holding the importance of risk aversion under transparent schemes fixed, the relative attractiveness of *ex ante* randomization increases, because the more balanced efforts chosen by the more risk-averse agent not only benefit the principal directly but also lower overall risk costs. Furthermore, we show numerically that *ex ante* randomization is more likely to dominate the best transparent scheme when (i) the agent's privately known preference between tasks is weaker, so the uncertainty about the weights in the compensation schedule induces a more balanced effort profile, (ii) the agent is more risk-averse, so opacity generates a stronger self-insurance motive for effort balance, (iii) efforts on the tasks are more complementary for the principal, so she values more highly the effort-balancing effects of opacity, or (iv) the errors in measuring performance on the tasks have higher correlation or lower variance, so there is less of a diversification cost to designing opaque schemes to induce highly balanced efforts.

□ **Related literature.** Our article builds on the theoretical analyses of Holmstrom and Milgrom (1987, 1991). The first of these provides conditions in a dynamic moral hazard setting under which a linear contract is optimal. A key message of Holmstrom and Milgrom (1987) is that linear contracts are appealing because they are robust to limitations on the principal's knowledge of the contracting environment. Discussing Mirrlees's (1974) result that the first-best outcome in a hidden-action model can be approximated by a step-function (hence, highly nonlinear) incentive scheme, they argue "to construct the [Mirrlees] scheme, the principal requires very precise knowledge about the agent's preferences and beliefs, and about the technology he controls. The two-wage scheme performs ideally if the model's assumptions are precisely met, but can be made to perform quite poorly if small deviations in the assumptions [. . .] are introduced."[11] Motivated not only by these robustness arguments, but also by the simplicity and pervasiveness of linear contracts, we focus our analysis on compensation schedules in which, *ex post*, after all choices are made and random variables are realized, payments are linear functions of the performance measures.

Analyses of multitask principal-agent models (e.g., Holmstrom and Milgrom, 1991; Baker, 1992) have highlighted the inefficiencies resulting under linear contracts from an agent's ability to privately choose how to allocate his efforts across different activities. When efforts on different tasks are technological substitutes for the agent, an increase in incentives on one task will typically induce the agent not only to raise effort on that task but also to lower efforts on others, an effect termed the "effort-substitution problem." One consequence of the effort-substitution problem that is often emphasized is that to induce an agent to exert effort on tasks that are difficult to measure, it may be necessary for contracts to offer low-powered incentives on all tasks, even those that are easy to measure. The effort-substitution problem is present in our model, and we show that with transparent linear incentive schemes, the inefficiencies it generates are dramatically exacerbated when the agent is better informed than the principal about his cost function. Nevertheless, our focus is not on the implications of the effort-substitution problem for the optimal overall strength of incentives. Rather, we focus on how opaque incentive schemes can mitigate the costs of the effort-substitution problem by making the relative rewards for different tasks random. Also, our analysis of opaque incentive schemes focuses primarily on the optimal degree of uncertainty about relative rewards rather than on the optimal overall strength of incentives.

Like us, MacDonald and Marx (2001) analyze a principal-agent model with two tasks, where the agent's efforts on the tasks are substitutes for the agent but complements for the principal, and where the agent is privately informed about his preferences. Because they restrict task outcomes to be binary, it is possible to solve for the optimal contract, and they show that the more complementary the tasks are for the principal, the more the optimal reward scheme makes

[11] Carroll (2015) also demonstrates an appealing robustness property of linear contracts. In a static model with limited liability, when the principal knows some but not all of the actions available to the agent and evaluates contracts according to their worst-case performance, a linear contract is optimal.

successes on the tasks complementary for the agent. They do not consider *ex ante* randomization, and in fact, under their specific assumptions, it would have no power to mitigate gaming.[12] In our model, with a more general production technology, optimal nonlinear, nonseparable contracts are prohibitively difficult to characterize, but at the same time, *ex ante* randomization over two linear schedules proves to be both a simple and a powerful tool for mitigating the excessive sensitivity of agents' effort allocations to their private information.

Randomization has, of course, been studied before in incentive provision. In general single-task hidden-action models allowing arbitrarily complex contracts, Gjesdal (1982) and Grossman and Hart (1983) show that exogenous randomization may be optimal, but only if the agent's risk tolerance varies with the level of effort he exerts. In our model, the agent's risk tolerance is independent of his effort level; the attractiveness of opaque incentives stems from their ability to mitigate the agency costs of *multitask* incentive problems when compensation schedules are constrained to be *ex post* linear.

The potential benefits of exogenous randomization have also been explored in hidden-information models, especially those studying the design of optimal tax schedules. Stiglitz (1982) and Pestieau, Possen, and Slutsky (1998), among others, have shown that randomization can facilitate the screening of privately informed individuals and is especially effective when private information is multidimensional. In our hidden-action cum hidden-information setting, in contrast, *ex ante* randomization in fact eliminates the need for screening.

The costs and benefits of transparency in incentive design are also explored in Jehiel (2015) and Lazear (2006). Jehiel (2015) shows in an abstract moral hazard setup that a principal may gain by keeping agents uninformed about some aspects of the environment (e.g., how important specific tasks are). The benefits of suppressing information in relaxing incentive constraints can outweigh the costs of agents' less efficient adaptation of actions to the environment. Lazear (2006), in a model in which agents have no hidden information, explores high-stakes testing in education and the deterrence of speeding and terrorism, identifying conditions under which a lack of transparency can have beneficial incentive effects. In Lazear's analysis of testing, there is an exogenous restriction on the number of topics that can be tested, whereas in our model, even when all tasks can be measured and rewarded, we show that deliberate opacity about the weights in the incentive scheme can be desirable.[13]

The remainder of the article proceeds as follows. Section 2 outlines our model. Section 3 studies transparent incentive schemes, and Section 4 analyzes opaque schemes. Section 5 identifies settings in which opaque schemes are dominated by transparent ones. Section 6 identifies environments in which optimally weighted opaque schemes dominate the best transparent one. Sections 7 and 8 contain extensions and concluding remarks. Proofs not provided in the text are in Appendix A. Appendix B contains further extensions of the baseline model.

2. The model

■ A principal (she) hires an agent (he) to perform a job for her. The agent's performance on the job has two distinct dimensions, which we term "tasks." Measured performance, x_j, on each

[12] In their model, *ex ante* randomization over which task to reward more highly would not generate a self-insurance motive for balancing efforts, even for a risk-averse agent. The reason is that, because effort affects the probability of good performance rather than the level of good performance, the marginal benefit to the agent of effort on a task would not be weighted by the agent's marginal utilities in the two events corresponding to the two possible compensation schedules. In our model, in contrast, the marginal benefit of effort on a task is weighted by the agent's marginal utilities. The difference in these marginal utilities is the source of the self-insurance motive for effort balance under *ex ante* randomization.

[13] The costs and benefits of transparency are also a focus of interest in international relations. Wikipedia defines the policy of "strategic ambiguity" as "the practice by a country of being intentionally ambiguous on certain aspects of its foreign policy [. . .]. It may be useful if the country has contrary foreign and domestic policy goals or if it wants to take advantage of risk aversion to abet a deterrence strategy." (en.wikipedia.org/wiki/Policy_of_deliberate_ambiguity). Multiple objectives of the principal and risk aversion of the agent are also important in our model in generating the beneficial incentive effects of opacity.

task $j = 1, 2$ is verifiable and depends both on the effort devoted by the agent to that task, e_j, and on the realization of a random shock, ε_j. In particular, $x_j = e_j + \varepsilon_j$, where $(\varepsilon_1, \varepsilon_2)$ have a symmetric bivariate normal distribution with mean 0, variance σ^2, and covariance $\rho\sigma^2 \geq 0$. The efforts chosen by the agent are not observable by the principal.

Our multitask moral hazard model incorporates three key ingredients that are featured in all of our motivating examples in Section 1. The first of these is that at the time of contracting, the agent is better informed than the principal about his cost of exerting efforts. Specifically, with probability $\frac{1}{2}$, the agent's cost function is $c_1(e_1, e_2) = \frac{1}{2}(e_1 + \lambda e_2)^2$, in which case we will term him a type-1 agent, and with probability $\frac{1}{2}$ his cost function is $c_2(e_1, e_2) = \frac{1}{2}(\lambda e_1 + e_2)^2$, in which case he will be termed a type-2 agent. The parameter λ is common knowledge, and $\lambda \geq 1$. For each type of agent $i = 1, 2$, efforts are perfect substitutes: $\frac{\partial c_i/\partial e_1}{\partial c_i/\partial e_2}$ does not vary with (e_1, e_2).[14] Nevertheless, because $\lambda \geq 1$, the type-i agent has a preference for task i: the marginal cost of effort on task j $(j \neq i)$ is λ times as large as that on task i.

The second key ingredient is the agent's risk aversion. We assume that both types of agent have an exponential von Neumann-Morgenstern utility function with coefficient of absolute risk aversion r, so the type-i agent's utility function is $U = -\exp\{-r(w - c_i(e_1, e_2))\}$, where w is the payment from the principal. The two types of agent are assumed to have the same level of reservation utility, which we normalize to zero in certainty-equivalent terms.

The third key feature of our model is that the agent's efforts on the tasks are complementary for the principal. We capture this by assuming that the principal's payoff, which consists of the benefit to her from the agent's efforts minus the payment to the agent, takes the following form:

$$\Pi = \frac{\delta \underline{e} + \overline{e}}{\delta + 1} - w,$$

where $\underline{e}$ is the smaller of the efforts on the two tasks, $\overline{e}$ is the larger of the efforts, and the parameter $\delta \in [1, \infty)$. Notice that as δ goes to ∞, the benefit to the principal goes to $\underline{e}$, so that the tasks are perfect complements for her. On the other hand, when $\delta = 1$, the principal's payoff is $\frac{1}{2}(\underline{e} + \overline{e})$, so that the tasks are perfect substitutes for her. When the agent chooses perfectly balanced efforts $\underline{e} = \overline{e} = e$, the principal's benefit is e, which is independent of δ.[15]

The relative size of δ and λ determines what allocation of effort across tasks would maximize social surplus. If $\delta > \lambda$, so the principal's desire for balanced efforts is stronger than the agent's preference across tasks, then the surplus-maximizing effort allocation involves both types of agent exerting equal effort on the two tasks. If, instead, $\delta < \lambda$, then in the socially efficient effort allocation, each type of agent focuses exclusively on his preferred task.

The principal's benefit, $\frac{\delta \underline{e} + \overline{e}}{\delta + 1}$, is assumed nonverifiable. Therefore, the only measures on which the agent's compensation can be based are x_1 and x_2. The principal chooses a compensation scheme to maximize her expected payoff, subject to participation and incentive constraints for the agent that reflect the agent's hidden information and hidden actions. We will compare incentive schemes according to the (expected) payoff generated for the principal.

Below, we consider a variety of incentive schemes. Throughout the analysis, we restrict attention to compensation schedules in which, *ex post*, after all choices are made and random variables are realized, the agent's payment is a linear and separable function of the performance measures: $w = \alpha + \beta_1 x_1 + \beta_2 x_2$. We will say an incentive scheme (possibly involving menus) is *transparent* if, at the time the agent signs the contract or makes his choice from the menu, he is certain about what values of α, β_1, and β_2 will be employed in determining his pay. If, instead, even after making his choice from a menu, the agent is uncertain about the value of α, β_1, or β_2, we will say that the incentive scheme is *opaque*.

[14] In Section 7, we show that our key results continue to hold when the degree of substitutability of efforts for the agent is high but imperfect.

[15] We assume throughout that difficulties of coordination would prevent the principal from splitting the job between two agents, with each agent responsible for only one dimension (task).

In the next section, we study transparent incentive schemes. Section 4 then analyzes the class of opaque scheme on which we focus, *ex ante randomization* (henceforth, EAR). A contract with EAR specifies that with probability $\frac{1}{2}$, the agent will be compensated according to $w = \alpha + \beta x_1 + k\beta x_2$ and with probability $\frac{1}{2}$, according to $w = \alpha + \beta x_2 + k\beta x_1$, where the parameter $k \in (-1, 1)$.[16] Under EAR, the principal commits to employ a randomizing device to determine which of these two linear schedules will be used. Thus, the agent, when choosing efforts, is uncertain about which performance measure will be more highly rewarded, and by varying the level of k, the principal can affect how much this uncertainty matters to the agent.[17]

3. Transparent incentive schemes

□ **The no hidden information benchmark.** Suppose that the principal can observe the agent's cost type and offer each type a different contract. This simplifies the setup from a model with hidden action (moral hazard) and hidden information (private information about types) into a model with only hidden action. We will refer to this as the "no hidden information benchmark" (henceforth, NHI). The NHI benchmark is important because, as we will see, there are environments in which optimally designed opaque contracts allow the principal, even in the presence of hidden information, to achieve a payoff arbitrarily close to that achievable in this benchmark.

In this setting, the optimal pair of contracts (one for each type of agent) can take one of two possible forms. The first form makes each type of agent willing to choose equal efforts on the two tasks but imposes a relatively large risk cost on the agent. The second form induces each type to exert effort only on his less costly task but provides better insurance for the agent.[18] The first form is a pair of contracts (C_1^{bal}, C_2^{bal}), where

$$C_1^{bal}: \; w_1 = \alpha + \beta x_1 + \lambda\beta x_2 \quad \text{and} \quad C_2^{bal}: \; w_2 = \alpha + \beta x_2 + \lambda\beta x_1,$$

with $\beta > 0$, and where the principal assigns the contract C_i^{bal} to the type-i agent. The incentive coefficients in C_i^{bal} are chosen to equate the ratio of the marginal benefits of efforts on the two tasks to the ratio of their marginal costs for type i. As stressed by Holmstrom and Milgrom (1991) and Milgrom and Roberts (1992), equalizing these ratios is necessary for a contract to induce strictly positive efforts on both tasks, an observation often referred to as the "equal compensation principle." Here, as these ratios are constant, independent of the chosen efforts, it follows that type i is indifferent over all nonnegative effort pairs satisfying $\beta = e_i + \lambda e_j$. Among such effort pairs, the principal prefers type i to choose the perfectly balanced effort allocation, $e_i = e_j = \frac{\beta}{1+\lambda}$, because efforts on the tasks are complementary for the principal ($\delta > 1$).

Throughout the article, we assume that the agent, if indifferent over effort pairs, chooses the pair that is best for the principal. This assumption is relevant only for transparent schemes; opaque schemes never leave the agent indifferent. Therefore, by assuming the best-case scenario

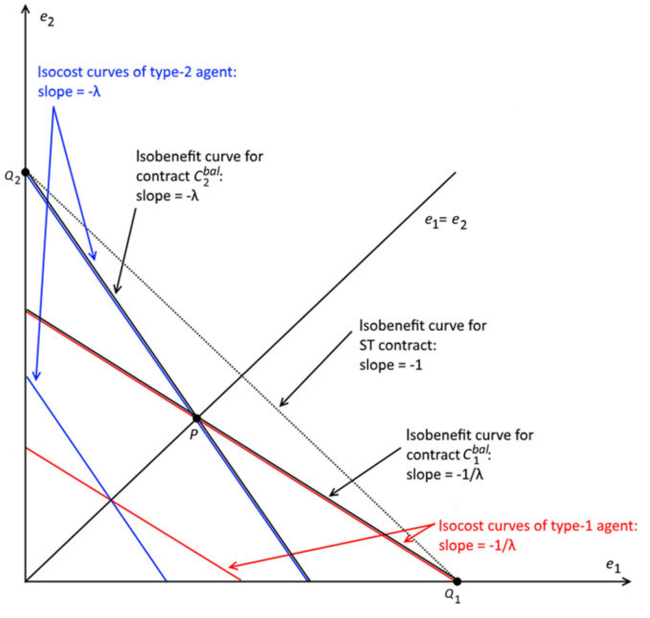
[16] In contrast to transparent incentive schemes, the performance of EAR cannot be improved by the inclusion of menus. Appendix B shows that the principal's payoff under EAR is highest when she offers a single EAR contract that randomizes with equal probability between the two wage schedules.

[17] The restriction of the contracting space to *ex post* linear contracts is crucial to our analysis. If arbitrarily complex nonlinear contracts were available to the principal, it would be possible to show, by extending an argument of Grossman and Hart (1983), that given any contract with EAR, there would exist a nonlinear transparent contract that provides both types of agent with the same expected utility as a function of efforts as the contract with EAR and that (because the agent is risk-averse) entails a lower payment by the principal. However, this construction would necessitate a nonlinear contract that is complicated to describe and difficult to understand, whereas a contract which randomizes over two linear schedules is considerably simpler to describe and understand. This view is supported by the findings of Abeler and Jäger (2015), who show that the real-effort choices of subjects faced with complex incentive schemes are more dispersed and further from the payoff-maximizing level than those of subjects faced with simple ones.

[18] Under our assumption that for both types of agent, efforts are perfect substitutes in the cost function, any linear contract *either* makes an agent willing to choose perfectly balanced efforts *or* induces him to exert effort on only one task.

FIGURE 1

Isocost and isobenefit curves under transparent contracts. Contract C_1^{bal} makes the type-1 agent willing to choose point P, at which $e_1 = e_2$, and similarly, the contract C_2^{bal} makes the type-2 agent also willing to choose P. The ST contract induces both types of agent to choose fully focused efforts: the type-1 agent chooses Q_1 and the type-2 agent Q_2. [Color figure can be viewed at wileyonlinelibrary.com]



for transparent schemes, we are strengthening our findings in Section 6 that opaque schemes can outperform transparent ones.

