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ABSTRACT

We introduce a general Principal-Agent model with subjective evaluation and malfeasance characterized by two-sided asymmetric information on performance that allows for an arbitrary information structure. Two generic contract forms are studied. An authority contract has the Principal reveal his information before the Agent responds with her information. Under such a contract, the Agent's compensation varies only with the Principal's information, while her information is used to punish untruthful behavior by the Principal. Conversely, a sales contract has the Agent reveal her information first. In this case, the Agent's performance incentives are affected by the information revealed by both parties. Because the Agent's information affects her compensation, the information revelation constraints are more complex under a sales contract, and provide a way to integrate Williamson's (1975) notion of guile into agency theory. We find that designing sales contracts for expert agents, such as physicians and financial advisors, are significantly more complex than designing optimal authority contracts.

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1. Introduction

An open challenge for the contract theory literature is to understand the wide variety of observed contracting relationships. In a seminal paper, Kerr (1975) provides a number of examples in which organizations introduced dysfunctional performance pay systems to illustrate that even successful firms are often challenged by the problem of incentive pay design. Milkovich and Wigdor (1991) advised the US federal government against the introduction of a performance pay system because the implementation costs would outweigh any performance gain. There is also a great deal of evidence that, despite an enormous amount of research and experimentation, reward systems in health care have not met expectations (McGuire (2000) and Frank and McGuire (2000)). Similarly, attempts to introduce better reward systems in education have not proven to be uniformly successful (Goodman and Turner (2010)). The purpose of this paper is to introduce a model that can help to explain why contracting in these environments is so difficult, and provide some tools for the analysis of optimal contracting with two-sided asymmetric information on performance.

Beginning with seminal work by Ross (1973), Harris and Raviv (1979) and Holmström (1979), the early work on the Principal-Agent problem characterizes the optimal contract with risk-averse parties and imperfect measures of the Agent's performance. When clear and unambiguous performance measures exist, optimal risk-sharing contracts should incorporate this information.[1] An important caveat occurs when the Agent must allocate her time over several tasks. Holmström and Milgrom (1991) show that under such situations, the optimal contract may have to reduce rewards on one informative performance measure in order to limit its negative externality upon other aspects of performance.

A paradigmatic example of this is the speed/quality trade-off. The time of completion of a project is easy to measure, but the quality is often hard to assess, particularly for complex goods such as software, professional services, food, wine and music. To mitigate such multi-tasking problems, parties can rely, in part, upon subjective evaluations of the difficult-to-measure elements of performance to provide rewards. Prendergast (1999) observes that the use of subjective performance evaluation on top of objective assessments is a common incentive system in organizations. When this happens, optimal contracts are required to be "self-enforcing" - the Principal (he) can provide incentives via rewards that vary with his subjective evaluations on the performance only if the Agent (she) in turn can provide incentives for the Principal to be truthful in his evaluations.[2]

Such incentives can be provided using a "relational contract" that views trade as a repeated game in which current performance is enforced by the threat of future punishments (Telser (1980) and Bull (1987)). Building upon the work of Abreu (1988), MacLeod and Malcomson (1989) provide a complete characterization of the set of self-enforcing relational contracts when performance is commonly observed by the Principal and the Agent, but not by outside parties. Levin (2003) relaxes this assumption to allow for asymmetric information in the Agent's cost and in the performance level (subjective evaluation). The key result is that the necessary and sufficient conditions for efficient production rely upon the existence of sufficient rents from continuing the relationship. The relational contracting literature has relied upon this result to focus on how these rents are generated, and how they constrain the set of feasible contracts. For example, Baker *et al.* (1994) show that rewards based upon objective measures can enhance the value of a relationship, thus creating a complementarity between subjective and objective performance measures. Kandori (1992) and Kranton

[1] For example, MacLeod and Parent (1999) find that performance pay in the United States is most prevalent in jobs with high quality performance measures such as sales and workers producing product to order.

[2] Prendergast (1993) and Prendergast and Topel (1996) show that the use of subjective performance evaluations to provide effort incentives is an important factor in explaining some ubiquitous features in organizations.

(1996) emphasize the role of social networks, while Klein and Leffler (1981), Kornhauser (1983), Greif (1989) and Banerjee and Duflo (2000) view reputation as a relational rent that can induce performance. Baker *et al.* (2002) consider the effect of vertical integration on the quality of the relational contract. Brown *et al.* (2004) show that a preference for reciprocity can provide a substitute for reputational concerns to enhance contract performance. Finally, Sobel (2006) has a model of opportunistic behavior in which informal contracts can support efficient trade within periods but lead to relationships that are inefficiently long lasting.