Figure 1 illustrates the outcomes from the contract pair (C_1^{bal}, C_2^{bal}) in the NHI benchmark when $\lambda > 1$. With transparent linear contracts, the cost of the risk imposed on the agent (stemming from the shocks to measured performance) is independent of the efforts chosen, so each type of agent maximizes expected utility by maximizing the difference between the expected wage payment and the quadratic effort cost. For a type-1 agent, the isocost curves (shown in red) are linear in (e_1, e_2)-space with slope equal to $-1/\lambda$. Under the contract C_1^{bal}, this agent's isobenefit curves (the curves of constant expected wage, one of which is shown in black) are also linear with the same slope $-1/\lambda$. Consequently, if for example, the type-1 agent finds it optimal to incur a total effort cost corresponding to the isocost curve through points P and Q_1 in the figure, he is indifferent over all effort pairs on this isocost curve, because they all yield the same expected wage. Hence, under our assumption on the agent's behavior when indifferent, he will choose the point P, at which $e_1 = e_2$. Symmetrically, for a type-2 agent, his isocost curves (blue) and the isobenefit curves corresponding to contract C_2^{bal} (black) are all linear with slope $-\lambda$, and because the value of β is the same in C_2^{bal} as in C_1^{bal}, the type-2 agent will also choose point P.

Suppose that, instead of tailoring the incentive coefficients to the agent's preferences over tasks, the principal offered both types of agent a "symmetric transparent" (henceforth, ST) contract

$$ST : w = \alpha + \beta x_1 + \beta x_2,$$

with β the same as in (C_1^{bal}, C_2^{bal}). Now, the isobenefit curves for both types of agent would have slope -1 (one such curve is shown in Figure 1 as the dotted black line), and for both types, the strictly optimal effort pair given the ST contract would be a corner solution, Q_1 for type 1 and Q_2 for type 2, corresponding to efforts fully focused on that type's less costly task. For $\lambda > 1$, the incentives provided by a symmetric transparent contract are unattractive for a principal who values effort balance: for any value of the principal's complementarity parameter δ such that $\delta > \lambda$, the principal's benefit $\frac{\delta \underline{e}+\bar{e}}{\delta+1}$ from the fully focused effort pairs Q_1 and Q_2 is strictly below that from the perfectly balanced pair P.

In the special case where $\lambda = 1$, there is only one type of agent, and C_1^{bal} and C_2^{bal} both reduce to the ST contract. In this special case, the ST contract makes the agent indifferent between effort pairs, and thus willing to choose balanced efforts $e_1 = e_2 = \frac{\beta}{2}$. Consequently, in the NHI benchmark, under our assumption on the agent's behavior when indifferent, the efforts induced by the contract pair (C_1^{bal}, C_2^{bal}), and hence the payoff received by the principal, are continuous in λ, approaching as $\lambda \to 1$ their values under the ST contract at $\lambda = 1$.

Even though inducing perfectly balanced efforts from both types of agent, via (C_1^{bal}, C_2^{bal}), is feasible in the NHI benchmark, it is not necessarily optimal, because of the cost of the risk imposed on the agent stemming from the shocks to the two performance measures. The second type of contract pair which can be optimal in the NHI benchmark is a pair of the form

$$C_1^{foc} : \ w_1 = \alpha + \beta x_1 - \rho\beta x_2 \quad \text{and} \quad C_2^{foc} : \ w_2 = \alpha + \beta x_2 - \rho\beta x_1,$$

with $\beta > 0$, where the principal assigns C_i^{foc} to the type-i agent. As contract C_i^{foc} has a strictly positive incentive coefficient only on x_i, this contract induces type i to exert effort only on his less costly task, task i, and for any $\lambda \geq 1$ to set $e_i = \beta$ and $e_j = 0$. Despite its drawback of inducing fully focused efforts, contract C_i^{foc} has the advantage of using performance on task j to provide insurance for the type-i agent (without weakening his incentives on task i), by optimally exploiting the correlation between the shocks to the two performance measures.[19] Among all contract pairs that induce each type to focus only on his less costly task, pairs of the form (C_1^{foc}, C_2^{foc}) are the most attractive for the principal.[20]

In choosing, in the NHI setting, between a contract pair of the form (C_1^{bal}, C_2^{bal}) and one of the form (C_1^{foc}, C_2^{foc}), the principal faces a trade-off between the more balanced efforts induced by the former and the lower risk cost imposed by the latter. The following lemma shows that, if and only if the efforts on the two tasks are sufficiently complementary for the principal, the benefits of the balanced efforts elicited by (C_1^{bal}, C_2^{bal}) outweigh the costs of the extra risk imposed on the agent by this contract pair.

Lemma 1. For any $\lambda \geq 1$, in the NHI benchmark, there exists a critical value of the task complementarity parameter δ in the principal's benefit function, $\delta^{NHI}(\lambda, r\sigma^2, \rho)$, increasing in each of its arguments, such that for $\delta > \delta^{NHI}$ (respectively, $\delta < \delta^{NHI}$), the principal's unique optimal contract pair has the form (C_1^{bal}, C_2^{bal}) (respectively, the form (C_1^{foc}, C_2^{foc})).

□ **The general case: hidden information.** In the general case where $\lambda > 1$ and the agent is privately informed about his preferences across tasks, the principal can use menus of contracts as a screening device. However, Lemma 2 shows that the power of menus to solve the effort-substitution problem is extremely limited in the presence of hidden information.

Lemma 2. When $\lambda > 1$, under hidden information, no menu of transparent linear contracts can induce both types of agent to choose strictly positive efforts on both tasks.

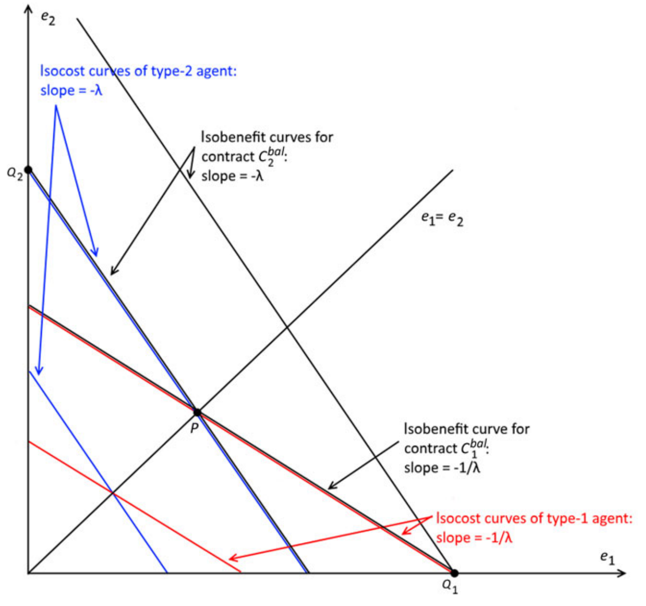
To understand Lemma 2, observe that the "equal compensation principle" has the following implication for a menu of transparent linear contracts: the only way to induce both types of agent

[19] The logic here is analogous to the logic behind using relative performance evaluation to minimize an agent's exposure to risk for any given level of incentives. See, for example, Holmstrom and Milgrom (1990).

[20] Although the values of α and β could in principle be allowed to differ between C_1^{bal} and C_2^{bal} and, analogously, between C_1^{foc} and C_2^{foc}, the symmetry of the model with respect to the two types of agent makes it optimal for these values to be the same within each type of contract pair. Moreover, this symmetry also implies that it is never uniquely optimal to offer a pair of the form (C_1^{foc}, C_2^{bal}) or (C_1^{bal}, C_2^{foc}).

FIGURE 2

Graphical explanation of Lemma 2. Faced with the menu (C_1^{bal}, C_2^{bal}), if the type-1 agent were to choose C_1^{bal}, the perfectly balanced efforts of point P would maximize his expected utility. However, choosing C_2^{bal} and fully focusing his efforts on task 1 (point Q_1) would yield strictly higher expected utility, because C_2^{bal} rewards task 1 more highly than does C_1^{bal}. [Color figure can be viewed at wileyonlinelibrary.com]



to exert strictly positive efforts on both tasks is to induce each type to choose a contract that rewards performance on his more costly task at a rate λ times as high as it rewards performance on his less costly task. Therefore, if a menu existed which could induce both types to choose strictly positive efforts on both tasks, it would have the form

$$C_1: \; w_1 = \alpha_1 + \beta_1 x_1 + \lambda\beta_1 x_2 \quad \text{and} \quad C_2: \; w_2 = \alpha_2 + \beta_2 x_2 + \lambda\beta_2 x_1,$$

and would induce the type-i agent to choose contract C_i.

We now use Figure 2, which builds on Figure 1, to explain why, no matter how (α_1, β_1, α_2, β_2) were chosen, a menu of the form above would give at least one type of agent an incentive to select the "wrong" contract from the menu, in which case, he would exert effort only on his less costly task. Suppose first that the principal sets $\beta_1 = \beta_2$ and $\alpha_1 = \alpha_2$, so that (C_1, C_2) matches the mirror-image pair (C_1^{bal}, C_2^{bal}) defined for the NHI benchmark. Then, if the type-1 agent were to choose C_1^{bal}, the perfectly balanced efforts of point P would maximize his expected utility. Moreover, given that C_1^{bal} and C_2^{bal} are mirror images of each other, point P would yield this agent the same expected utility under both contracts. Yet, if the type-1 agent chose C_2^{bal}, under which his isobenefit curves would be more steeply negatively sloped (with slope $-\lambda$) than his isocost curves, then fully focusing his efforts by choosing point Q_1 would yield him strictly higher utility than would point P: he would incur the same overall effort cost as at P but would earn a strictly higher expected wage. Therefore, if $\beta_1 = \beta_2$ and $\alpha_1 = \alpha_2$, the type-1 agent strictly prefers to choose contract C_2^{bal} over C_1^{bal}, and symmetrically, the type-2 agent strictly prefers to choose C_1^{bal} over C_2^{bal}.[21]

[21] The point Q_1 is not the type-1 agent's optimal effort choice under C_2^{bal} (he would prefer an effort pair with an even higher value of e_1, and $e_2 = 0$), but because Q_1 yields the type-1 agent higher expected utility than does P, it follows that this agent strictly prefers C_2^{bal} to C_1^{bal}.

The principal could, by raising β_1 and α_1 sufficiently relative to β_2 and α_2, induce the type-1 agent to choose C_1 from the menu (C_1, C_2). However, because for any β_1 and α_1, C_1 rewards task 2 more highly than task 1, the type-2 agent always derives strictly higher expected utility from C_1 than does the type-1 agent. Thus, any adjustment in β_1 and α_1 that made the type-1 agent willing to choose C_1 would continue to induce the type-2 agent to select C_1, and would thus induce the latter agent to choose fully focused efforts.

In sum, with transparent linear contracts, which correspond in Figures 1 and 2 to linear isobenefit curves, the only way to solve the effort-substitution problem for a given type of agent is to reward more highly his more costly task. However, because the bribe implicit in such a contract is even more attractive to the other type of agent, it is impossible, even with menus of transparent linear contracts, to solve the effort-substitution problem for both types of agent in the presence of hidden information.

The above discussion shows that the principal might benefit from contracting instruments that generate convexity in the isobenefit curves. The isocost curves of the two types of agent are linear but differently sloped. Therefore, contracts that yield sufficiently convex isobenefit curves could simultaneously make interior effort choices optimal for both types of agent. We will see in Section 4 that *ex ante* randomization (EAR) over linear schedules putting asymmetric weights on the performance measures can indeed generate sufficiently convex isobenefit curves to mitigate the effort-substitution problem.

Before analyzing EAR, though, we characterize the optimal menu of transparent linear contracts and summarize some of its key properties. Recall that Lemma 2 shows that no menu of transparent linear contracts can induce both types of agent to choose strictly positive efforts on both tasks. Thus, any menu must induce strictly positive efforts on both tasks *either* from one type of agent *or* from neither type of agent. By an extension of the logic used, for the NHI benchmark, to confine attention to contracts C_i^{bal} and C_i^{foc}, an optimal menu inducing the former pattern of efforts must have the following form, which we term an "asymmetric transparent menu" (henceforth, ATM):

$$C_1^{ATM}: \; w_1 = \alpha_1 + \beta_1 x_1 - \rho\beta_1 x_2 \quad \text{and} \quad C_2^{ATM}: \; w_2 = \alpha_2 + \beta_2 x_2 + \lambda\beta_2 x_1.$$

Similarly, an optimal menu inducing the latter pattern of efforts must have the form

$$C_1^{STM}: \; w_1 = \alpha + \beta x_1 - \rho\beta x_2 \quad \text{and} \quad C_2^{STM}: \; w_2 = \alpha + \beta x_2 - \rho\beta x_1,$$

which we term a "symmetric transparent menu" (henceforth, STM).

The two mirror-image contracts in an STM match the contracts (C_1^{foc}, C_2^{foc}). Each of these contracts attaches a positive coefficient to only one performance measure. Hence, each type of agent chooses from the menu the schedule which rewards performance on his preferred task and exerts effort only on that task. As was explained when we defined contract C_i^{foc}, the negative coefficient $-\rho\beta$ on output x_j in C_i^{STM} uses the correlation between the shocks to x_1 and x_2 to provide insurance to the type-i agent.

Now consider an ATM. Through appropriate choice of (α_1, α_2), given (β_1, β_2), an ATM of the form above induces the type-2 agent to select schedule C_2^{ATM}, which leaves him indifferent over all effort pairs such that $\beta_2 = e_1 + \lambda e_2$. Given our assumption on the agent's behavior when indifferent, the type-2 agent therefore chooses the perfectly balanced effort allocation $e_1 = e_2 = \frac{\beta_2}{1+\lambda}$. At the same time, the type-1 agent is induced to select the schedule C_1^{ATM}, which incentivizes him to choose fully focused efforts (and uses the coefficient on x_2 to provide insurance). Inducing the type-1 agent to choose C_1^{ATM} over C_2^{ATM} necessitates leaving a rent to this agent type. This rent arises because the contract C_2^{ATM} designed for the type-2 agent bribes that agent to choose balanced efforts by rewarding task 1 exactly λ times more highly than task 2. However, C_2^{ATM} is even more attractive to the type-1 agent, for whom task 1 is the less costly task.

Relative to an STM, an ATM has the benefit of inducing one type of agent (here, type 2) to choose balanced efforts, but it imposes more risk on that agent type and also necessitates leaving a rent to the other type (here, type 1). Whether this benefit of an ATM outweighs these costs depends on whether δ, the strength of the principal's preference for balanced efforts, is large enough.

Proposition 1.

(i) When the agent is privately informed about his preferences, there exists a critical $\delta^{HI}(\lambda, r\sigma^2, \rho)$, increasing in each of its arguments, such that for $\delta > \delta^{HI}$, the best transparent menu for the principal is an optimally designed ATM, and for $\delta < \delta^{HI}$, her best transparent menu is an optimally designed STM.

(ii) For all $\lambda > 1$ and for all $(r\sigma^2, \rho)$, $\delta^{HI}(\lambda, r\sigma^2, \rho) > \delta^{NHI}(\lambda, r\sigma^2, \rho)$, and as $\lambda \to 1$, $\delta^{HI} - \delta^{NHI} \to 0$.

(iii) For any $\lambda > 1$, if $\delta > \delta^{NHI}(\lambda, r\sigma^2, \rho)$, the principal is strictly worse off when hidden information is present than when it is absent.

(iv) For $\delta > \delta^{HI}(1, r\sigma^2, \rho)$, the limit as $\lambda \to 1$ of the principal's maximized payoff under hidden information is strictly below her maximized payoff in the NHI benchmark.

The result in (ii) that $\delta^{HI}(\lambda, r\sigma^2, \rho) > \delta^{NHI}(\lambda, r\sigma^2, \rho)$, for all $\lambda > 1$, says that the principal's complementarity parameter δ must be larger when hidden information is present than when it is absent for it to be optimal for her to induce balanced efforts (even from just one type of agent). The reason is the informational rent that hidden information forces the principal to leave to one agent type when offering an ATM.[22]

Part (iii) of the proposition follows from the facts, proved in Lemmas 1 and 2, that for $\delta > \delta^{NHI}$ it is a strict optimum for the principal in the NHI benchmark to induce both types of agent to choose perfectly balanced efforts and that this outcome is infeasible under hidden information. Part (iv) shows that under hidden information, when $\delta > \delta^{HI}(1, r\sigma^2, \rho)$, the principal's maximized payoff drops *discontinuously* as λ is increased from 1 (where an ST contract is optimal and induces perfectly balanced efforts) to a value slightly greater than 1 (where the optimal scheme is an ATM).[23] This discontinuous drop reflects the impossibility, for even a small degree of privately known preference across tasks, of inducing balanced efforts from both types with a transparent scheme. In contrast, in the NHI benchmark, where it is feasible to induce balanced efforts from both types for all λ, the principal's maximized payoff decreases continuously as λ is increased from 1.

4. Opaque incentive schemes: *ex ante* randomization

■ A contract with *ex ante randomization* (EAR) specifies that with probability $\frac{1}{2}$, the agent will be compensated according to $w = \alpha + \beta x_1 + k\beta x_2$, and with probability $\frac{1}{2}$, according to $w = \alpha + \beta x_2 + k\beta x_1$, where the key parameters are the incentive intensity $\beta > 0$ and the weighting factor $k \in (-1, 1)$.[24] Under this incentive scheme, the principal commits to employ a randomizing device to determine whether the agent's pay will be more sensitive to performance on task 1 or task 2. If the agent chooses unequal efforts on the tasks, the principal's randomization exposes the agent to extra wage risk, risk against which he can insure himself by choosing more balanced efforts. By varying k, the principal can affect how much risk the randomization per se imposes on the agent and can thereby affect the strength of the agent's incentives to balance his efforts. If k were equal to 1, the randomized scheme would collapse to the symmetric transparent (ST) contract defined in Section 3, which, whenever $\lambda > 1$, induces both types of agent to exert effort

[22] The gap between δ^{HI} and δ^{NHI} remains even for $r = 0$, highlighting that it arises from hidden information alone, rather than from the combination of hidden information and risk aversion.