This literature illustrates that a large number of economic institutions are explicitly designed to create social norms and rents that can be harnessed for informal contract enforcement. However, it does not address the classic Principal-Agent issue: how does variation in information about the performance level shape the optimal contract? One reason for this gap is that the introduction of asymmetric information to a repeated game dramatically increases the complexity of the problem (Kandori and Matsushima (1998) and Kandori (2002)).[3] Levin (2003) makes significant progress by focusing upon "full-review" contracts where the Principal truthfully reports his private evaluation of performance every period in equilibrium. He shows that when both players are risk-neutral, the optimal contract takes a simple one-step compensation structure - the Agent is rewarded and retained if and only if the performance exceeds a threshold. Fuchs (2007), using the idea of "re-usability of punishments" of Abreu *et al.* (1991), relaxes the "full-review" assumption and shows that, when only the Principal has information about the performance level, efficiency is enhanced by delaying payments to the Agent. Chan and Zheng (2011) and Maestri (2012) make further progress on the understanding of dynamic contracting under subjective evaluation by considering the case where the Agent also has information on the performance level.

MacLeod (2003), using ideas from Abreu *et al.* (1990) and Kandori and Matsushima (1998), introduces a reduced-form model of relational contracts which allows one to study the effects of risk aversion and correlation in information. He observes that a key ingredient in a relational contract is that in every period, parties can coordinate their rewards and punishments conditional upon past events. For example, if the Principal is perceived to have deviated from an agreement, the parties can coordinate upon an equilibrium punishment for the Principal.[4] MacLeod (2003) introduces two ideas. First, subjective evaluation can be modeled explicitly as a problem of asymmetric information - the same performance level by the Agent can generate different information to the Principal and the Agent, which in turn represents differences in perception of the Agent's performance. The extent to which the evaluations are objective then depends upon the degree of correlation in information. Second, when information is asymmetric, then as Myerson and Satterthwaite (1983) show, the optimal exchange mechanism necessarily entails a social loss. This is modeled by allowing the Agent to impose a deadweight loss upon the Principal if she believes that she has been treated unfairly.

In this paper, we build upon these observations to extend this model in a number of directions. First, MacLeod (2003) assumes that only the Principal has a noisy measure of performance while the Agent observes a noisy signal of the Principal's information. We call this the "informed-Principal" case.[5] We relax this assumption to allow for an arbitrary information structure that also includes, among others, the "expert-Agent" case. By this, we are referring to a situation where the Agent's information about the performance

[3] This class of games is termed "repeated games with private monitoring" in the literature.

[4] Abreu *et al.* (1990) and Kandori and Matsushima (1998) show that in order to work out the possible equilibrium actions in each period, the only information that is needed is the set of possible equilibrium payoffs for future periods.

[5] The information environment studied in Chan and Zheng (2011) and Maestri (2012) also correspond to the informed-Principal case here. Most of the other work in subjective evaluation, including Levin (2003) and Fuchs (2007), consider the case where the Agent has no information about the performance at all.

level is superior to that of the Principal, a case that corresponds to the problem of contracting for a "credence good" (Darby and Karni (1973) and Emons (1997)). This is an important class of contracting problems, that includes contracting for expert advice from physicians, lawyers, consultants and financial advisers.

Second, we consider two generic contract forms that are distinguished by the timing of information revelation. The first is an "authority contract" under which the Principal has to reveal his information of the performance level before the Agent responds with her information. This contract form has a sharp prediction: only the Principal's information is used to provide incentives for effort, while the Agent's information is used to provide incentives for the Principal to reveal his information truthfully. The literature on relational contracts tends to focus upon ensuring that the Agent can punish the Principal for deviation. In contrast, this model also provides predictions regarding the *pattern* of organizational conflict as a function of the observed signals. In particular, an efficient relational contract should *modulate* socially inefficient conflicts by restricting their occurrence to states in which the Agent has high quality information regarding possible mis-reporting by the Principal.[6]

Next we consider a "sales contract" under which the Agent reveals her information before the Principal responds with his. In practice, this can be implemented with a contract under which the Agent sets the price, hence the term "sales contract". The Principal then responds by imposing a deadweight loss upon the Agent when he believes that the price is inconsistent with his private information. This contract can be seen as a general version of contracts that have been used to study credence goods where the terms of trade are often determined by the good or service provider.