[23] Note that we are continuing to use our assumption that the agent, when indifferent over effort pairs, chooses the pair that maximizes the principal's payoff.

[24] The lump-sum payment α has no effect on the agent's effort incentives, and will optimally be set by the principal to make the participation constraint binding for both types of agent.

only on their preferred task. The smaller k is, the greater is the risk imposed on the agent by the principal's randomization, and therefore the stronger are the agent's incentives to self-insure by choosing more balanced efforts.

As the two equally likely compensation schedules under EAR are mirror images with respect to the two tasks and the cost functions of the two types of agent are also mirror images, the optimal effort choices of the two types of agent will also be mirror images. Hence, we can describe both agents' optimal efforts by the same pair $(\overline{e}^{EAR}, \underline{e}^{EAR})$, where $\overline{e}^{EAR}$ denotes the effort on the agent's less costly task and $\underline{e}^{EAR}$ the effort on the agent's more costly task. Furthermore, because the principal's benefit function depends only on the minimum and maximum of the efforts on the two tasks, and not which task attracted larger effort, the principal's expected payoff under EAR can also be written as a function of $(\overline{e}^{EAR}, \underline{e}^{EAR})$.

Proposition 2.

(i) Under EAR, $k < \frac{1}{\lambda}$ is a necessary condition for each agent's optimal efforts on both tasks to be strictly positive. When EAR induces interior solutions for efforts,

(ii) the efforts choices of each type of agent satisfy

$$\overline{e}^{EAR} + \lambda \underline{e}^{EAR} = \frac{\beta(1+k)}{\lambda+1} \tag{1}$$

$$\exp\left[r\beta(1-k)\left(\overline{e}^{EAR} - \underline{e}^{EAR}\right)\right] = \frac{\lambda - k}{1 - k\lambda}; \tag{2}$$

(iii) the gap in efforts, $\overline{e}^{EAR} - \underline{e}^{EAR}$, is increasing in λ, approaching 0 as $\lambda \to 1$; decreasing in $r\beta$, approaching 0 as $r\beta \to \infty$; and increasing in k, approaching 0 as $k \to -1^+$;

(iv) the principal's expected payoff under EAR, for given $\beta > 0$ and $k \in (-1, \frac{1}{\lambda})$, is

$$\begin{aligned}\Pi^{EAR}(\beta, k) = {} & \frac{\delta \underline{e}^{EAR} + \overline{e}^{EAR}}{\delta + 1} - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} \\ & - \frac{1}{2} r\sigma^2\beta^2(1 + 2\rho k + k^2) - \frac{1}{2r}\ln\left[\frac{(\lambda+1)^2(1-k)^2}{4(1-k\lambda)(\lambda-k)}\right].\end{aligned} \tag{3}$$

If $k \geq \frac{1}{\lambda}$, then for both types of agent, *whichever compensation schedule is randomly selected*, the ratio of the marginal benefit of effort on the less costly task to that on the more costly task is at least as large as the corresponding ratio of the marginal costs and strictly larger for one schedule. By the "equal compensation principle," therefore, both agent types would exert effort only on their less costly task.

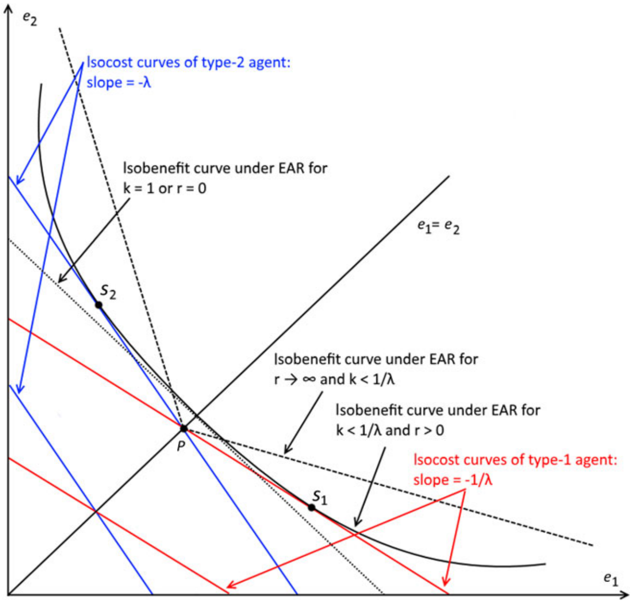
For both types of agent, the effort cost is a function of $\overline{e} + \lambda \underline{e}$. Therefore, we will refer to the quantity $\overline{e} + \lambda \underline{e}$ as the *aggregate effort*. Equation (1) shows the aggregate effort induced by EAR (at an interior solution), and equation (2) yields the gap between efforts on the two tasks.

Equation (1) follows from the following two facts. Under EAR, the sum of the marginal costs of effort on the two tasks is $(1+\lambda)(\overline{e} + \lambda \underline{e})$ and the sum of the marginal monetary returns to effort is $\beta(1+k)$ because, whatever the outcome of the randomization, one task will be rewarded at rate β and the other at rate $k\beta$. Note that the aggregate effort induced by EAR is independent of the agent's risk aversion. To understand equation (2), observe that each type of agent's expected utility under EAR can be written as

$$-\exp\left\{-r[b(\overline{e}, \underline{e}) - c(\overline{e}, \underline{e}) - \mathcal{RP}]\right\}, \tag{4}$$

FIGURE 3

Under EAR with $k < 1$, the isobenefit curves for a risk-averse agent are convex to the origin and symmetric about the line $e_1 = e_2$. For the solid black isobenefit curve, each type of agent's optimal effort pair (S_1 for type 1 and S_2 for type 2) is a point of tangency between that curve and an isocost curve for that type of agent. [Color figure can be viewed at wileyonlinelibrary.com]



where $c(\overline{e}, \underline{e}) = \frac{1}{2}(\overline{e} + \lambda\underline{e})^2$ is the cost of efforts, $\mathcal{RP} = \frac{1}{2}r\sigma^2\beta^2(1 + 2\rho k + k^2)$ is the risk premium stemming from the shocks to measured performance, and $b(\overline{e}, \underline{e})$ is the certainty equivalent of the benefit, under EAR, from effort levels $(\overline{e}, \underline{e})$ and is given by

$$b(\overline{e}, \underline{e}) = \alpha + \frac{\beta(1+k)}{2}(\overline{e} + \underline{e}) - \frac{1}{r}\ln\left\{\frac{\exp\left[-\frac{1}{2}r\beta(1-k)(\overline{e} - \underline{e})\right] + \exp\left[\frac{1}{2}r\beta(1-k)(\overline{e} - \underline{e})\right]}{2}\right\}. \quad (5)$$

Note that $b(\overline{e}, \underline{e})$ is less than $\alpha + \frac{\beta(1+k)}{2}(\overline{e} + \underline{e})$, the expected payment under EAR. The negative term in (5) is the risk premium stemming from the principal's randomization over payment schedules. Because $\mathcal{RP}$ is independent of efforts, an interior solution $(\overline{e}, \underline{e})$ must equate $\frac{\partial b}{\partial \overline{e}} / \frac{\partial b}{\partial \underline{e}}$ to $\frac{\partial c}{\partial \overline{e}} / \frac{\partial c}{\partial \underline{e}}$, which yields equation (2).

In contrast to transparent linear contracts, under EAR, the isobenefit curves of $b(\overline{e}, \underline{e})$ for a risk-averse agent are *convex* to the origin. As the effort gap between the two tasks $\overline{e} - \underline{e}$ rises from 0, $\frac{\partial b}{\partial \overline{e}} / \frac{\partial b}{\partial \underline{e}}$ falls from 1. This convexity reflects that when the efforts are more unequal, the wage risk from the randomization is greater, so the incentive to self-insure by reducing $\overline{e} - \underline{e}$ is stronger.

Figure 3 illustrates the effort incentives created by EAR. With e_1 on the horizontal and e_2 on the vertical axis, isocost curves for the type-1 agent are shown in red and isocost curves for the type-2 agent in blue. Defining $b(e_1, e_2)$ by substituting e_1 for $\overline{e}$ and e_2 for $\underline{e}$ in equation (5), we plot the isobenefit curves of $b(e_1, e_2)$ in black. As compensation under EAR is *ex ante* symmetric with respect to the two performance measures, these isobenefit curves are symmetric about the line $e_1 = e_2$. For each type of agent, equation (1) determines which isocost curve (corresponding to a level of aggregate effort) the chosen effort pair lies on. The solution to equation (2) is represented, for each type, by a point of tangency between that isocost curve and an isobenefit curve of $b(e_1, e_2)$. In Figure 3, the optimal effort pair for the type-1 agent is S_1, with $e_1 > e_2 > 0$, and that for the type-2 agent is, by symmetry, S_2, with $e_2 > e_1 > 0$.

Equation (2) and Figure 3 both show how each type of agent's optimal degree of self-insurance against the wage risk imposed by EAR varies with the parameters of the incentive scheme and with his preferences. First, the smaller the parameter k is, the more different the two possible compensation schedules are and the more costly the wage risk imposed by the randomization. This is reflected in greater convexity of the isobenefit curves ($\frac{\partial b}{\partial \overline{e}}/\frac{\partial b}{\partial \underline{e}}$ falling from 1 faster as $\overline{e} - \underline{e}$ rises from 0).[25] As a consequence, reducing k strengthens the agent's incentive to self-insure by choosing more balanced efforts, and the optimal effort gap $\overline{e} - \underline{e}$ falls. As $k \to -1^+$, the self-insurance motive approaches its strongest level, and the optimal effort gap approaches 0.

Second, greater risk aversion of the agent (larger r) and a larger value of the incentive intensity β also make the wage risk imposed by the randomization more costly and so, just like a smaller k, make the isobenefit curves more convex. As a result, the larger is $r\beta$, the stronger is the self-insurance incentive under EAR, and thus the smaller the optimal effort gap $\overline{e} - \underline{e}$. In Figure 3, as $r \to \infty$, the slope of the isobenefit curves approaches $-k$ for points below the 45-degree line and $-1/k$ for points above the 45-degree line. One such curve is shown by the dashed black line. Hence, for $k < 1/\lambda$, as $r \to \infty$, the optimal effort gap $\overline{e} - \underline{e}$ for each type of agent approaches 0. This corresponds to full self-insurance. Moreover, it follows from equation (1) that for each type of agent, his optimal effort pair remains on the same isocost curve as r increases, and hence as $r \to \infty$ with β held fixed, each type's optimal choice approaches point P.

If k were 1 or the agent were risk-neutral, then equation (5) and Figure 3 show that the isobenefit curves of $b(\overline{e}, \underline{e})$ would be linear with slope -1, coinciding with the isobenefit curves for an ST contract as defined in Section 3. One such curve is shown by the dotted black line. In either of these extreme cases, therefore, EAR would, like an ST contract, induce fully focused efforts for any $\lambda > 1$.

Finally, the smaller the cost difference between tasks (i.e., the smaller is λ and thus the closer the slope of the linear isocost curves to -1), the less costly it is for the agent to self-insure by choosing a smaller effort gap $\overline{e} - \underline{e}$. As $\lambda \to 1$, full self-insurance becomes optimal, so $\overline{e} - \underline{e}$ approaches 0.

Introducing a small amount of hidden information about the agent's preferences (raising λ from 1) has a strikingly different effect under EAR than under transparent contracts. Under EAR, for any value of $k \in (-1, 1)$, both the agent's efforts and the principal's payoff are continuous in λ at $\lambda = 1$ as long as the agent is risk-averse. In contrast, Proposition 1 shows that the principal's payoff under an optimal menu of transparent contracts drops discontinuously as λ is raised from 1. Thus, EAR is more robust to the introduction of private information on the part of the agent than is the best transparent menu.[26] EAR is also more robust to uncertainty about the magnitude of λ than is a transparent menu: if the principal tries to design a transparent menu to induce one type of agent to choose balanced efforts but is even slightly wrong about the magnitude of λ, her payoff will be discontinuously lower than if she were right. The performance of EAR does not display this extreme sensitivity.[27]

The effort-balancing incentives generated by EAR do, however, come at a cost in terms of the risk imposed on the risk-averse agent. As shown by equations (4) and (5), EAR imposes two distinct types of risk costs. The first is the risk stemming from the shocks to measured performance (which is the risk that would be imposed by a transparent contract of the form $w = \alpha + \beta x_1 + k\beta x_2$) and represented by the term $\mathcal{RP}$ in (4). The second is the risk imposed by the principal's

[25] In fact, for $k \in (-1, 0)$, the risk from the randomization makes $\frac{\partial b}{\partial \overline{e}}$ negative for $\overline{e} - \underline{e}$ sufficiently large (but $\frac{\partial b}{\partial \underline{e}}$ is always positive), so for $k \in (-1, 0)$, the isobenefit curves of $b(e_1, e_2)$ become positively sloped far enough away from the 45-degree line.

[26] Even outside the exponential-normal framework we have been using, EAR induces more balanced efforts than an ST contract and is more robust to the introduction of hidden information, as shown in Appendix B.

[27] Bond and Gomes (2009) also study a multitask principal-agent setting in which a small change in the agent's preferences can result in a large change in the behavior induced by a contract and a consequent large drop in the principal's payoff, a situation they term "contract fragility."

randomization over payment schedules, given by the negative term in (5), reflecting the amount by which $b(\overline{e}, \underline{e})$ falls short of the expected wage under EAR. Correspondingly, in the principal's payoff expression (3) in Proposition 2, the penultimate term is the risk premium stemming from the shocks, and the final term is the risk premium stemming from the randomization.

We saw above how the principal, under EAR, can affect the strength of the agent's incentives for balanced efforts by varying k, the parameter representing the degree of asymmetry in the weights on the performance measures in the two possible compensation schedules. However, k also affects the level of aggregate effort induced, because as equation (1) shows, aggregate effort is proportional to $\beta(1+k)$. To isolate the effect of k on the principal's payoff, holding aggregate effort fixed, we define $B \equiv \beta(1+k)$ and use equations (1) and (2) to reexpress the principal's payoff (3) as a function of B and k:

$$\Pi^{EAR}(B,k) = \frac{\delta \underline{e}^{EAR} + \overline{e}^{EAR}}{\delta+1} - \frac{B^2}{2(\lambda+1)^2} - \frac{1}{2} r\sigma^2 B^2 \frac{1+2\rho k + k^2}{(1+k)^2} - \frac{1}{2r} \ln\left[\frac{(\lambda+1)^2(1-k)^2}{4(1-k\lambda)(\lambda-k)}\right], \quad (6)$$

where

$$\frac{\delta \underline{e}^{EAR} + \overline{e}^{EAR}}{\delta+1} = \frac{B}{(\lambda+1)^2} - \frac{\delta-\lambda}{\delta+1} \frac{\ln\left(\frac{\lambda-k}{1-k\lambda}\right)}{(\lambda+1) r B \left(\frac{1-k}{1+k}\right)}. \quad (7)$$

Equations (6) and (7) show that increasing k has three effects. First, a larger k raises the effort gap $\overline{e} - \underline{e}$ and, with B and hence aggregate effort $\overline{e} + \lambda \underline{e}$ held fixed, this larger gap lowers the principal's benefit $\frac{\delta \underline{e} + \overline{e}}{\delta+1}$ whenever $\delta > \lambda$. Second, a larger k, because it induces less balanced efforts, raises the cost of compensating the agent for the risk imposed by the randomization per se. This second effect of raising k also reduces the principal's payoff and is reflected in the final term in (6). Finally, a larger k reduces the cost (per unit of aggregate effort induced) of the risk imposed on the agent from the shocks to measured performance. This improved diversification raises $\Pi^{EAR}(B,k)$, as reflected in the second-to-last term in (6).

In general, the optimal design of a contract with EAR involves a trade-off among these three different effects. Weighting the performance measures more equally in the two possible compensation schedules is costly in terms of effort balance and thereby in terms of the risk imposed by the randomization, but is helpful in allowing better diversification of the measurement errors. The next proposition describes how the optimal value of k varies with several parameters of the contracting environment, holding fixed the aggregate effort to be induced, and also how the optimal k changes as the desired aggregate effort changes.

Proposition 3. For any given level of aggregate effort to be induced, the optimal level of k under EAR is smaller (the optimal weights on the performance measures should be more unequal)

(i) the larger is δ, given $\delta > \lambda$ (i.e., the stronger the principal's preference for balanced efforts);
(ii) the smaller is r, holding $r\sigma^2$ fixed (i.e., the less risk-averse the agent, holding fixed the importance of risk aversion under transparent contracts);
(iii) the smaller is $\sigma^2(1-\rho)$ (i.e., the lower the importance of diversification of the risk from the shocks to measured performance);
(iv) the smaller is B (i.e., the smaller the level of aggregate effort to be induced).

In Section 7, where we study EAR in a setting with an arbitrary number n of tasks, we show that changes in the number of randomly chosen tasks to reward have the same qualitative effects on incentives and risk as do changes in the weighting parameter k in the two-task model. Consequently, the comparative statics results for the optimal number of tasks to reward are the same as those above for the optimal k.

5. When are transparent incentive schemes preferred?

■ Section 4 showed that the key advantage of EAR is the effort-balancing incentives it generates for the privately informed risk-averse agent. Proposition 4 below identifies environments in which this benefit of opacity in mitigating gaming is outweighed by the higher wages that EAR requires the principal to pay because of the higher risk costs imposed on the agent. The proposition also demonstrates that each of the three key model ingredients we have highlighted—the agent's hidden information about his preferences, the agent's risk aversion, and the principal's desire for the agent's efforts to be balanced across tasks—is *necessary* for EAR to dominate the best transparent scheme.

Proposition 4. For any given (β, k), with $k \in (-1, 1)$, EAR yields a strictly lower payoff for the principal than a suitably designed transparent contract, if any of the following conditions hold:

(ia) $\lambda > 1$ and the principal knows which task the agent finds less costly;
(ib) $\lambda = 1$, so the agent finds both tasks equally costly, and $\rho < 1$;
(ii) the agent is not sufficiently risk-averse for EAR to induce positive effort on both tasks;
(iii) $\delta \leq \lambda$, so the principal's desire for balanced efforts is outweighed by the agent's preference across tasks.

Underlying each part of this proposition is the demonstration that, given any EAR scheme and the aggregate effort $\overline{e}^{EAR} + \lambda \underline{e}^{EAR}$ it induces, there exists a transparent contract that induces the same level of aggregate effort and that imposes lower overall risk costs on the agent. For part (ia), where there is no hidden information, the relevant transparent contract for the type-i agent is C_i^{bal}, as defined in Section 3, with the incentive coefficient β in C_i^{bal} set equal to $\overline{e}^{EAR} + \lambda \underline{e}^{EAR}$. For parts (ib), (ii), and (iii), the relevant transparent contract is an ST contract, as also defined in Section 3, with β again set equal to $\overline{e}^{EAR} + \lambda \underline{e}^{EAR}$. Both of these contracts impose strictly lower risk costs on the agent than EAR because they avoid the explicit randomization and because, by virtue of weighting the two performance measures more equally than under EAR, they better diversify the risks from the shocks to measured performance.

In each of the four parts of Proposition 4, the constructed transparent contract yields a higher overall expected payoff to the principal than EAR because, in addition to imposing lower overall risk costs on the agent and inducing the same effort costs, it generates a weakly larger benefit $\frac{\delta \underline{e} + \overline{e}}{\delta + 1}$ for the principal. In part (ia), given the absence of hidden information, the contract C_i^{bal} generates perfectly balanced efforts from the type-i agent, whereas EAR does not. In parts (ib) and (ii), the constructed ST contract induces exactly the same effort pair from each type of agent as EAR does (perfectly balanced in the former case, where $\lambda = 1$, and fully focused in the latter). Finally, in part (iii), the principal's benefit is higher from the ST contract because, when $\delta \leq \lambda$, the fully focused efforts induced by the ST contract are socially more efficient than the partially balanced efforts induced by EAR.

Proposition 4 highlights that although opaque contracts can mitigate the gaming problem, there are a variety of settings in which the principal will not want to use them, because these incentive benefits are outweighed by the cost of compensating the agent for the imposition of greater risk. Proposition 4 also emphasizes that each of our three key model ingredients is *necessary* for EAR to outperform the best transparent menu. The next section identifies when these three key ingredients together are *sufficient* for EAR to do so.

6. When are opaque incentive schemes preferred?

■ We now analytically and later numerically identify environments in which opaque schemes, when designed optimally, strictly dominate the best transparent menu. In each of the three environments for which we prove the superiority of EAR analytically, this superiority follows in the limit from our demonstration that EAR allows the principal to achieve a payoff arbitrarily close to what she could achieve if she knew the agent's preferences across tasks, as in the NHI benchmark. Hence, in these limiting environments, EAR eliminates the efficiency losses from the agent's hidden information.

It may initially seem surprising that we can find environments in which optimally designed EAR yields the principal a payoff arbitrarily close to her NHI benchmark payoff. The explanation is as follows. In each of our three limiting environments, EAR, with the weighting parameter k adjusted optimally, *simultaneously* induces essentially perfectly balanced efforts and diversifies the risk from the shocks to measured performance as well as in the NHI benchmark.

Despite our focus on limiting environments, our analytical results are strong in two respects. First, they show not only that optimally designed EAR outperforms the best transparent menu under hidden information, but also that it approximates the principal's payoff in the NHI benchmark. Second, they show that *for any level of aggregate effort to be induced,* EAR dominates the best transparent menu. Hence, even without optimizing the overall intensity of incentives, we can be sure that in these environments (and those close to them), EAR dominates. Thus, even if the benefit component of the principal's payoff were scaled up or down relative to the wage cost, the results of Propositions 5, 6, and 7 would continue to hold.

□ **Weak preferences across tasks for the agent.** Consider first a setting in which the agent has private information about his preferences, but the magnitude of his preference across tasks is very weak. Formally, we study the case in which λ is strictly greater than but arbitrarily close to 1, which we term the limiting case as $\lambda \to 1^+$.

We saw in Section 4 that under EAR, the agent's effort choices and the principal's payoff are continuous in λ at $\lambda = 1$. This robustness of EAR to the introduction of hidden information underlies the superiority of this scheme as $\lambda \to 1^+$, as we now show.

Proposition 2 shows that as $\lambda \to 1$, so the two tasks become equally costly, $\overline{e} - \underline{e} \to 0$ for any $k \in (-1, 1)$ under EAR. Equations (6) and (7) show how varying k affects the principal's payoff from EAR, $\Pi^{EAR}(B, k)$, holding fixed at $\frac{B}{1+\lambda}$ the level of aggregate effort induced. Whereas in general, as discussed in Section 4, increasing k has conflicting effects on $\Pi^{EAR}(B, k)$, in the limit as $\lambda \to 1$, the situation is dramatically simpler:

$$\lim_{\lambda \to 1} \Pi^{EAR}(B, k) = \frac{B}{4} - \frac{B^2}{8} - \frac{1}{2} r\sigma^2 B^2 \left(\frac{1 + 2\rho k + k^2}{(1 + k)^2} \right). \tag{8}$$

Because, as $\lambda \to 1$, efforts under EAR become perfectly balanced, the risk cost imposed by the randomization tends to zero. Hence, an increase in k has only one effect on $\Pi^{EAR}(B, k)$, holding B fixed: it improves the diversification of the shocks to measured performance, as reflected in the final term of (8). Thus, as $\lambda \to 1$, $\Pi^{EAR}(B, k)$ is increasing in k (strictly so for $\rho < 1$), as long as k induces interior solutions, which it does as long as $k < \frac{1}{\lambda}$. Therefore, as $\lambda \to 1$, $\Pi^{EAR}(B, k)$ is maximized, for any B, by setting k arbitrarily close to, but less than, 1 ($k \to 1^-$). With k set in this way, the principal's payoff approaches

$$\lim_{k \to 1} \lim_{\lambda \to 1} \Pi^{EAR}(B, k) = \frac{B}{4} - \frac{B^2}{8} - \frac{1}{4} r\sigma^2 B^2 (1 + \rho). \tag{9}$$

The right-hand side of (9) equals the payoff the principal would achieve, if λ were exactly equal to 1, from a symmetric transparent (ST) contract with $\beta = \frac{B}{2}$, because such a contract would induce effort $\frac{B}{4}$ on each task and generate the same diversification of the shocks as EAR does when $k \to 1^-$.[28] Thus, for any B, as $\lambda \to 1^+$, the principal's payoff under optimally weighted EAR is arbitrarily close to that from an ST contract when the agent has no preference between tasks.[29]

[28] See equation (A1) in the proof of Lemma 1 in Appendix A, and set $\lambda = 1$.

[29] Note that when $\lambda = 1$, an ST contract leaves the agent indifferent to how total effort is split between the tasks, whereas under EAR, for any $k < 1$, the optimal allocation of efforts is unique. Thus, when $\lambda = 1$, with the weighting

For the NHI benchmark, Section 3 shows that the efforts and payoff from the contract pair (C_1^{bal}, C_2^{bal}) are continuous at $\lambda = 1$, where they match the efforts and payoff from the ST contract. Lemma 1 shows that as $\lambda \to 1$, a pair of the form (C_1^{bal}, C_2^{bal}) is strictly optimal for the principal as long as $\delta > \lim_{\lambda \to 1} \delta^{NHI}(\lambda, r\sigma^2, \rho)$. On the other hand, Proposition 1 shows that under hidden information, even as $\lambda \to 1^+$, the principal's maximized payoff from a transparent menu is bounded away from that in the NHI benchmark, because even for λ arbitrarily close to 1, it is impossible to induce positive efforts on both tasks from both types of agent.

The arguments in the preceding paragraphs together imply:

Proposition 5. Consider the limiting case as $\lambda \to 1^+$. Under EAR, for any given level of aggregate effort, $\overline{e} + \lambda \underline{e}$, to be induced:

(i) the gap in efforts, $\overline{e} - \underline{e}$, approaches 0 for any $k \in (-1, 1)$;
(ii) the optimal value of $k \to 1^-$;
(iii) with k adjusted optimally, the principal's payoff under EAR approaches her payoff in the NHI benchmark from (C_1^{bal}, C_2^{bal}). This limiting payoff equals the principal's payoff from the symmetric transparent (ST) contract at $\lambda = 1$.

Therefore, for $\delta > \lim_{\lambda \to 1} \delta^{NHI}(\lambda, r\sigma^2, \rho)$, EAR with k and β adjusted optimally strictly dominates the best transparent menu under hidden information.

□ **Large risk aversion and small variance of the shocks.** Consider now the effect of increasing the agent's coefficient of absolute risk aversion r, holding fixed the value of the product $r\sigma^2$. This change has no impact on the principal's payoff from any transparent scheme, because with transparent schemes, the agent's efforts are independent of r and the risk premium from the shocks to measured performance depends on r only via the product $r\sigma^2$. This change does, however, increase the principal's payoff under EAR, as long as EAR induces interior solutions for efforts. The reason is that, as shown by equations (1) and (2), an increase in the agent's risk aversion r has no effect on the aggregate effort induced by EAR, but strengthens the agent's incentive to self-insure against the wage risk from the randomization. The resulting reduction in $\overline{e} - \underline{e}$ both raises the principal's benefit, as shown in equation (7), and reduces the cost of compensating the agent for the risk from the randomization, as shown by the final term in (6). To summarize:

Lemma 3. Holding $r\sigma^2$ fixed, increasing r increases the principal's payoff from EAR, as long as EAR induces interior solutions for efforts, but leaves the principal's payoff from any transparent scheme unchanged.

It follows from Lemma 3 that the more risk-averse the agent, holding $r\sigma^2$ fixed, the more likely it is that optimally designed EAR will dominate the best transparent menu. We now consider the limiting case where r gets very large and σ^2 gets very small, with $r\sigma^2$ fixed at $R < \infty$. Proposition 2 shows that, in this environment, for any $k \in (-1, \frac{1}{\lambda})$, $(\overline{e} - \underline{e}) \to 0$ under EAR. As the agent becomes infinitely risk-averse, it becomes optimal for him to choose perfectly balanced efforts, which provide full self-insurance against the wage risk generated by the randomization.

Under EAR, in the limit as $r \to \infty$ and $\sigma^2 = \frac{R}{r} \to 0$, both $\overline{e}$ and $\underline{e}$ approach $\frac{B}{(\lambda+1)^2}$ (as long as $k < \frac{1}{\lambda}$). As a consequence, $\Pi^{EAR}(B, k)$, as given by equations (6) and (7), simplifies to

$$\lim_{r \to \infty, \sigma^2 = R/r \to 0} \Pi^{EAR}(B, k) = \frac{B}{(\lambda + 1)^2} - \frac{B^2}{2(\lambda + 1)^2} - \frac{1}{2} R B^2 \frac{1 + 2\rho k + k^2}{(1 + k)^2}. \tag{10}$$

parameter k set arbitrarily close to (but less than) 1, EAR not only yields the principal a payoff arbitrarily close to the best-case payoff from the ST contract, but EAR also ensures that the agent has a *strict* preference for choosing perfectly balanced efforts.

Equation (10) shows that, in this limiting case, the only effect on $\Pi^{EAR}(B, k)$ of increasing k, over the range $k \in (-1, \frac{1}{\lambda})$ where the induced gap in efforts $(\overline{e} - \underline{e})$ is approximately 0, is to improve the diversification of the shocks to measured performance. Hence, just as when $\lambda \to 1^+$, it is optimal for the principal to set k arbitrarily close to, but less than, $\frac{1}{\lambda}$ $(k \to (\frac{1}{\lambda})^-)$, thereby generating a payoff approaching

$$\lim_{k \to (1/\lambda)^-} \lim_{r \to \infty, \sigma^2 = R/r \to 0} \Pi^{EAR}(B, k) = \frac{B}{(\lambda+1)^2} - \frac{B^2}{2(\lambda+1)^2} - \frac{1}{2} R B^2 \frac{\lambda^2 + 2\rho\lambda + 1}{(\lambda+1)^2}. \tag{11}$$

The right-hand side of (11) is exactly the payoff the principal would obtain, in the NHI benchmark, from using (C_1^{bal}, C_2^{bal}) with $\beta = \frac{B}{1+\lambda}$, because this pair of contracts would induce from each type of agent effort $\frac{B}{(\lambda+1)^2}$ on each task and would impose a risk premium (from the shocks to measured performance) given by the final term.[30]

Thus, as $r \to \infty$ and $\sigma^2 = \frac{R}{r} \to 0$, optimally weighted EAR allows the principal, for any B, to get arbitrarily close to her payoff in the NHI benchmark. By Proposition 1, the best transparent menu under hidden information leaves the principal strictly worse off than in the NHI benchmark whenever $\delta > \delta^{NHI}(\lambda, R, \rho)$. Thus, we have proved:

Proposition 6. Consider the limiting case where $r \to \infty$ and $\sigma^2 = \frac{R}{r} \to 0$. Under EAR, for any given level of aggregate effort, $\overline{e} + \lambda\underline{e}$, to be induced:

(i) the gap in efforts, $\overline{e} - \underline{e}$, approaches 0 for any λ and for any $k < \frac{1}{\lambda}$;
(ii) the optimal value of $k \to (\frac{1}{\lambda})^-$;
(iii) with k adjusted optimally, the principal's payoff under EAR approaches her payoff in the NHI benchmark from (C_1^{bal}, C_2^{bal}).

Therefore, for $\delta > \delta^{NHI}(\lambda, R, \rho)$, EAR with k and β adjusted optimally strictly dominates the best transparent menu under hidden information.

□ **High correlation between the shocks or small variance.** Our third limiting environment is one in which diversification of the risk from the shocks to the performance measures becomes irrelevant, either because the correlation, ρ, between the shocks approaches 1 or because their variance, σ^2, approaches 0. Proposition 3 showed that as $\sigma^2(1-\rho)$, which captures the importance of diversification of the risk from the shocks, falls, the optimal value of the weighting factor k under EAR falls, for any given level of aggregate effort induced. As $\sigma^2(1-\rho)$ approaches 0, the principal's payoff $\Pi^{EAR}(B, k)$, given in (6) and (7), becomes a *decreasing* function of k, for any given B, because the risk premium due to the shocks, $\frac{1}{2} r\sigma^2 B^2 \frac{1+2\rho k + k^2}{(1+k)^2}$, becomes independent of k in this limit.

Hence, when $\sigma^2(1-\rho) \to 0$, it becomes optimal under EAR to use k to induce essentially perfectly balanced efforts, by setting k arbitrarily close to, but larger than, -1 $(k \to -1^+)$. With k set in this way, for the case $\rho \to 1$, the principal achieves under EAR a payoff arbitrarily close to[31]:

$$\lim_{k \to -1^+} \lim_{\rho \to 1} \Pi^{EAR}(B, k) = \frac{B}{(\lambda+1)^2} - \frac{B^2}{2(\lambda+1)^2} - \frac{1}{2} r\sigma^2 B^2. \tag{12}$$

Similarly, for the case $\sigma^2 \to 0$, the principal's payoff under EAR approaches

$$\lim_{k \to -1^+} \lim_{\sigma^2 \to 0} \Pi^{EAR}(B, k) = \frac{B}{(\lambda+1)^2} - \frac{B^2}{2(\lambda+1)^2}. \tag{13}$$

[30] See equation (A1) in Appendix A, and set $r\sigma^2 = R$.

[31] As k is lowered, the coefficient β must be raised to keep aggregate effort, which is proportional to $B \equiv \beta(1+k)$, fixed. The value of k must remain slightly larger than -1 to ensure that aggregate effort is strictly positive.

The right-hand side of (12) (respectively, (13)) matches what the principal would obtain, in the NHI benchmark with $\rho = 1$ (respectively, $\sigma^2 = 0$), from using (C_1^{bal}, C_2^{bal}) to induce perfectly balanced efforts and setting $\beta = \frac{B}{1+\lambda}$.[32] Thus, in this limiting environment as well, optimally weighted EAR yields the principal as high a payoff as in the absence of hidden information, for any level of aggregate effort induced. Combining these results with Proposition 1 yields:

Proposition 7. Consider the limiting case where $\sigma^2(1-\rho) \to 0$. Under EAR, for any given level of aggregate effort, $\overline{e} + \lambda \underline{e}$, to be induced:

(i) the optimal value of $k \to -1^+$, and the resulting gap in efforts, $\overline{e} - \underline{e}$, approaches 0 for any λ;
(ii) with k adjusted optimally, the principal's payoff under EAR approaches her payoff in the NHI benchmark from (C_1^{bal}, C_2^{bal}).

Therefore, for all δ such that it is optimal in the NHI benchmark to induce perfectly balanced efforts, EAR with k and β adjusted optimally strictly dominates the best transparent menu under hidden information.