Models of credence goods typically use binary signals to model the potential for the under-provision of quality or over-charging of the customers.[7] In our model, effort is a continuous variable and we allow for an arbitrary number of signals. The timing of information revelation in the sales contract implies that the Agent's rewards are determined by her report, while the Principal's information ensures that the Agent reveals his information truthfully. As Myerson (1986) first showed for multistage games, the simple revelation principle may no longer apply. In the case of a sales contract, the Agent can manipulate the Principal's information via her effort choice. A consequence of this is that in some cases, even if a contract is incentive compatible conditional upon the contractual effort obligation, the Agent may still have incentives to alter her effort and then mis-report her information accordingly. In other words, under the sales contract, there is the *combined* risk of moral hazard and deceitful reporting behavior that can restrict the set of feasible contracts. This corresponds exactly to the type of behavior that Williamson (1975) calls opportunistic because it entails the use of "guile": the use of self-disbelieved promises.[8]

Guile arises in our model when the Agent changes her effort and then, *before* information is revealed to each party, plans to mislead the Principal accordingly. Thus, a feasible contract needs to *jointly* satisfy the Agent's incentive constraint for all ex-ante reporting strategies and effort choices.[9] This then implies an incentive constraint that is an order of magnitude more complex than checking the Agent's truthful-reporting constraints on the equilibrium path after the Agent has supplied the contractual effort terms. This has a number of consequences. First, the standard Principal-Agent model suggests that the most informed

[6] Li and Matouschek (2013) also study the management of conflicts in relational contract. The difference there is that conflict arises as a result of an exogenous random shock to the Principal's cost of adhering to the contractual terms, and this shock is independent of the Agent's effort. Here, the amount of conflicts and the states at which they should occur are highly dependent on the effort that the Principal wants to induce from the Agent.

[7] See the review by Dulleck and Kerschbamer (2006).

[8] See Williamson (1975) Section 2.2.

[9] The Agent's joint-strategy for information revelation and effort choice here is an example of the "manipulative strategy" considered in Myerson (1986).

individual should be setting the contractual terms. Such intuition might not hold here because even if the Agent is better informed than the Principal, contracting via sales contract might be more inefficient because of its more stringent set of constraints due to guile.

Second, the fact that the constraint space is more stringent for the sales contract may help to explain the many failures of performance pay systems. This intuition spills over to the consumer product market. A nice example of this is the recent Volkswagen scandal where the car manufacturer implanted a software to "cheat" government environmental testing systems (altering the effort obligation), and then lied to the public by advertising their diesel automobiles as "green" (mis-reporting information). More generally, our model provides a precise way to think about the observation of Williamson (1975) that:

> "Opportunism extends the conventional assumption of self-interest seeking with guile and has profound implications for choosing between alternative contractual relationships."[10]

Within the paradigm of the standard Principal-Agent model, Williamson's comment is puzzling because the model always assumes that contracts are designed while taking into account how individuals behave. Hence it has not been obvious what these profound implications are.

Our model also features malfeasance. By malfeasance, we refer to actions that the Agent can take to obtain a reward that do not have any benefit to the Principal (Becker and Stigler (1974)). We add this feature to highlight that guile is not a pure artifact of multi-tasking. A classic example of malfeasance is the mis-guided compensation scheme of Lincoln Electric company which linked its typists' pay to a measurement system on the typewriter that records the number of keys hit by the typist (Fast and Berg (1975)). The company was surprised to discover a typist hitting the same key repeatedly during her lunch break to generate a "high performance signal" for herself. In this example the typist is just rationally responding to the rewards provided by the firm. She would be engaging in guile if this behavior is also combined with being untruthful regarding how she spends her time.

The agenda of the paper is as follows. The next section introduces the model and notation. Section 2.5 works out the optimal contract in the presence of malfeasance alone, and provides necessary and sufficient conditions for the existence of a malfeasance-free contract. This distinguishes the effect of malfeasance from guile. Next, section 3 introduces subjective evaluation and the rest of the paper focuses on characterizing the optimal authority and sales contracts. We follow Grossman and Hart (1983) and consider implementing an agreed upon effort level via a contract with the lowest cost. Since the parties are assumed to be risk-neutral with unlimited liability, the optimal contract is one that minimizes the deadweight loss due to conflicts necessary to obtain truthful information revelation. We show that the problem of guile distinguishes the two contracting problems.

Section 4 studies the guile constraint in detail and provides some illustrative examples that link guile to constraints on performance pay. In particular, any sales contract under which the Agent can, through her reports on her performance, alter her effort-dependent part of the reward while leaving her expected compensation unchanged, is susceptible to guile. This implies that guile is a potential problem when the Agent's truthful-reporting constraint binds on the equilibrium path. Finally, section 5 concludes with a discussion of the results and potential avenues for future research. All omitted proofs are in Appendix A.

[10]Ibid, Page 26.