□ **Numerical results.** A general analytic characterization of the optimal values of the weighting factor k and the incentive intensity β under EAR is prohibitively complex. As shown in equations (6) and (7), k has complicated nonlinear effects on the principal's payoff, and even if k were fixed at some specified value (e.g., 0), the optimal β would be the solution to a cubic equation, because increasing β not only increases incentives for aggregate effort (equation (1)), but also strengthens the agent's self-insurance motive for balancing efforts (equation (2)).

This section uses numerical methods to optimize both the weighting factor k and the incentive intensity β under EAR. We then compare the principal's maximized payoff under EAR to that under the best transparent menu. Recall that the best transparent menu, characterized in Proposition 1, is either an asymmetric transparent menu (ATM), inducing one type of agent to choose perfectly balanced efforts and the other fully focused efforts, or a symmetric transparent menu (STM), inducing both types to choose fully focused efforts. The numerical analysis demonstrates the robustness of the effects highlighted by our analyses of limiting environments. Specifically, it confirms that the benefits of EAR in inducing balanced efforts are more likely to outweigh the extra risk costs it imposes when (i) the agent's privately known preference between tasks is weaker (λ is smaller), so for any weighting factor k his optimal effort profile is more balanced, (ii) the agent is more risk-averse (r is larger), so EAR generates a stronger self-insurance motive for effort balance, (iii) efforts on the tasks are more complementary for the principal (δ is higher), or (iv) the errors in measuring performance have larger correlation (ρ is larger) or smaller variance (σ^2 is smaller), so there is less of a diversification cost to designing EAR to induce highly balanced efforts.

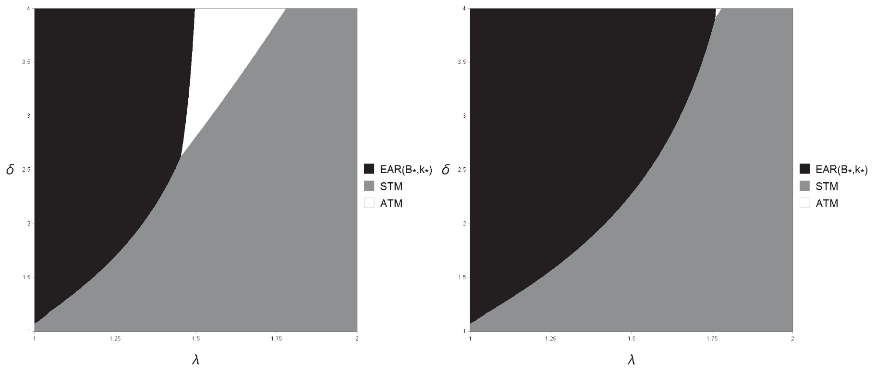
Figure 4(a) plots the regions in which EAR (black), STM (gray), or ATM (white) are optimal for the principal for different combinations of the agent's preference parameter λ and the principal's task complementarity parameter δ, holding the other parameters fixed at $r = 4$, $\sigma^2 = 0.02$, and $\rho = 0$. EAR is optimal for λ not too large and δ sufficiently large. As the strength λ of the agent's preference between tasks rises, and hence his optimal effort gap, *ceteris paribus*, becomes larger, it eventually becomes too costly for the principal to compensate him for the total costs of the risk imposed by EAR, even when δ, capturing the importance of effort balance to the principal, is high. Consistent with Proposition 1, between the two types of transparent menus ATM and STM, the former is optimal only when δ is sufficiently large relative to λ.

Figure 4(b) shows how the dominance regions for the three incentive schemes change as the agent's risk aversion r increases and the variance σ^2 of the shocks to the performance measures falls, holding $r\sigma^2$ constant (and keeping $\rho = 0$). The contrast between Figures 4(a) and 4(b)

[32] See equation (A1) in Appendix A, and set $\rho = 1$ (respectively, $\sigma^2 = 0$).

FIGURE 4

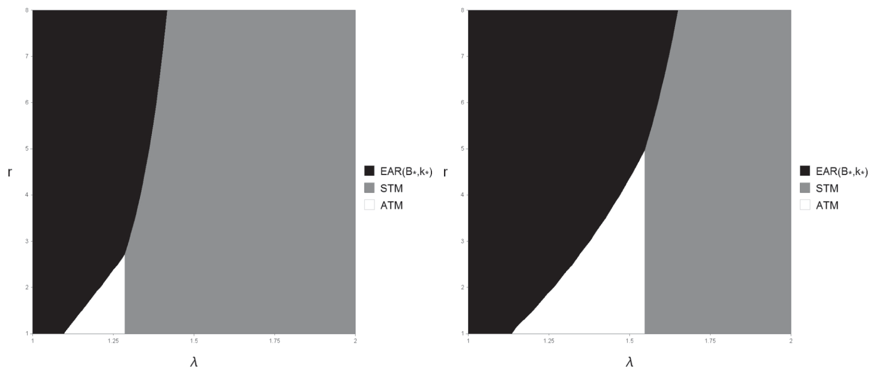
Optimal schemes for different combinations of λ and δ, with $\rho = 0$



(a) $r = 4$ and $\sigma^2 = 0.02$ (b) $r = 8$ and $\sigma^2 = 0.01$

FIGURE 5

Optimal schemes for different combinations of λ and *r*, with $r\sigma^2 = 0.08$ and $\rho = 0$



(a) $\delta = 2$ (b) $\delta = 3$

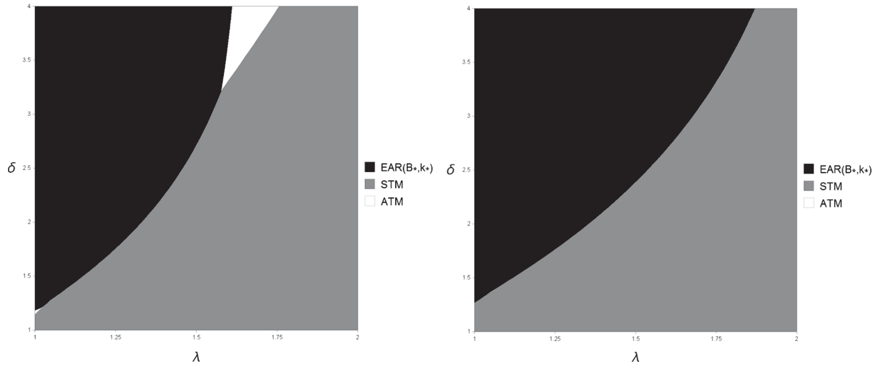
illustrates the implication of Lemma 3 in Section 6: increasing the risk aversion of the agent, holding $r\sigma^2$ constant, expands the region in parameter space in which EAR outperforms the best transparent menu. The expansion of the dominance region for EAR occurs primarily at the expense of the dominance region for ATM.

Figure 5(a) plots the dominance regions for different combinations of the agent's preference parameter λ and risk aversion r, adjusting σ^2 as r changes so as to keep $r\sigma^2$ constant at 0.08 and fixing $\delta = 2$ and $\rho = 0$. As implied by Lemma 3 and Proposition 6, for any λ there is a critical value of r above which EAR is superior to the best transparent menu. Figure 5(a) shows that this critical value of r is increasing in λ, because as λ increases, inducing balanced efforts under EAR necessitates imposing greater risk on the agent. Furthermore, this critical r increases more steeply with λ for (the large) values of λ for which STM dominates ATM. This is because the payoff from STM is independent of λ, whereas that from ATM (like that from EAR) declines with λ.

Figure 5(b) shows how the dominance regions change as the principal's task complementarity parameter δ increases from 2 to 3, keeping everything else the same as in Figure 5(a). As balanced efforts become more important to the principal, the dominance region for EAR expands, as does

FIGURE 6

Optimal schemes for different combinations of λ and δ, with $r = 4$ and $\sigma^2 = 0.02$



(a) $\rho = 0.5$ (b) $\rho = 0.9$

that for ATM. These expansions arise because EAR and ATM, unlike STM, achieve some degree of effort balance.

Figures 6(a) and 6(b) show that raising the correlation ρ of the shocks to the performance measures improves the performance of EAR relative to that of the transparent menus. These figures plot the dominance regions for different combinations of λ and δ, using the same parameter values as Figure 4(a) (where $\rho = 0$), except that now $\rho = 0.5$ and $\rho = 0.9$. Contrasting these three figures shows that the dominance region for EAR expands with the increase in ρ, primarily at the expense of that for ATM. Consistent with Propositions 3 and 7, the relative attractiveness of optimally designed EAR increases as ρ rises, because there is less of a diversification cost to using a low value of the weighting factor k to induce highly balanced efforts. For exactly the same reason, the dominance region for EAR expands when the variance σ^2 of the shocks falls.[33]

These numerical results demonstrate the robustness of the effects highlighted by our analytical results for the limiting environments. They confirm that EAR is more likely to dominate the best transparent menu when the agent's privately known preference between tasks is weaker, when the agent is more risk-averse, when the tasks are more complementary for the principal, or when the shocks to the performance measures have higher correlation or lower variance.

7. Extensions and robustness

□ **Alternative assumptions on the principal's commitment powers.** We have analyzed the trade-offs involved in the choice between transparent and opaque incentive schemes under the assumption that under EAR the principal can, before the agent makes his effort choices, commit to randomizing uniformly between the two compensation schedules.[34] It is natural to wonder whether opaque incentive schemes corresponding to alternative assumptions about the principal's commitment powers would change our conclusions.

Assume, instead, that the principal chooses the randomizing probability at the same time as the agent chooses efforts. We term this incentive scheme *interim randomization*. We can prove that under interim randomization, the unique (Bayes-Nash) equilibrium is exactly the same as the outcome described in Proposition 2, so all of our results on the benefits and costs of opacity

[33] To save space, we have omitted the figures illustrating this last result.

[34] Given the power to commit to a randomizing probability, it is optimal for the principal to commit to randomize uniformly. Doing so results in the most balanced profile of effort choices, assessed *ex ante*, and also avoids leaving any rent to either type of agent.

continue to hold.[35] Thus, the attractive properties of EAR are not crucially dependent on the principal's having the power to commit to the randomizing probability.

We also obtain qualitatively similar results for another class of opaque incentive schemes. Under a contract with *ex post discretion* (EPD), the principal, *after* observing the performance measures x_1 and x_2, chooses whether to pay the agent according to $w = \alpha + \beta x_1 + k\beta x_2$ or $w = \alpha + \beta x_2 + k\beta x_1$, where again $k \in (-1, 1)$. EPD provides the agent with the same self-insurance motive but also generates an additional incentive for effort balance. The principal's strategic *ex post* choice of which linear schedule to use means that the more the agent focuses his effort on his preferred task, the less likely that task is to be the more highly compensated one, so the lower the relative marginal return to that task. In an earlier version of this article (Ederer, Holden, and Meyer, 2014), we showed that the opaque incentives resulting from EPD generate at least as great a payoff for the principal as EAR. This is because (i) EPD induces a strictly smaller gap in efforts $\overline{e} - \underline{e}$ than EAR, but the two schemes induce the same aggregate effort $\overline{e} + \lambda\underline{e}$ and hence the same total cost of effort, and because (ii) EPD imposes lower risk costs on the agent than EAR. As a result, the beneficial incentive effects of EAR are robust even if the agent suspects that the principal might deviate to EPD.

□ **Imperfect substitutability of efforts for the agent.** So far, we have assumed that efforts are perfect substitutes in the agent's cost function. This assumption does not qualitatively affect the performance of EAR, but it simplifies the analysis of transparent schemes. However, even with some substitutability of efforts, transparent schemes continue to suffer dramatically from the problem of gaming by an agent with hidden information. As we show in Appendix B, it remains true that (i) if tasks are sufficiently complementary for the principal, EAR is superior to transparent menus in settings where EAR generates very strong incentives for balanced efforts, and (ii) in such settings, EAR eliminates the efficiency losses from the agent's hidden information.

□ **Opaque incentives and the choice of how many tasks to reward.** We have assumed so far that the job performed by the agent involves only two distinct tasks (dimensions) and that noisy measures of performance on both tasks are used in opaque incentive schemes. When, however, performance on a job has many distinct dimensions, the costs of monitoring the different dimensions may become significant. The principal can economize on monitoring costs, while still providing incentives for balanced efforts, by randomizing over compensation schedules each of which rewards only a subset of the tasks. In Appendix B, we study some of the trade-offs involved in the design of randomized incentive schemes in environments with many tasks. We find that reducing the number of tasks randomly selected to be rewarded, holding fixed the aggregate effort induced, has qualitatively the same effects on the agent's incentives and on the principal's payoff as reducing the weighting coefficient k in EAR in the two-task model. Analogously with Proposition 3, therefore, the optimal number of tasks to reward is smaller, (i) the stronger the principal's preference for balanced efforts, (ii) the less risk-averse the agent (holding $r\sigma^2$ fixed), (iii) the lower the importance of diversification of the risk from the shocks to measured performance, and (iv) the smaller the level of aggregate effort to be induced.

[35] To see that the outcome described in Proposition 2 is *an* equilibrium under interim randomization, note that given that the two types of agent are equally likely and given that their effort profiles are mirror images, the principal anticipates equal expected output on the two tasks, so is willing to randomize uniformly over the two mirror-image compensation schedules. Given that the principal randomizes uniformly, the optimal behavior for each type of agent is clearly as described in the proposition. To see that this outcome is the *unique* equilibrium, observe that if the two types of agent conjectured that the principal would assign a probability greater than (less than) 1/2 to the schedule rewarding task 1 more highly than task 2, then from the principal's point of view, the *ex ante* expected profile of efforts chosen by the agents would be skewed toward task 1 (task 2), so the principal would strictly prefer to choose the schedule rewarding task 2 more (less) highly than task 1.

8. Conclusion

■ Gaming of incentive schemes is a serious concern to incentive designers in a wide range of settings. We analyzed a principal-agent model in which the agent's superior information about the environment leads to severe gaming of menus of transparent linear contracts. In contrast, opaque incentive schemes not only mitigate the agent's gaming but can yield a higher overall payoff for the principal, despite imposing additional risk on the agent. In general, the principal faces a trade-off between the benefits of the more efficient effort allocations induced by opaque schemes and the costs of the greater risk they impose.

We showed that opaque schemes are superior when (i) the agent's privately known preference between tasks is weak, so even a small degree of opacity generates a high degree of effort balance; or (ii) the agent's risk aversion is significant, so opaque schemes give him a powerful self-insurance motive for balancing efforts; or (iii) the principal values effort balance highly; or (iv) the errors in measuring performance on the tasks have large correlation or small variance. Our analysis also identifies conditions under which the benefits of opacity in mitigating gaming are outweighed by the higher wages that it forces the principal to pay because of the greater risk imposed on the agent.

We emphasize that, because of the agent's hidden information, opaque schemes can dominate transparent ones even when pay can be based upon measured performance on both tasks. When costs of measurement constrain an incentive designer to use only one performance measure, the attractiveness of opacity about which task will be measured and rewarded is clearly significantly enhanced relative to the best transparent contract rewarding only one task.

Our analysis suggests that even beyond the specific multitask setting on which we have focused, opacity of incentive schemes can be a valuable tool for incentive designers when there are restrictions on the complexity of reward schemes or when resources for monitoring agents are limited. By making agents more uncertain about the consequences of their actions for their rewards, opaque schemes can help principals mitigate the costs of gaming by agents who are exploiting their hidden information. Future research should explore the benefits of opaque incentive schemes in deterring gaming in other settings, identifying under what conditions these incentive benefits can outweigh the risk costs of opacity.

Appendix A

This appendix contains proofs for all the main results of the article.

Proof of Lemma 1. Consider first the pair of contracts (C_1^{bal}, C_2^{bal}). Under our assumption on the agent's behavior when indifferent over effort pairs, C_i^{bal} induces agent i to choose $e_i = e_j = \frac{\beta}{1+\lambda}$, yielding each type i a certainty equivalent of

$$ACE_i\left(C_i^{bal}\right) = E(w_i) - c_i(e_1, e_2) - \frac{1}{2} r\sigma^2 var(w_i) = \alpha + \beta^2 - \frac{\beta^2}{2} - \frac{1}{2} r\sigma^2\beta^2(1 + 2\rho\lambda + \lambda^2).$$

The principal will set α to satisfy each type's participation constraint with equality, and her expected payoff from each type, as a function of β, will be

$$\Pi^{bal}(\beta) = \frac{\beta}{1+\lambda} - \frac{\beta^2}{2} - \frac{1}{2} r\sigma^2\beta^2(1 + 2\rho\lambda + \lambda^2). \quad (A1)$$

With β chosen optimally, the resulting maximized payoff is

$$\Pi^{bal} = \frac{1}{2(1+\lambda)^2\left[1 + r\sigma^2(1 + 2\rho\lambda + \lambda^2)\right]}. \quad (A2)$$

This payoff is continuous as $\lambda \to 1$.