2. The Model

This section outlines the Principal-Agent model. We assume that both parties are risk-neutral so that we can focus upon the single margin of incentives versus information revelation. Sections 2.1 and 2.2 introduce the environment and the information structure that allows for arbitrary correlation between the information of the Agent and the Principal. Section 2.3 introduces contracts, and section 2.4 discusses the two contract forms that are the focus of the analysis - authority and sales contracts. Section 2.5 provides existence results for the symmetric information benchmark, followed by the analysis of subjective evaluation in the next section.

2.1. **The Environment.** Consider a Principal-Agent model with risk-neutral parties.[11] The Agent privately allocates effort to a number of tasks from the set $\{H, 1, 2, 3, ..., \bar{m}\} = \{H\} \cup \mathbb{M}$. The effort vector is given by $\vec{\lambda} = [\lambda_H, \lambda_1, ..., \lambda_{\bar{m}}] \in [0,1]^{\bar{m}+1}$ where λ_τ is the effort exerted on task $\tau \in \{H\} \cup \mathbb{M}$. Each task τ can generate either a "successful" outcome $o = \tau$ or a low outcome $o = L$, and λ_τ is the probability of getting the "successful" outcome τ. Each "successful" outcome τ is associated with a value of B_τ to the Principal while the value of outcome L is normalized to 0. Only task $\tau = H$ is a productive task ($B_H > 0$); all other tasks $m \in \mathbb{M}$ (the *malfeasance set*) are non-productive tasks ($B_m = 0$) corresponding to *malfeasance* - costly actions that have no productive benefit, but might be rewarded via the performance contract.

Outcomes are not directly observable,[12] but they generate separate signals for the Principal and the Agent. When a non-productive task in the malfeasance set $\mathbb{M}$ generates its "successful" outcome which is of no value to the Principal, the Principal might still perceive it as valuable via the signal he receives. For example, a car that is sent in for routine maintenance may have no problem, but the mechanic may nevertheless perform unnecessary "repairs." Upon observing the amount of work done on his car, the car-owner might mistakenly believe that the mechanic has helped him avert certain disaster![13] Such a scenario is an example of malfeasance. The difference between malfeasance and shirking is that malfeasance still incurs costly effort by the Agent but it is intended only to affect the signals that the Principal receives, and thereby potentially enhances her income under the compensation contract. In contrast, shirking is a reduction in effort, rather than a reallocation of effort to another task.

Let the Agent's cost of exerting effort $\vec{\lambda}$ be $V\left(\sum_{\tau \in \{H\} \cup \mathbb{M}} \lambda_\tau\right)$ which satisfies:

Assumption 1. $V : [0, 1) \to \Re_+$ *is any twice differentiable and strictly convex function such that* $V(0) = 0$, $V'(0) \geq 0$ *and* $\lim_{\lambda \to 1} V(\lambda) = \infty$.

To simplify notation, we also let $V\left(\vec{\lambda}\right) = V\left(\sum_{\tau \in \{H\} \cup \mathbb{M}} \lambda_\tau\right)$.[14] The Agent has an outside option of U^0 and we do not impose any limited liability on her. The outside option for the Principal is normalized to zero and he derives a fixed gain from trade U^{P0}, even when the Agent's effort is zero on all tasks. To make the analysis non-vacuous, we also assume the *efficiency of trade condition* (ETC); trade is efficient in the absence of costs of contract formation:

[11] We use the male pronoun for the Principal and the female pronoun for the Agent.

[12] For concreteness, one can think of B_τ as some future payoff where the value is not immediately realized. Alternatively, it is plausible that the values of the outcomes are never observed even after it is derived (see next footnote).

[13] In this example, it is plausible to view the values of the outcomes as never observable. If the car was indeed faulty and the mechanic carries out the necessary repair, the car-owner derives some positive value from averting the potential accident. If the car was in perfect condition but the mechanic carries out unnecessary repairs which has no value to the car-owner, the outcome is still "no accident". Since both outcomes are identical, the car-owner cannot differentiate between the two. See Ely and Välimäki (2003) for a discussion of this problem for firm reputations.

[14] While this is a little unorthodox in mathematics, it is quite standard in object-oriented computer programming where the type of argument ($\vec{\lambda} \in [0, 1)^{\bar{m}+1}$ or $\lambda \in [0, 1)$) determines the method to be applied.

Assumption 2. *(ETC.) It is assumed that* $U^{P0} - U^0 \geq 0$.

Let λ^{FB} be the efficient effort level which is uniquely defined by $V'\left(\lambda^{FB}\right) = B_H$. In that case, the first best surplus net of outside options is:

$$Surplus^{FB} \quad = \quad U^{P0} + \lambda^{FB} B_H - V\left(\lambda^{FB}\right) - U^0 \geq 0. \tag{2.1}$$

Assumptions 1 and 2 are maintained throughout the paper. The parties' ability to achieve the first-best surplus $Surplus^{FB}$ is constrained by the availability of information regarding effort. We assume that the Principal and the Agent each receives a *private* signal of performance,[15] denoted respectively by $t, s \in S = \{0, 1, ..., n-1\}$, where S, the set of possible signals, is a finite set with $n \geq 2$ elements. These signals have the same "meaning" to the two parties. For example, if $s = 10$ means that the food is excellent according to the Agent, the Principal will have the same interpretation for $t = 10$. However, he may perceive the quality differently when he receives a signal of, say, $t = 8$ which means that the food is good but not excellent. The two parties can then reasonably disagree regarding the quality of performance. This provides a precise notion of subjective evaluation where the extent to which parties' signals are correlated provides a measure of the subjectivity level (or the lack of it); when signals are perfectly correlated, the judgments are objective, and we are back in the standard Principal-Agent framework.

2.2. **Signal-generating Process.** The signal-generating process begins with a set of states given by $ts \in S^2$. We refer to t observed by the Principal or s observed by the Agent as a *signal*, and the joint-realization ts as a *state.* The set S^2 denotes the set of all possible states. To exploit the linear structure of the problem, we index each state ts by an index function $\mathcal{I} : S^2 \to \{0, 1, \ldots, n^2 - 1\}$ where $\mathcal{I}(ts) = (n \times t) + s$.[16] Thus for a state-contingent vector $\vec{x} \in \Re^{n^2}$, x_{ts} refers to the $\mathcal{I}(ts)$-th entry of vector $\vec{x}$.

Let the probability of state ts under outcome $o \in O \equiv \{L\} \cup \{H\} \cup \mathbb{M}$ be given by:

$$Prob\,[ts|o] \quad = \quad \Gamma^o_{ts}. \tag{2.2}$$

Let $\vec{\Gamma}^o$ be the corresponding $1 \times n^2$ probability vector $\left[\Gamma^o_{\mathcal{I}(ts)}\right]_{ts \in S^2}$. As a convention, we let all probability vectors be row vectors and all state-contingent variable vectors be column vectors. Thus the expected value of a state-contingent variable $\vec{x} \in \Re^{n^2}$ is $E\,[\vec{x}|o] = \vec{\Gamma}^o \vec{x}$, where all multiplications of vectors in this paper refer to the inner-product. If the Principal correctly anticipates the effort $\vec{\lambda}$ exerted by the Agent, both parties will have the same *ex-ante* unconditional probability of state ts:

$$\begin{aligned} \Gamma_{ts}\left(\vec{\lambda}\right) \equiv Prob\left[ts|\vec{\lambda}\right] &= \sum_{\tau \in \{H\} \cup \mathbb{M}} \lambda_\tau \Gamma^\tau_{ts} + \left(1 - \sum_{\tau \in \{H\} \cup \mathbb{M}} \lambda_\tau\right) \Gamma^L_{ts} \\ &= \Gamma^L_{ts} + \sum_{\tau \in \{H\} \cup \mathbb{M}} \lambda_\tau \hat{\Gamma}^\tau_{ts}, \end{aligned}$$

where the marginal effect of effort λ_τ on the probability of state ts is defined by:

$$\hat{\Gamma}^\tau_{ts} \quad = \quad \Gamma^\tau_{ts} - \Gamma^L_{ts}, \quad \forall \tau \in \{H\} \cup \mathbb{M}.$$

[15]This asymmetry in information on the performance prohibits the Principal from efficiently "selling the firm" to the Agent.

[16]As a convention, all indexes of vectors and matrices will begin from 0 instead of 1 throughout the paper. The convention is the same as is used in C and python programming languages, as is our convention on indexing which proceeds row wise. In contrast, FORTRAN indexes begin with 1, and uses column wise indexing.

In vector form, we have:

$$\vec{\Gamma}\left(\vec{\lambda}\right) = \vec{\Gamma}^L + \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau \vec{\hat{\Gamma}}^\tau \in \Re^{n^2}.$$

Notice that under Assumption 1, the Agent always chooses $\vec{\lambda}$ such that $\sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau < 1$, which ensures that $\vec{\Gamma}\left(\vec{\lambda}\right)$ is a valid probability vector.

We follow Grossman and Hart (1983) and frame the problem in terms of finding a contract that implements an agreed-upon effort obligation, $\vec{\lambda}$, at the lowest cost. We ensure the existence of a non-degenerate optimal contract by requiring the full-support assumption:

Definition 1. The effort obligation $\vec{\lambda}$ satisfies the *Full Support Condition (FSC) at* $\vec{\lambda}$ if $\Gamma_{ts}\left(\vec{\lambda}\right) > 0, \forall ts \in S^2$.