Now consider the pair of contracts (C_1^{foc}, C_2^{foc}). C_i^{foc} induces type i to choose $e_i = \beta$ and $e_j = 0$. The principal will set α to satisfy each type's participation constraint with equality, and her expected payoff from each type, as a function of β, will then be

$$\Pi^{foc}(\beta) = \frac{\beta}{\delta + 1} - \frac{\beta^2}{2} - \frac{1}{2} r\sigma^2\beta^2\left(1 - \rho^2\right).$$

With β chosen optimally, the resulting maximized payoff is

$$\Pi^{foc} = \frac{1}{2(\delta+1)^2[1+r\sigma^2(1-\rho^2)]}. \tag{A3}$$

Comparison of the expressions for Π^{bal} and Π^{foc} shows that there is a critical value of δ,

$$\delta^{NHI}(\lambda, r\sigma^2, \rho) \equiv (\lambda+1)\left[\frac{1+r\sigma^2(1+2\rho\lambda+\lambda^2)}{1+r\sigma^2(1-\rho^2)}\right]^{\frac{1}{2}} - 1, \tag{A4}$$

above (below) which $\Pi^{bal} > (<)\, \Pi^{foc}$. It is straightforward to verify that δ^{NHI} is increasing in each of its arguments. ■

Proof of Lemma 2. For a transparent menu of linear contracts to induce both types of agent to exert strictly positive efforts on both tasks, it is necessary that each type be induced to choose a contract that equates the (constant) ratio of the marginal benefits of efforts on the tasks to the (constant) ratio, for that type, of the marginal costs. Therefore, if such a menu existed, it would have the form

$$C_1: \ w_1 = \alpha_1 + \beta_1 x_1 + \lambda\beta_1 x_2 \quad \text{and} \quad C_2: \ w_2 = \alpha_2 + \beta_2 x_2 + \lambda\beta_2 x_1,$$

and would induce agent i to choose C_i.

Let $ACE_i(C_j)$ denote the certainty equivalent achieved by agent i from selecting contract C_j and choosing efforts optimally. For agent 1 to be willing to choose C_1 requires $ACE_1(C_1) \geq ACE_1(C_2)$, and the analogous self-selection constraint for agent 2 is $ACE_2(C_2) \geq ACE_2(C_1)$. Now for all $\lambda > 1$, $ACE_2(C_1) > ACE_1(C_1)$, because agent 1's certainty equivalent from contract C_1 equals that which he would obtain from focusing all his effort on task 1 (which is one of his optimal effort allocations), whereas agent 2's certainty equivalent from C_1 equals that which he would obtain from focusing all his effort on task 2 (which is his unique optimal effort choice), and task 2 is more highly rewarded than task 1 in contract C_1. Similarly, for all $\lambda > 1$, $ACE_1(C_2) > ACE_2(C_2)$. If $ACE_1(C_1) \geq ACE_2(C_2)$, then $ACE_2(C_1) > ACE_1(C_1)$ implies that $ACE_2(C_1) > ACE_2(C_2)$, so the self-selection constraint for agent 2 would be violated. If, instead, $ACE_1(C_1) < ACE_2(C_2)$, then $ACE_1(C_2) > ACE_2(C_2)$ implies that $ACE_1(C_1) < ACE_1(C_2)$, so the self-selection constraint for agent 1 would be violated. Therefore, there is no way to choose $(\alpha_1, \beta_1, \alpha_2, \beta_2)$ so that the menu above induces both types of privately informed agent to choose the contract that would make each willing to choose perfectly balanced efforts. Hence, perfectly balanced efforts from both types of agents cannot be achieved.

Furthermore, faced with a menu of transparent linear contracts, an agent either is willing to exert perfectly balanced efforts or strictly prefers fully focused efforts. Therefore, this argument also shows that it is not possible for the principal to induce both types of agent to exert strictly positive efforts on both tasks. ■

Proof of Proposition 1.

Part (i). Consider first an STM, consisting of the contract pair

$$C_1^{STM}: \ w_1 = \alpha + \beta x_1 - \rho\beta x_2 \quad \text{and} \quad C_2^{STM}: \ w_2 = \alpha + \beta x_2 - \rho\beta x_1.$$

Agent i strictly prefers contract C_i to contract C_j and, having chosen C_i, will then set $e_i = \beta$ and $e_j = 0$. This STM generates the same outcome, for each type of agent, as the principal achieves in the NHI benchmark setting from the contract pair (C_1^{foc}, C_2^{foc}). Therefore, the principal's maximized payoff from an STM, Π^{STM}, is given by the expression in (A3). Compared to an STM, an ST contract would, for all $\lambda > 1$, also induce fully focused efforts from both agent types but would impose a larger risk premium and hence, generate a lower payoff for the principal.

Now consider an ATM, consisting of the contract pair

$$C_1^{ATM}: \ w_1 = \alpha_1 + \beta_1 x_1 - \rho\beta_1 x_2 \quad \text{and} \quad C_2^{ATM}: \ w_2 = \alpha_2 + \beta_2 x_2 + \lambda\beta_2 x_1.$$

In this menu, C_i is the contract intended for agent i. If agent 2 chooses C_2, he would be indifferent over all effort pairs such that $\beta_2 = e_1 + \lambda e_2$. Given our assumption on the agent's behavior when indifferent, agent 2 chooses the perfectly balanced effort allocation $e_1 = e_2 = \frac{\beta_2}{1+\lambda}$. If, instead, agent 2 chooses C_1, he would set $e_1 = \frac{\beta_1}{\lambda^2}$ and $e_2 = 0$. If agent 1 chooses C_1, he would set $e_1 = \beta_1$ and $e_2 = 0$, whereas if he chooses C_2, he would set $e_1 = \lambda\beta_2$ and $e_2 = 0$.

The certainty equivalents that each of C_1 and C_2 offers to each type of agent are:

$$ACE_1(C_1) = \alpha_1 + \frac{(\beta_1)^2}{2} - \frac{1}{2}r\sigma^2(\beta_1)^2(1-\rho^2); \ ACE_1(C_2) = \alpha_2 + \frac{(\lambda\beta_2)^2}{2} - \frac{1}{2}r\sigma^2(\beta_2)^2(\lambda^2+2\rho\lambda+1);$$

$$ACE_2(C_2) = \alpha_2 + \frac{(\beta_2)^2}{2} - \frac{1}{2}r\sigma^2(\beta_2)^2(\lambda^2+2\rho\lambda+1); \ ACE_2(C_1) = \alpha_1 + \frac{(\beta_1)^2}{2\lambda^2} - \frac{1}{2}r\sigma^2(\beta_1)^2(1-\rho^2).$$

As the principal is equally likely to be facing each type of agent, her problem is to choose $(\alpha_1, \beta_1, \alpha_2, \beta_2)$ to maximize

$$\frac{1}{2}\left[\frac{\beta_1}{\delta+1} - \alpha_1 - (\beta_1)^2\right] + \frac{1}{2}\left[\frac{\beta_2}{1+\lambda} - \alpha_2 - (\beta_2)^2\right],$$

subject to participation and self-selection constraints for both types of agent:

$$ACE_2(C_2) \geq 0 \quad \text{and} \quad ACE_2\,(C_2) \geq ACE_2(C_1),$$
$$ACE_1(C_1) \geq 0 \quad \text{and} \quad ACE_1\,(C_1) \geq ACE_1(C_2).$$

Because for all $\lambda > 1$ we have $ACE_1(C_2) > ACE_2(C_2)$, agent 1's participation constraint will not bind, and hence agent 1 earns an "information rent."

For the two self-selection constraints to be satisfied simultaneously, it is necessary that $\beta_1 \geq \lambda\beta_2$. For given (β_1, β_2), it is optimal for the principal to set α_2 so agent 2's participation constraint binds and to set α_1 so agent 1's self-selection constraint binds. Then, the constraint $\beta_1 \geq \lambda\beta_2$ is both necessary and sufficient for agent 2 to be willing to choose C_2. We may then restate the principal's problem as

$$\max_{\beta_1,\beta_2} \left\{ \begin{array}{l} \frac{1}{2}\left[\frac{\beta_1}{\delta+1} - \frac{(\beta_1)^2}{2} - \frac{1}{2}r\sigma^2(\beta_1)^2(1-\rho^2) - (\lambda^2-1)\frac{(\beta_2)^2}{2}\right] \\ +\frac{1}{2}\left[\left(\frac{\beta_2}{1+\lambda}\right) - \frac{(\beta_2)^2}{2} - \frac{1}{2}r\sigma^2(\beta_2)^2(\lambda^2+2\rho\lambda+1)\right] \end{array} \right\} \quad \text{s.t.} \quad \beta_1 \geq \lambda\beta_2.$$

There exists a $\hat{\delta}$ such that the constraint $\beta_1 \geq \lambda\beta_2$ will be binding at the optimum if and only if $\delta \geq \hat{\delta}$. If $\delta < \hat{\delta}$, then the principal's maximized payoff from this "unconstrained" ATM (ATMU) is

$$\Pi^{ATMU} = \frac{1}{4(\delta+1)^2}\left[\frac{1}{1+r\sigma^2(1-\rho^2)} + \frac{(1+\delta)^2}{(1+\lambda)^2}\frac{1}{\lambda^2+r\sigma^2(\lambda^2+2\rho\lambda+1)}\right],$$

whereas if $\delta \geq \hat{\delta}$, then her maximized payoff from the "constrained" ATM (ATMC) is

$$\Pi^{ATMC} = \frac{(\lambda^2+\lambda+\delta+1)^2}{8(\delta+1)^2(1+\lambda)^2\left\{\lambda^2 + r\sigma^2\left[\left(1-\frac{\rho^2}{2}\right)\lambda^2+\rho\lambda+\frac{1}{2}\right]\right\}}.$$

It remains to determine whether an ATM (unconstrained or constrained) or an STM is optimal. It can be checked that the crucial comparison is between Π^{STM} and Π^{ATMU} and furthermore that if

$$\delta < \delta^{HI}(\lambda, r\sigma^2, \rho) \equiv (\lambda+1)\sqrt{\frac{\lambda^2+r\sigma^2(\lambda^2+2\rho\lambda+1)}{1+r\sigma^2(1-\rho^2)}} - 1,$$

then the best STM dominates the best ATM, whereas if $\delta > \delta^{HI}(\lambda, r\sigma^2, \rho)$, then the best ATM dominates the best STM. We have $\delta^{HI} < \hat{\delta}$. This proves part (i).

Part (ii). This is easily confirmed algebraically.

Part (iii). This is proved in the second paragraph of the text following the statement of the proposition.

Part (iv). For $\delta > \delta^{HI}(1, r\sigma^2, \rho) = \delta^{NHI}(1, r\sigma^2, \rho)$, the limit as $\lambda \to 1$ of the principal's maximized payoff in the NHI benchmark is the limit as $\lambda \to 1$ of Π^{bal}, as given in equation (A2). Under hidden information, when $\delta > \delta^{HI}(1, r\sigma^2, \rho)$, the principal's best transparent menu for λ sufficiently close to 1 is an ATM. We know that $\Pi^{ATMC} \leq \Pi^{ATMU}$, and it is easy to confirm algebraically that for $\delta > \delta^{HI}(1, r\sigma^2, \rho)$,

$$\lim_{\lambda\to 1}\Pi^{ATMU} < \lim_{\lambda\to 1}\Pi^{bal}.$$

■

Proof of Proposition 2.

Parts (i) and (ii). For each type of agent, let $\overline{e}$ (respectively, $\underline{e}$) denote effort on his less costly (respectively, more costly) task, and define $\overline{x}$ and $\underline{x}$ analogously. Under EAR, with probability $\frac{1}{2}$, $w = \alpha + \beta\overline{x} + k\beta\underline{x}$, in which case we let $\overline{EU}$ denote an agent's expected utility, and with probability $\frac{1}{2}$, $w = \alpha + \beta\underline{x} + k\beta\overline{x}$, in which case we denote expected utility by $\underline{EU}$.

Recall that $k \in (-1, 1)$. Each agent's unconditional expected utility under EAR is

$$\begin{aligned}\frac{1}{2}\overline{EU} + \frac{1}{2}\underline{EU} &= -\frac{1}{2}E\exp\left\{-r\left[\alpha+\beta\overline{x}+k\beta\underline{x}-\frac{1}{2}(\overline{e}+\lambda\underline{e})^2\right]\right\} \\ &\quad -\frac{1}{2}E\exp\left\{-r\left[\alpha+\beta\underline{x}+k\beta\overline{x}-\frac{1}{2}(\overline{e}+\lambda\underline{e})^2\right]\right\} \\ &= -\frac{1}{2}\exp\left\{-r\left[\alpha+\beta\overline{e}+k\beta\underline{e}-\frac{r}{2}\sigma^2\beta^2(1+2\rho k+k^2)-\frac{1}{2}(\overline{e}+\lambda\underline{e})^2\right]\right\} \\ &\quad -\frac{1}{2}\exp\left\{-r\left[\alpha+\beta\underline{e}+k\beta\overline{e}-\frac{r}{2}\sigma^2\beta^2(1+2\rho k+k^2)-\frac{1}{2}(\overline{e}+\lambda\underline{e})^2\right]\right\}\end{aligned} \quad \text{(A5)}$$

Hence, the first-order conditions for interior solutions for $\overline{e}$ and $\underline{e}$, respectively, are

$$\frac{1}{2}\left[\beta - (\overline{e} + \lambda\underline{e})\right]\overline{EU} + \frac{1}{2}\left[k\beta - (\overline{e} + \lambda\underline{e})\right]\underline{EU} = 0$$

$$\frac{1}{2}\left[k\beta - \lambda\left(\overline{e} + \lambda\underline{e}\right)\right]\overline{EU} + \frac{1}{2}\left[\beta - \lambda\left(\overline{e} + \lambda\underline{e}\right)\right]\underline{EU} = 0.$$

These first-order conditions can be rewritten as

$$\beta\overline{EU} + k\beta\underline{EU} = (\overline{e} + \lambda\underline{e})(\overline{EU} + \underline{EU}) \tag{A6}$$

$$k\beta\overline{EU} + \beta\underline{EU} = \lambda(\overline{e} + \lambda\underline{e})(\overline{EU} + \underline{EU}). \tag{A7}$$

Equations (A6) and (A7) in turn imply

$$\overline{EU} + k\underline{EU} = \frac{k}{\lambda}\overline{EU} + \frac{1}{\lambda}\underline{EU}.$$

If $k \in [\frac{1}{\lambda}, 1)$, then the left-hand side of this equation strictly exceeds the right-hand side, so in this case interior solutions for efforts cannot exist. This proves Part (i).

Adding the first-order conditions (A6) and (A7) and rearranging yields equation (1). Using (1) to substitute for aggregate effort $(\overline{e} + \lambda\underline{e})$ in (A6) yields, after a little algebra, $(\lambda - k)\overline{EU} + (k\lambda - 1)\underline{EU} = 0$, which simplifies to equation (2).

Part (iii). Solving (2) for $\overline{e} - \underline{e}$ yields $\overline{e} - \underline{e} = [\ln(\frac{\lambda-k}{1-k\lambda})]/[r\beta(1-k)]$. For $k \in (-1, \frac{1}{\lambda})$ and $\lambda > 1$, therefore, $\overline{e} - \underline{e}$ is greater than 0, increasing in λ and k, and decreasing in $r\beta$. $(\overline{e} - \underline{e}) \to 0$ as $\lambda \to 1$, $k \to -1^+$, or $r\beta \to \infty$.

Part (iv). Using (1) and (2) to substitute into (A5), and then simplifying, allows us to express each type of agent's expected utility under EAR as

$$\frac{1}{2}\overline{EU} + \frac{1}{2}\underline{EU} = -\exp\left\{-r\left[\alpha + \beta(\overline{e} + k\underline{e}) - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1 + 2\rho k + k^2)\right.\right.$$
$$\left.\left. - \frac{1}{r}\ln\left(\frac{1 + \frac{\lambda-k}{1-k\lambda}}{2}\right)\right]\right\}.$$

Because both types receive the same expected utility, it is optimal for the principal to set α to ensure that their participation constraints bind. Setting α in this way (so that the whole expression in square brackets above is equal to 0), the principal's expected payoff, for given (β, k), can be simplified to equation (3) as follows:

$$\begin{aligned}\Pi^{EAR}(\beta, k) &= \frac{\delta\underline{e} + \overline{e}}{\delta + 1} - \alpha - \frac{1}{2}\beta(\overline{e} + k\underline{e}) - \frac{1}{2}\beta(\underline{e} + k\overline{e}) \\ &= \frac{\delta\underline{e} + \overline{e}}{\delta + 1} + \frac{1}{2}\beta(1-k)(\overline{e} - \underline{e}) - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1 + 2\rho k + k^2) - \frac{1}{r}\ln\left(\frac{1 + \frac{\lambda-k}{1-k\lambda}}{2}\right) \\ &= \frac{\delta\underline{e} + \overline{e}}{\delta + 1} - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1 + 2\rho k + k^2) - \frac{1}{2r}\ln\left[\frac{(\lambda+1)^2(1-k)^2}{4(1-k\lambda)(\lambda-k)}\right],\end{aligned}$$

where the final line uses (2). ■

Proof of Proposition 3. Define $B \equiv \beta(1+k)$ and note, from (1), that aggregate effort $\overline{e} + \lambda\underline{e}$ is proportional to B. Using (1), (2), and $\beta = \frac{B}{1+k}$ to substitute into (3) yields (6) and (7) in the text. To prove the claims regarding the effect of varying δ, r (with $r\sigma^2$ fixed), or $\sigma^2(1-\rho)$ on the optimal level of k, we use (6) and (7) to examine the sign of the cross-partial derivative of $\Pi^{EAR}(B, k)$ with respect to k and the relevant parameter, holding B and hence aggregate effort fixed. For Part (iv), we examine the sign of the cross-partial derivative of $\Pi^{EAR}(B, k)$ with respect to k and B.

Part (i). Only the second term on the right-hand side of (7) generates a nonzero value of $\frac{\partial^2\Pi}{\partial\delta\partial k}$. As long as $\delta > \lambda$, $\frac{\partial^2\Pi}{\partial\delta\partial k} < 0$, so the optimal k decreases as δ increases.

Part (ii). With $r\sigma^2$ held fixed, only the second term on the right-hand side of (7) and the fourth term in (6) vary as r increases. Examining these terms shows that $\frac{\partial^2\Pi}{\partial r\partial k} > 0$, so as r decreases (holding $r\sigma^2$ fixed), the optimal k decreases.

Part (iii). $\frac{\partial\Pi}{\partial k}$ depends on σ^2 and ρ only via the third term in (6), and $\frac{\partial\Pi}{\partial k}$ is increasing in $\sigma^2(1-\rho)$, so the optimal k decreases as $\sigma^2(1-\rho)$ decreases.

Part (iv). $\frac{\partial^2\Pi}{\partial B\partial k} > 0$, so as the B to be induced decreases, the optimal k decreases. ■

Proof of Proposition 4.

Part (ia). Given what will be shown in parts (ib), (ii), and (iii), it suffices to focus here on the case where $\delta > \lambda > 1$ and where EAR, for the given (β, k) with $k \in (-1, 1)$, induces interior optimal efforts. We will show that EAR yields a strictly lower expected payoff for the principal than a suitably designed contract of the form C_i^{bal}, as defined in Section 3.

Using equations (1) and (2) in Proposition 2 to substitute for $\bar{e}^{EAR}$ and $\underline{e}^{EAR}$ in equation (3), we have

$$\Pi^{EAR}(\beta, k) = \frac{\beta(1+k)}{(\lambda+1)^2} - \frac{\delta-\lambda}{\delta+1}\frac{\ln\left(\frac{\lambda-k}{1-k\lambda}\right)}{(\lambda+1)r\beta(1-k)} - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2}$$
$$-\frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2) - \frac{1}{2r}\ln\left[\frac{(\lambda+1)^2(1-k)^2}{4(1-k\lambda)(\lambda-k)}\right]$$
$$< \frac{\beta(1+k)}{(\lambda+1)^2} - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2).$$

The inequality follows from the assumptions that $\delta > \lambda > 1$ and $k > -1$ and the fact, proved in Part (i) of Proposition 2, that $k < \frac{1}{\lambda}$ is a necessary condition for EAR to induce interior optimal efforts.

If the principal knows which task the agent finds less costly, so we are in the NHI benchmark, the principal can induce the agent to choose perfectly balanced efforts by offering the type-i agent a contract of the form C_i^{bal}: $w = \alpha + \beta^{bal} + \lambda\beta^{bal}$ for some β^{bal}. By choosing $\beta^{bal} = \frac{\beta(1+k)}{\lambda+1}$, the principal can induce with C_i^{bal} the same aggregate effort as under EAR for the given values of β and k. Using $\beta^{bal} = \frac{\beta(1+k)}{\lambda+1}$ and equation (A1), we can write the principal's payoff under C_i^{bal} as

$$\Pi^{bal}(\beta^{bal}) = \frac{\beta(1+k)}{(\lambda+1)^2} - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\frac{\beta^2(1+k)^2}{(\lambda+1)^2}(1+2\rho\lambda+\lambda^2).$$

Hence,

$$\Pi^{bal}(\beta^{bal}) - \Pi^{EAR}(\beta, k) > \frac{1}{2}r\sigma^2\beta^2(1+k)^2\left[\frac{(1+2\rho k+k^2)}{(1+k)^2} - \frac{(1+2\rho\lambda+\lambda^2)}{(\lambda+1)^2}\right]$$
$$\geq 0,$$

where the second inequality follows because $k < 1/\lambda$ and because $\frac{(1+2\rho k+k^2)}{(1+k)^2}$ is decreasing in k and equals $\frac{(1+2\rho\lambda+\lambda^2)}{(\lambda+1)^2}$ for $k = 1/\lambda$. The second inequality is strict for $\rho < 1$.

Part (ib). We will show that for $\lambda = 1$ and any given (β, k) with $k \in (-1, 1)$, EAR yields a weakly lower expected payoff for the principal than a suitably designed symmetric transparent (ST) contract, of the form defined in Section 3, and a strictly lower expected payoff if $\rho < 1$.

For $\lambda = 1$, aggregate effort under EAR is $\bar{e}^{EAR} + \lambda\underline{e}^{EAR} = \frac{\beta(1+k)}{2}$, and $\bar{e}^{EAR} = \underline{e}^{EAR} = \frac{\beta(1+k)}{4}$. Hence, for $\lambda = 1$, equation (3) simplifies to

$$\Pi^{EAR}(\beta, k) = \frac{\beta(1+k)}{4} - \frac{1}{8}\beta^2(1+k)^2 - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2). \tag{A8}$$

Consider now an ST contract with coefficient β^{ST} chosen to induce the same level of aggregate effort as under EAR for the given values of β and k: $\beta^{ST} = \frac{\beta(1+k)}{2}$. Given that $\lambda = 1$, $\bar{e}^{ST} = \underline{e}^{ST} = \frac{\beta(1+k)}{4}$, so the ST contract induces exactly the same effort levels on each task as EAR. The principal's payoff under the ST contract is

$$\Pi^{ST}(\beta^{ST}) = \frac{\beta^{ST}}{2} - \frac{1}{2}(\beta^{ST})^2 - r\sigma^2(\beta^{ST})^2(1+\rho) = \frac{\beta(1+k)}{4} - \frac{1}{8}\beta^2(1+k)^2 - \frac{1}{4}r\sigma^2\beta^2(1+k)^2(1+\rho). \tag{A9}$$

Subtracting (A8) from (A9) yields

$$\Pi^{ST}(\beta^{ST}) - \Pi^{EAR}(\beta, k) = \frac{1}{2}r\sigma^2\beta^2[(1+2\rho k+k^2) - \frac{(1+\rho)}{2}(1+k)^2] = \frac{1}{4}r\sigma^2\beta^2(1-k)^2(1-\rho).$$

Hence, with $\lambda = 1$ and $\rho < 1$, $\Pi^{ST}(\beta^{ST}) - \Pi^{EAR}(\beta, k) > 0$. If $\rho = \lambda = 1$, then $\Pi^{ST}(\beta^{ST}) - \Pi^{EAR}(\beta, k) = 0$.

Part (ii). When EAR induces a corner solution for efforts (so $\underline{e}^{EAR} = 0$), the first-order condition (A6) for $\bar{e}^{EAR}$ reduces to:

$$\exp\left\{r\beta\bar{e}^{EAR}(1-k)\right\} = \frac{\beta - \bar{e}^{EAR}}{\bar{e}^{EAR} - k\beta}. \tag{A10}$$

Because the left-hand side of (A10) is strictly greater than 1 for $k < 1$, (A10) implies that $\bar{e}^{EAR} < \frac{\beta(1+k)}{2}$. When EAR induces each type of agent to choose the corner solution $(\bar{e}^{EAR}, 0)$, each type's expected utility can be written as

$$\frac{1}{2}\overline{EU} + \frac{1}{2}\underline{EU} = -\exp\left\{-r\left[\alpha + \beta\bar{e} - \frac{1}{2}\bar{e}^2 - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2) - \frac{1}{r}\ln\left(\frac{1+\exp\{r\beta(1-k)\bar{e}\}}{2}\right)\right]\right\}.$$

The principal optimally sets α so that both types' participation constraints bind (i.e., so that the whole expression in square brackets above is 0). Setting α in this way, the principal's expected payoff, for given (β, k), can be simplified as follows:

$$\begin{aligned}\Pi^{EAR}(\beta,k) &= \frac{\bar{e}}{\delta+1} - \alpha - \frac{1}{2}\beta\bar{e} - \frac{1}{2}\beta k\bar{e}\\ &= \frac{\bar{e}}{\delta+1} + \frac{1}{2}\beta(1-k)\bar{e} - \frac{1}{2}\bar{e}^2 - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2)\\ &\quad -\frac{1}{r}\ln\left(\frac{1+\exp\{r\beta(1-k)\bar{e}\}}{2}\right)\\ &= \frac{\bar{e}}{\delta+1} - \frac{1}{2}\bar{e}^2 - \frac{1}{2}r\sigma^2\beta^2\left(1+2\rho k+k^2\right) - \frac{1}{2r}\ln\left(\frac{[1+\exp\{r\beta(1-k)\bar{e}\}]^2}{4\exp\{r\beta(1-k)\bar{e}\}}\right)\\ &< \frac{\bar{e}}{\delta+1} - \frac{1}{2}\bar{e}^2 - \frac{1}{2}r\sigma^2\beta^2\left(1+2\rho k+k^2\right),\end{aligned}$$

where the inequality follows because $\exp\{r\beta\bar{e}^{EAR}(1-k)\} > 1$.

Consider now an ST contract with incentive coefficient β^{ST} chosen to induce the same effort pair $(\bar{e}^{EAR}, 0)$ as under EAR for the given values of β and k: $\beta^{ST} = \bar{e}^{EAR}$. The principal's payoff under this ST contract is

$$\Pi^{ST}(\beta^{ST}) = \frac{\bar{e}^{EAR}}{\delta+1} - \frac{1}{2}(\bar{e}^{EAR})^2 - r\sigma^2(\bar{e}^{EAR})^2(1+\rho). \tag{A11}$$

Therefore,

$$\begin{aligned}\Pi^{ST}(\beta^{ST}) - \Pi^{EAR}(\beta,k) &> \frac{1}{2}r\sigma^2\left[\beta^2(1+2\rho k+k^2) - 2(\bar{e}^{EAR})^2(1+\rho)\right]\\ &> \frac{1}{2}r\sigma^2\beta^2\left[(1+2\rho k+k^2) - \frac{(1+\rho)}{2}(1+k)^2\right]\\ &= \frac{1}{4}r\sigma^2\beta^2(1-k)^2(1-\rho)\\ &\geq 0,\end{aligned}$$

where the second strict inequality follows from the fact that $\bar{e}^{EAR} < \frac{\beta(1+k)}{2}$.

Part (iii). We will show that, when $\lambda \geq \delta \geq 1$, with at least one of these inequalities strict, then for any (β, k) with $k \in (-1, 1)$ such that EAR induces strictly positive efforts on both tasks, EAR yields a strictly lower expected payoff for the principal than a suitably designed ST contract.

Starting from equation (3) in Proposition 2, we can write

$$\begin{aligned}\Pi^{EAR}(\beta,k) &= \left(\frac{\delta\underline{e}^{EAR}+\bar{e}^{EAR}}{\delta+1}\right) - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2)\\ &\quad -\frac{1}{2r}\ln\left[\frac{(\lambda+1)^2(1-k)^2}{4(1-k\lambda)(\lambda-k)}\right]\\ &< \left(\frac{\delta\underline{e}^{EAR}+\bar{e}^{EAR}}{\delta+1}\right) - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2)\\ &\leq \left(\frac{\lambda\underline{e}^{EAR}+\bar{e}^{EAR}}{\delta+1}\right) - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2)\\ &= \frac{1}{\delta+1}\frac{\beta(1+k)}{\lambda+1} - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - \frac{1}{2}r\sigma^2\beta^2(1+2\rho k+k^2).\end{aligned}$$

The first inequality follows from the assumptions that $\lambda > 1$ and $k > -1$ and the fact that $k < \frac{1}{\lambda}$ is necessary for EAR to induce interior optimal efforts. The second inequality follows because $\lambda \geq \delta$, and the final equality follows from equation (1) in Proposition 2.

Consider now an ST contract with incentive coefficient β^{ST} chosen to induce the same aggregate effort as under EAR for the given values of β and k: $\beta^{ST} = \frac{\beta(1+k)}{1+\lambda}$. As $\lambda > 1$, the ST scheme induces $\overline{e} = \beta^{ST}$, $\underline{e} = 0$, and the principal's payoff under this ST contract is

$$\Pi^{ST}(\beta^{ST}) = \frac{1}{\delta+1}\frac{\beta(1+k)}{\lambda+1} - \frac{\beta^2(1+k)^2}{2(\lambda+1)^2} - r\sigma^2\frac{\beta^2(1+k)^2}{(\lambda+1)^2}(1+\rho).$$

Hence,

$$\begin{aligned}\Pi^{ST}(\beta^{ST}) - \Pi^{EAR}(\beta,k) &> \frac{1}{2}r\sigma^2\beta^2\left[(1+2\rho k+k^2) - 2\frac{(1+k)^2}{(\lambda+1)^2}(1+\rho)\right]\\ &> \frac{1}{2}r\sigma^2\beta^2\left[(1+2\rho k+k^2) - \frac{(1+k)^2}{2}(1+\rho)\right]\\ &= \frac{1}{4}r\sigma^2\beta^2(1-k)^2(1-\rho)\\ &\geq 0.\end{aligned}$$

The second strict inequality follows because $\lambda > 1$. ■

Appendix B

□ **Imperfect substitutability of efforts for the agent.** Let the two equally likely types of agent have cost functions of the form

$$c(\overline{e},\underline{e}) = \frac{1}{2}(\overline{e}^2 + 2s\lambda\overline{e}\underline{e} + \lambda^2\underline{e}^2), \tag{B1}$$

where the parameter $s \in [0, 1]$ measures the degree of substitutability of efforts. Perfect substitutability corresponds to $s = 1$ and no substitutability to $s = 0$.

With the cost function given in (B1), the ratio of the marginal cost of effort on the agent's costlier task to that on his cheaper task is $\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}} = \frac{s\lambda\overline{e}+\lambda^2\underline{e}}{\overline{e}+s\lambda\underline{e}}$. When efforts are imperfect substitutes for the agent ($s < 1$), the isocost curves of $c(\overline{e}, \underline{e})$ are concave to the origin: starting from perfectly balanced efforts, as the agent shifts his effort allocation toward his preferred task (increasing $\overline{e}$ and decreasing $\underline{e}$), $\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}}$ falls. However, the minimum value of this ratio, attained when $\underline{e} = 0$, is $s\lambda$. It follows that as long as $s\lambda \geq 1$ (representing a situation of high, but imperfect, substitutability), a symmetric transparent contract (for which the isobenefit curves have slope -1) still induces fully focused efforts from both types of agent, just as with perfect substitutability.

It also follows that, under hidden information, the only way with transparent contracts to induce interior efforts from both types of agent is to induce each type to choose, from a menu, a contract that rewards his costlier task at least $s\lambda$ times as highly as his cheaper task. However, with $s\lambda \geq 1$, the bribe implicit in such a contract is even more attractive to the other type of agent. As a consequence, Lemma 2 continues to hold as long as $s\lambda \geq 1$, implying that it is impossible, even with menus of transparent linear contracts, to solve simultaneously the effort-substitution and the hidden-information problems.

In the NHI benchmark, on the other hand, the principal can offer each type of agent a contract of the form $w = \alpha + \beta\overline{x} + v\beta\underline{x}$ with $v \geq 1$, where $\overline{x}$ (respectively, $\underline{x}$) denotes measured performance on the preferred (respectively, other) task. The weighting factor v is a choice variable for the principal, and under the simplifying assumption that the tasks are perfect complements for her ($\delta \to \infty$), it is always optimal for her to induce each type to choose equal efforts on the two tasks, which is achieved by $v^{NHI} = \frac{\lambda(\lambda+s)}{1+s\lambda}$. This finding, combined with the generalization of Lemma 2 noted above, implies that the principal's maximized payoff from transparent menus under hidden information is bounded away from that in the NHI benchmark.

Importantly, the incentives provided by EAR are not qualitatively affected by whether efforts are imperfect or perfect substitutes for the agent. EAR continues to give the risk-averse agent an incentive to partially self-insure by choosing relatively balanced efforts on the two tasks. Interior optimal efforts under EAR satisfy

$$\frac{\partial c}{\partial \overline{e}} + \frac{\partial c}{\partial \underline{e}} = \beta(1+k) \tag{B2}$$

and

$$\exp\left[r\beta(1-k)(\overline{e}-\underline{e})\right] = \frac{\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}} - k}{1 - k\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}}}. \tag{B3}$$

Equation (B3) generalizes (2), replacing the constant λ with the function $\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}}$ of $(\overline{e}, \underline{e})$.

Consider now the three environments studied in detail in Section 6. As $\lambda \to 1^+$ or as $r \to \infty$, $\sigma^2 = \frac{R}{r} \to 0$, it follows from (B3) that EAR induces perfectly balanced efforts for any $k \in (-1, \frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}})$.[36] Therefore, in these limiting cases, the only effect of increasing k is to improve the diversification of the risk from the shocks. Hence, it is optimal in both environments to set k as large as possible subject to keeping efforts perfectly balanced, that is, to take $k \to (\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}})^-$. With perfectly balanced efforts, we have $\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}} = \frac{1+s\lambda}{\lambda(\lambda+s)} = 1/v^{NHI}$, so it follows that as $\lambda \to 1^+$ or as $r \to \infty$, $\sigma^2 = \frac{R}{r} \to 0$, the optimal k approaches $1/v^{NHI}$. Therefore, just as in the original model, in these two limiting environments, optimally weighted EAR generates a payoff for the principal arbitrarily close to what she achieves in the NHI benchmark. In the setting where $\sigma^2(1-\rho) \to 0$, the weight k has no effect on diversification, so it is optimal under EAR to set k to induce perfectly balanced efforts; in this setting, too, optimally weighted EAR generates a payoff arbitrarily close to that in the NHI benchmark.

As long as $s\lambda \geq 1$, we saw above that under hidden information, the principal's maximized payoff from transparent menus is bounded away from that in the NHI benchmark. It follows, therefore, that in the environments studied in Section 6, optimally designed EAR is superior to the best transparent menu. Hence, allowing the agent's efforts on the tasks to be less than perfect substitutes in his cost function does not alter our main results.

□ ***Ex ante* randomization and the choice of how many tasks to reward.** In Section 7, we discussed the trade-offs involved in the design of randomized incentive schemes in environments with many tasks. In this section, we provide the derivations for our results.