The FSC assumes that all states occur with strictly positive probability under $\vec{\lambda}$.[17] Its satisfaction ensures that optimal payments can be bounded; if some states were instead perfectly informative of malfeasance, then the moral hazard problem could be solved at zero cost by imposing large penalties when these states occur, as in Becker and Stigler (1974).

It would be convenient to define the probabilities that each signal is observed by the respective party. For $o \in \{L\} \cup \{H\} \cup \mathbb{M}$, let:

$$\gamma_t^o \equiv \sum_{s\in S} \Gamma_{ts}^o \quad \forall t \in S, \tag{2.3}$$

$$\beta_s^o \equiv \sum_{t\in S} \Gamma_{ts}^o \quad \forall s \in S, \tag{2.4}$$

where γ_t^o is the probability of the Principal observing signal t under outcome o, while β_s^o is the probability of the Agent observing signal s under outcome o. Analogously, we let $\vec{\gamma}^o = \left[\gamma_0^o, \ldots, \gamma_{n-1}^o\right]$ and $\vec{\beta}^o = \left[\beta_0^o, \ldots, \beta_{n-1}^o\right]$ be the respective $1 \times n$ probability vectors for the Principal's and the Agent's signals.

The probability that the Principal observes signal $t \in S$ under effort $\vec{\lambda}$ is thus:

$$\begin{aligned}\gamma_t\left(\vec{\lambda}\right) \equiv Prob\left[t\middle|\vec{\lambda}\right] &= \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau \gamma_t^\tau + \left(1 - \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau\right)\gamma_t^L \\ &= \gamma_t^L + \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau \hat{\gamma}_t^\tau,\end{aligned}$$

with $\hat{\gamma}_t^\tau = \gamma_t^\tau - \gamma_t^L$, the marginal effect of effort λ_τ on signal t for the Principal. The vectors $\vec{\gamma}\left(\vec{\lambda}\right)$ and $\vec{\hat{\gamma}}^\tau$ are then the respective $1 \times n$ vectors for $\gamma_t\left(\vec{\lambda}\right)$ and $\hat{\gamma}_t^\tau$.

Similarly, the probability that the Agent observes signal $s \in S$ under effort $\vec{\lambda}$ is:

$$\begin{aligned}\beta_s\left(\vec{\lambda}\right) \equiv Prob\left[s\middle|\vec{\lambda}\right] &= \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau \beta_s^\tau + \left(1 - \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau\right)\beta_s^L \\ &= \beta_s^L + \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau \hat{\beta}_s^\tau,\end{aligned}$$

[17] Since $\sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda_\tau < 1$, having $\Gamma_{ts}^L > 0 \ \forall ts \in S^2$ would suffice for FSC, but is not necessary.

with $\hat{\beta}_s^\tau = \beta^\tau - \beta^L$, the marginal effect of effort λ_τ on signal s for the Agent. Vectors $\vec{\beta}\left(\vec{\lambda}\right)$ and $\vec{\hat{\beta}}^\tau$ are then defined analogously to $\vec{\gamma}\left(\vec{\lambda}\right)$ and $\vec{\hat{\gamma}}^\tau$.

Given that the correlation between the players' signals plays an important role in the form of the optimal contract, we define:

$$q_{ts}\left(\vec{\lambda}\right) = Pr\left[s \middle| t, \vec{\lambda}\right] = \frac{\Gamma_{ts}\left(\vec{\lambda}\right)}{\gamma_t\left(\vec{\lambda}\right)}. \tag{2.5}$$

$q_{ts}\left(\vec{\lambda}\right)$ is the conditional probability of the Agent observing signal s when the Principal observes signal t under effort $\vec{\lambda}$. Similarly, we let:

$$r_{ts}\left(\vec{\lambda}\right) = Pr\left[t \middle| s, \vec{\lambda}\right] = \frac{\Gamma_{ts}\left(\vec{\lambda}\right)}{\beta_s\left(\vec{\lambda}\right)}, \tag{2.6}$$

be the conditional probability of the Principal observing signal t when the Agent observes signal s under effort $\vec{\lambda}$.

2.3. **Contracts.** A contract in this model specifies the state-contingent costs for the Principal and state-contingent wages for the Agent. In addition, we allow both the Principal and the Agent to impose conflict costs upon the other. This captures the notion of conflict in a relationship. The extent to which such conflicts are possible and required in equilibrium depends upon the context. For example, if the Agent receives a payment that is less than what she perceives to be deserving, she might retaliate with lower-quality services in the future or try to harm the reputation of the Principal. In this sense, such conflicts can be viewed as "behavioral" responses that are implemented when the parties disagree on their evaluations of the performance level.