Let the job performed by the agent consist of $n > 2$ tasks, for each of which measured performance $x_j = e_j + \epsilon_j$, where $(\epsilon_1, \ldots, \epsilon_n)$ have a symmetric multivariate normal distribution with mean 0, variance σ^2, and pairwise correlation $\rho \geq 0$. Suppose there are n equally likely types of agent, with the agent of type i having cost function $c_i(e_1, \ldots, e_n) = \frac{1}{2}(\lambda e_i + \sum_{j \neq i} e_j)^2$, where $\lambda > 1$. Thus, each type of agent has a particular *dislike* for exactly one of the n tasks, and λ measures the intensity of this dislike. Let the principal's payoff be given by

$$\Pi = \frac{\delta}{\delta + n - 1} \min\{e_1, \ldots, e_n\} + \frac{1}{\delta + n - 1} \left(\sum_{j=1}^{n} e_j - \min\{e_1, \ldots, e_n\} \right) - w,$$

where δ parameterizes the strength of the principal's desire for a balanced effort profile. As in the two-task model, the socially efficient effort profile is perfectly balanced whenever $\delta > \lambda$.

Consider an EAR scheme in which each subset of κ out of n tasks is chosen with equal probability, and each task in the chosen subset is rewarded at rate β. We will not explicitly model the direct costs of generating the performance measures. As this scheme is symmetric with respect to all n tasks and each type of agent's preferences are symmetric with respect to each of his $n-1$ "nondisliked" tasks, each agent's optimal effort profile can be described by $\underline{e}$, his effort on his disliked task, and by $\overline{e}$, his effort on each of the other tasks. If the task that an agent dislikes is included (respectively, not included) in the chosen subset, denote his (conditional) expected utility by $\underline{EU}$ (respectively, $\overline{EU}$). For any given task, the number of subsets that include it is $\binom{n-1}{\kappa-1}$, and the number that do not is $\binom{n}{\kappa} - \binom{n-1}{\kappa-1} = \binom{n-1}{\kappa}$. Hence, each type of agent's unconditional expected utility is

$$\frac{\binom{n-1}{\kappa}}{\binom{n}{k}} \overline{EU} + \frac{\binom{n-1}{\kappa-1}}{\binom{n}{k}} \underline{EU}.$$

We focus on the case where optimal efforts are interior.

The aggregate effort exerted by an agent is $\lambda \underline{e} + (n-1)\overline{e}$, which we define as A. To find the optimal level of A, we equate the sum over all tasks of the expected marginal monetary returns to effort to the sum over all tasks of the marginal cost of effort. Formally, this corresponds to adding the first-order conditions for effort on each of the n tasks. This yields $\kappa\beta = (n-1+\lambda)A$, so the optimal level of $A = \frac{\kappa\beta}{n-1+\lambda}$. To derive the optimal value of $\overline{e} - \underline{e}$, we need the first-order condition for $\underline{e}$, which is

$$\binom{n-1}{\kappa-1} [\beta - \lambda A] \underline{EU} + \binom{n-1}{\kappa} [-\lambda A] \overline{EU} = 0, \tag{B4}$$

because the net marginal monetary return to $\underline{e}$ is $\beta - \lambda A$ if the subset of rewarded tasks includes the agent's disliked one and is $-\lambda A$ otherwise. Substituting for the optimal value of A in (B4) and rearranging yields

$$\overline{e} - \underline{e} = \frac{1}{r\beta} \ln \left[\frac{\lambda(n-\kappa)}{n-1-(\kappa-1)\lambda} \right].$$

A necessary condition for interior solutions is $\kappa - 1 \leq \frac{n-1}{\lambda}$. Each type of agent's unconditional expected utility is given by

$$EU = -\frac{\binom{n-1}{\kappa-1}}{\binom{n}{\kappa}} \exp\left\{ -r \left[\alpha + \beta((\kappa-1)\overline{e} + \underline{e}) - \frac{1}{2} \frac{\kappa^2\beta^2}{(\lambda+n-1)^2} - \frac{1}{2} r\sigma^2\beta^2\kappa(1+\rho(\kappa-1)) \right] \right\}$$

[36] If $k > \frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}}$, (B3) shows that EAR cannot induce interior solutions for efforts.

$$-\frac{\binom{n-1}{\kappa}}{\binom{n}{\kappa}}\exp\left\{-r\left[\alpha+\beta\kappa\overline{e}-\frac{1}{2}\frac{\kappa^2\beta^2}{(\lambda+n-1)^2}-\frac{1}{2}r\sigma^2\beta^2\kappa(1+\rho(\kappa-1))\right]\right\}.$$

The principal will optimally set α to ensure that the participation constraint binds for each type of agent. With α set in this way, and using the expressions for each type of agent's optimal choices of A and $\overline{e}-\underline{e}$, the principal's expected payoff as a function of β and κ can be simplified to

$$\Pi(\beta,\kappa)=\frac{\delta\underline{e}+(n-1)\overline{e}}{\delta+n-1}-\frac{\kappa^2\beta^2}{2(\lambda+n-1)^2}-\frac{1}{2}r\sigma^2\beta^2\kappa(1+\rho(\kappa-1))-\frac{1}{nr}\ln\left[\frac{(n-\kappa)^{n-\kappa}(n-1+\lambda)^n}{n^n\lambda^\kappa((n-1)-(\kappa-1)\lambda)^{n-\kappa}}\right], \tag{B5}$$

where

$$\frac{\delta\underline{e}+(n-1)\overline{e}}{\delta+n-1}=\frac{\kappa\beta}{(\lambda+n-1)^2}-\frac{(\delta-\lambda)(n-1)}{(\delta+n-1)(\lambda+n-1)r\beta}\ln\left[\frac{\lambda(n-\kappa)}{(n-1)-(\kappa-1)\lambda}\right]. \tag{B6}$$

Using $\tilde{\beta}=\kappa\beta$ to substitute for β in the above payoff expression yields the following expressions:

$$\Pi(\tilde{\beta},\kappa)=\frac{\delta\underline{e}+(n-1)\overline{e}}{\delta+n-1}-\frac{\tilde{\beta}^2}{2(\lambda+n-1)^2}-\frac{1}{2}r\sigma^2\tilde{\beta}^2\frac{(1+\rho(\kappa-1))}{\kappa}-\frac{1}{nr}\ln\left[\frac{(n-\kappa)^{n-\kappa}(n-1+\lambda)^n}{n^n\lambda^\kappa((n-1)-(\kappa-1)\lambda)^{n-\kappa}}\right], \tag{B7}$$

where

$$\frac{\delta\underline{e}+(n-1)\overline{e}}{\delta+n-1}=\frac{\tilde{\beta}}{(\lambda+n-1)^2}-\frac{(\delta-\lambda)(n-1)\kappa}{(\delta+n-1)(\lambda+n-1)r\tilde{\beta}}\ln\left[\frac{\lambda(n-\kappa)}{(n-1)-(\kappa-1)\lambda}\right]. \tag{B8}$$

Holding $\tilde{\beta}$ fixed and varying κ isolates the effect of changing the number of tasks rewarded, holding fixed the level of aggregate effort. Comparison of equations (B7)–(B8) with equations (6)–(7) reveals that changes in κ have qualitatively the same three effects on the principal's payoff in this n-task model as do variations in the weighting coefficient k in EAR in the original two-task model. Specifically, an increase in κ, by inducing a larger gap $\overline{e}-\underline{e}$, has two negative effects: first, it lowers the principal's benefit $\underline{e}+\frac{n-1}{\delta}\overline{e}$ when aggregate effort is held fixed, as long as $\delta>\lambda$. This corresponds to the fact that (B8) is decreasing in κ. Second, it raises the cost of compensating the agent for the risk imposed by the exogenous randomization (this corresponds to the fact that the term in square brackets in (B7) is increasing in κ). At the same time, raising κ also improves the diversification of the risk from the shocks to measured performance. This is reflected in the fact that $\frac{1+\rho(\kappa-1)}{\kappa}$ in (B7) is decreasing in κ.

To verify the first three comparative statics claims in Section 7 regarding the optimal value of κ, we need to sign the cross-partial derivative of $\Pi(\tilde{\beta},\kappa)$ in (B7) with respect to κ and the relevant parameter, holding $\tilde{\beta}$ fixed. It is straightforward to show that $\frac{\partial^2\Pi}{\partial\delta\partial\kappa}<0$, $\frac{\partial^2\Pi}{\partial r\partial\kappa}>0$, and $\frac{\partial^2\Pi}{\partial(\sigma^2(1-\rho))\partial\kappa}>0$, from which the claims follow. The final claim follows from the fact that $\frac{\partial^2\Pi}{\partial\tilde{\beta}\partial\kappa}>0$.

□ **Menus of opaque incentive schemes.** This section shows that the performance of EAR cannot be improved by the use of menus. Consider the following incentive-compatible menu of two incentive schemes, each involving randomization. For $k\in(-1,1)$, Scheme $i\in\{1,2\}$, intended for the agent who prefers task i, specifies that with probability $p\in(\frac{1}{2},1)$, $w=\alpha+\beta x_i+k\beta x_j$, and with probability $1-p$, $w=\alpha+\beta x_j+k\beta x_i$. As $p\to 1/2$, the two schemes become identical, so the menu reduces to EAR.

The value of p has no effect on aggregate effort. However, as p rises, each type of agent faces less uncertainty about his compensation schedule, hence has weaker incentives to self-insure by balancing his effort choices, so the induced effort gap $\overline{e}-\underline{e}$ rises. In this respect, a larger p mirrors the effect of a larger weighting parameter k. Nevertheless, there is a crucial difference between p and k. An increase in k improves the diversification of the risk from the shocks to measured performance. However, because, regardless of the value of p, the agent is ultimately paid either $\alpha+\beta x_1+k\beta x_2$ or $\alpha+\beta x_2+k\beta x_1$, changes in p have no effect on the diversification of this risk.

In consequence, whereas Proposition 3 and Section 6 showed that the weighting factor k is a valuable instrument in the design of opaque schemes, we have the following negative conclusion for the role of p: if a symmetric menu of randomized schemes with parameters (β,k,p) induces interior solutions for efforts, then as long as $\delta>\lambda$, the principal's payoff will be increased by lowering p to $1/2$, thus replacing such a menu by EAR as analyzed in Section 4. Hence, the principal's payoff from EAR cannot be augmented by the use of menus.

□ **Beyond the exponential-normal model.** Our findings that opaque incentive schemes induce more balanced efforts than symmetric transparent ones and do so in a way more robust to hidden information of the agent, apply even outside the exponential-normal framework. Let the measurement technology remain $x_i=e_i+\varepsilon_i$, but now let $(\varepsilon_1,\varepsilon_2)$ have an arbitrary symmetric joint density. Let each type of agent's utility be $U(w - c(\overline{e}, \underline{e}))$, with $U(\cdot)$ an arbitrary strictly concave function and $c(\overline{e}, \underline{e})$, as in (B1), reflecting imperfect substitutability of efforts.

Under EAR, interior optimal effort choices for each type of agent satisfy

$$\frac{\partial c}{\partial \overline{e}} + \frac{\partial c}{\partial \underline{e}} = \beta(1+k) \quad \text{and} \quad \frac{E\left[U'(\cdot)I_{\{\underline{x} \text{ is more highly rewarded}\}}\right]}{E\left[U'(\cdot)I_{\{\overline{x} \text{ is more highly rewarded}\}}\right]} = \frac{\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}} - k}{1 - k\frac{\partial c/\partial \underline{e}}{\partial c/\partial \overline{e}}}.$$

The second equation is a generalized version of (2) and shows that just as for the exponential-normal model, EAR gives the risk-averse agent an incentive to choose more balanced efforts to partially self-insure against the risk stemming from the uncertainty about which payment schedule will ultimately be used.

Nevertheless, we can show that whenever the symmetric transparent contract induces interior efforts, EAR does as well, and effort choices under EAR are more balanced than under the ST contract. Moreover, when efforts are perfect substitutes for the agent ($s = 1$), as λ increases from 1, $\overline{e}^{EAR}/\underline{e}^{EAR}$ increases continuously from 1, whereas $\overline{e}^{ST}/\underline{e}^{ST}$ jumps from 1 to ∞. Thus, even outside the exponential-normal framework, EAR provides stronger incentives for effort balance and is more robust to hidden information.

References

Abeler, J. and Jäger, S. "Complex Tax Incentives." *American Economic Journal: Economic Policy*, Vol. 7 (2015), pp. 1–28.

Baker, G.P. "Incentive Contracts and Performance Measurement." *Journal of Political Economy*, Vol. 100 (1992), pp. 598–614.

Barron, D., Georgiadis, G., and Swinkels, J. "Optimal Contracts with a Risk-Taking Agent." Kellogg School of Management Working Paper, 2017. https://www.kellogg.northwestern.edu/faculty/georgiadis/RiskTakingContracts.pdf

Bentham, J. *Constitutional Code*. Vol. 1. London: R. Heward, 1830.

Bevan, G. and Hood, C. "Targets, Inspections, and Transparency." *British Medical Journal*, Vol. 328 (2004), pp. 598.

Bond, P. and Gomes, A. "Multitask Principal-Agent Problems: Optimal Contracts, Fragility, and Effort Misallocation." *Journal of Economic Theory*, Vol. 144 (2009), pp. 175–211.

Burgess, S., Propper, C., Ratto, M., and Tominey, E. "Incentives in the Public Sector: Evidence from a Government Agency." *Economic Journal*, Vol. 127 (2017), pp. F117–F141.

Carrell, S.E. and West, J.E. "Does Professor Quality Matter? Evidence from Random Assignment of Students to Professors." *Journal of Political Economy*, Vol. 118 (2010), pp. 409–432.

Carroll, G. "Robustness and Linear Contracts." *American Economic Review*, Vol. 105(2) (2015), pp. 536–563.

Dranove, D., Kessler, D., McClellan, M., and Satterthwaite, M. "Is More Information Better? The Effects of 'Report Cards' on Health Care Providers." *Journal of Political Economy*, Vol. 111 (2003), pp. 555–588.

Ederer, F., Holden, R., and Meyer, M. "Gaming and Strategic Opacity in Incentive Provision." Cowles Foundation Working Paper No. 1935, 2014.

Forbes, S., Lederman, M., and Tombe, T. "Quality Disclosure Programs and Internal Organizational Practices: Evidence from Airline Flight Delays." *American Economic Journal: Microeconomics*, Vol. 7 (2015), pp. 1–26.

Frankel, A. and Kartik, N. "Muddled Information." Chicago Booth Working Paper, 2014. https://faculty.chicagobooth.edu/alexander.frankel/research/pdf/mudinf.pdf

Gjesdal, F. "Information and Incentives: The Agency Information Problem." *Review of Economic Studies*, Vol. 49 (1982), pp. 373–390.

Gravelle, H., Sutton, M., and Ma, A. "Doctor Behaviour under a Pay for Performance Contract: Treating, Cheating and Case Finding?" *Economic Journal*, Vol. 120 (2010), pp. F129–F156.

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

Holmstrom, B. and Milgrom, P. "Aggregation and Linearity in the Provision of Intertemporal Incentives." *Econometrica*, Vol. 55 (1987), pp. 303–328.

———. "Regulating Trade Among Agents." *Journal of Institutional and Theoretical Economics*, Vol. 146 (1990), pp. 85–105.

———. "Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design." *Journal of Law, Economics, and Organization*, Vol. 7 (1991), pp. 24–52.

Jehiel, P. "On Transparency in Organizations." *Review of Economic Studies*, Vol. 82 (2015), pp. 736–761.

Jehiel, P. and Newman, A.F. "Loopholes: Social Learning and the Evolution of Contract Form." BU Working Paper, 2011. http://people.bu.edu/afnewman/papers/loopholes.pdf

Larkin, I. "The Cost of High-Powered Incentives: Employee Gaming in Enterprise Software Sales." *Journal of Labor Economics*, Vol. 32 (2014), pp. 199–227.

Lazear, E.P. "Speeding, Terrorism, and Teaching to the Test." *Quarterly Journal of Economics*, Vol. 121 (2006), pp. 1029–1061.

MacDonald, G. and Marx, L.M. "Adverse Specialization." *Journal of Political Economy*, Vol. 109 (2001), pp. 864-899.

Milgrom, P. and Roberts, J. *Economics, Organization and Management*. Englewood Cliffs: Prentice-Hall, 1992.

MIRRLEES, J.A. "Notes on Welfare Economics, Information and Uncertainty." In M. Balch, D. McFadden, and S. Wu, eds., *Essays in Equilibrium Behavior under Uncertainty*. Amsterdam: North-Holland, 1974.

OSLER, M. "The Case Against Transparency in Law School Rankings Methodology." *Law School Innovation*, May 4, 2010. lsi.typepad.com/lsi/2010/05/the-case-against-transparency-in-law-school-rankings-methodology.html.

OYER, P. "Fiscal Year Ends and Nonlinear Incentive Contracts: The Effect on Business Seasonality." *Quarterly Journal of Economics*, Vol. 113 (1998), pp. 149–185.

PESTIEAU, P., POSSEN, U.M., AND SLUTSKY, S.M. "The Value of Explicit Randomization in the Tax Code." *Journal of Public Economics*, Vol. 67 (1998), pp. 87–103.

SCOTT, R.E. AND TRIANTIS, G.G. "Anticipating Litigation in Contract Design." *Yale Law Journal*, Vol. 115 (2006), pp. 814–879.

STIGLITZ, J. "Self-Selection and Pareto Efficient Taxation." *Journal of Public Economics*, Vol. 17 (1982), pp. 213–240.

WEISBACH, D.A. "An Efficiency Analysis of Line Drawing in the Tax Law." *Journal of Legal Studies*, Vol. 29 (2000), pp. 71–97.