We adopt a reduced-form approach to these conflicts to focus upon the interplay between conflict and contract form. The equilibria described here can be mapped to a corresponding equilibrium for a repeated game. However, this is the class of repeated game with private monitoring, and since the contract and effort choices are both taken from a continuum, the set of possible histories is very large, which in turn dramatically increases the complexity of the analysis (Kandori and Matsushima (1998) and Kandori (2002)).

Our concern here is to understand the contract form with subjective evaluation that minimizes the social cost of conflict required to implement a given effort level by the Agent. The only significant ingredient that is missing in our treatment is a constraint upon the size of the conflict. The literature on relational contracts, beginning with MacLeod and Malcomson (1989), Baker *et al.* (2002) and Levin (2003), has tended to focus upon the role of this constraint upon the existence of a contract. By putting aside this issue, we are able to illustrate a complex relationship between information revelation and contract form.

Following Myerson and Satterthwaite (1983), we invoke the revelation principle and add incentive constraints for both parties to truthfully reveal their information as part of the contract design. The interpretation of a contract depends upon the context. In general, this means that after the parties have agreed upon the contract terms, neither party can benefit by deviating from these terms. This notion of a self-enforcing contract is consistent with the way that it is used in the relational contracting literature, to indicate that the actions taken by individuals are carried out in their best interest.

It is shown later that the problem is convex and hence there is no gain from randomization. Accordingly, let c_{ts} be the Principal's cost and w_{ts} be the Agent's wage in state ts under the contract. These costs and wages are net of the conflict imposed by the other party and must satisfy the *relaxed budget constraint (RBC)*:

$$c_{ts} \geq w_{ts}, \forall ts \in S^2. \tag{2.7}$$

The social deadweight loss due to the conflict at state ts is:

$$\delta_{ts} = c_{ts} - w_{ts} \geq 0. \tag{2.8}$$

This social loss is the sum of conflicts imposed by the Principal upon the Agent, and by the Agent upon the Principal.[18] What is crucial is that these conflicts are pure losses; they are not transfers.[19] In effect, we are relaxing the budget-balancing constraint that is well-known to reduce the set of feasible contracts. Let $\vec{c} = \left[c_{\mathcal{I}(ts)}\right]_{ts\in S^2}$, $\vec{w} = \left[w_{\mathcal{I}(ts)}\right]_{ts\in S^2}$ and $\vec{\delta} = \left[\delta_{\mathcal{I}(ts)}\right]_{ts\in S^2}$ be the cost, wage and social loss vectors respectively.

A contract is formally defined as a triplet:

$$\psi = \left\{\vec{\lambda}, \vec{c}, \vec{w}\right\} \in \Psi \equiv [0,1)^{\bar{m}+1} \times \Re^{n^2} \times \Re^{n^2},$$

which specifies the Agent's effort obligation, and the Principal's cost and the Agent's wage at each state. When the parties abide by the conditions of the contract, the expected payoffs (net of outside options) of the Principal and the Agent are respectively:

$$\begin{aligned} U^P(\psi) &= U^{P0} + \lambda_H B_H - \vec{\Gamma}\left(\vec{\lambda}\right)\vec{c}, \\ U^A(\psi) &= \vec{\Gamma}\left(\vec{\lambda}\right)\vec{w} - V\left(\vec{\lambda}\right) - U^0. \end{aligned} \tag{2.9}$$

Since parties are risk-neutral, we can add up these two expressions to obtain a measure of the total surplus from the relationship under contract ψ:

$$Surplus(\psi) = \lambda_H B_H - V\left(\vec{\lambda}\right) + U^{P0} - U^0 - \vec{\Gamma}\left(\vec{\lambda}\right)\vec{\delta}. \tag{2.10}$$

From this expression, it is immediate that the first-best entails $\lambda_H = \lambda^{FB}$ (as defined in (2.1)), $\lambda_m = 0\ \forall m \in \mathbb{M}$ and $\vec{\delta} = \vec{0}$. We will address the issue of when the first-best surplus can be achieved and when it cannot be.

For the Agent to accept a contract ψ, his *Participation Constraint (PC)* must be satisfied:

$$U^A(\psi) = \vec{\Gamma}\left(\vec{\lambda}\right)\vec{w} - V\left(\vec{\lambda}\right) - U^0 \geq 0. \tag{2.11}$$

Next, notice that the payoffs to the Agent are linear in the probability distribution $\vec{\Gamma}\left(\vec{\lambda}\right)$. This, combined with the fact that V is strictly convex, implies that the Agent's optimal choice of $\vec{\lambda}$ is determined by the first-order conditions that for all $\tau \in \{H\} \cup \mathbb{M}$:

$$\lambda_\tau\left(\vec{\hat{\Gamma}}^\tau \vec{w} - V'(\vec{\lambda})\right) = 0, \tag{2.12}$$

$$\vec{\hat{\Gamma}}^\tau \vec{w} - V'(\vec{\lambda}) \leq 0. \tag{2.13}$$

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[18]One could also view δ_{ts} as the level of *aggrievement* in the sense of Hart and Moore (2007).

[19]In some cases, employment can be organized so that these losses are implemented as a transfer to other workers (see Malcomson (1984) and Carmichael (1983)). In this case, these losses are then no longer social losses. However, doing so introduces the problem of collusion among agents and contracts will then have to be designed to be collusion-proof, which adds further complexity to the contract design.

All the probabilities must satisfy $\lambda_\tau \geq 0$ and hence, the complementary slackness condition (2.12) is the requirement that either $\lambda_\tau = 0$ or the returns from effort on τ is equal to the marginal cost of effort.

Let $MB(\vec{w}) = \max_{\tau \in \{H\} \cup \mathbb{M}} \vec{\hat{\Gamma}}^\tau \vec{w}$. It follows that a necessary condition for $\lambda_\tau > 0$ is that $\vec{\hat{\Gamma}}^\tau \vec{w} = MB(\vec{w})$. This has two implications. First, if $\vec{\hat{\Gamma}}^H \vec{w} < MB(\vec{w})$, then $\lambda_H = 0$. Second, if it is optimal for the Agent to choose $\lambda_H > 0$, then it is (weakly) optimal to set $\lambda_m = 0$ for all $m \in \mathbb{M}$. Since $B_m = 0$, $\forall m \in \mathbb{M}$, malfeasance is never part of an optimal contract. Hence we only consider contracts with $\lambda_H > 0$ and $\lambda_m = 0$ $\forall m \in \mathbb{M}$. More generally, if it is optimal to set $\lambda_H = 0$, then there is no need for performance pay and thus, no malfeasance.

Given these observations, and for notational conciseness, when we write effort "λ", we are referring to an effort choice $\vec{\lambda} = [\lambda, 0, \dots, 0]$; that is, $\lambda_H = \lambda$ and $\lambda_m = 0$ $\forall m \in \mathbb{M}$. In addition, we let $\Gamma_{ts}(\lambda)$ denote $\Gamma^L_{ts} + \lambda \hat{\Gamma}^H_{ts}$, the probability of state ts under effort λ on only the productive task H, and let $\vec{\Gamma}(\lambda)$ be the corresponding probability row vector. The same applies to $\gamma_t(\lambda)$, $\beta_s(\lambda)$, $q_{ts}(\lambda)$ and $r_{ts}(\lambda)$. Analogously, when we say the FSC (definition 1) is satisfied at λ, we mean that the FSC is satisfied at effort vector $[\lambda, 0, ..., 0]$ (i.e. $\Gamma_{ts}(\lambda) > 0$ $\forall ts \in S^2$). Lastly, since all relevant contracts should be malfeasance-free, we denote a contract by $\psi = \{\lambda, \vec{c}, \vec{w}\}$ with the understanding that the effort vector obligation involved is $[\lambda, 0, ..., 0]$. The contract ψ will then have to be designed to make these choices incentive-compatible for the Agent.

In particular, from (2.12) and (2.13), a wage vector $\vec{w} \in \Re^{n^2}$ will induce effort obligation λ from the Agent if it satisfies the *incentive constraint for effort (ICE):*

$$\vec{\hat{\Gamma}}^H \vec{w} \geq V'(\lambda), \tag{2.14}$$

and the *incentive constraint for no-malfeasance (ICM)* :

$$\vec{\hat{\Gamma}}^m \vec{w} \leq V'(\lambda), \quad \forall m \in \mathbb{M}. \tag{2.15}$$

Condition (2.14) requires the Agent to have the incentive to select $\lambda_H \geq \lambda$ while (2.15) ensures that she has no incentive to carry out malfeasance. The reason for using a weak inequality in (2.14) is that it allows us to sign the Lagrangian multiplier associated with this constraint (as shown below). From the Principal's point of view, having higher effort is desirable, and thus he would be willing to select the least expensive contract that ensures the Agent chooses an effort λ_H that is at least as high as λ. In the Principal's cost-minimizing contract design problem, this constraint will bind.

It is immediate that the set of wage vectors $\vec{w}$ that satisfy PC (2.11), ICE (2.14) and ICM (2.15) is convex. The contract-design problem is finding a feasible contract $\psi \in \Psi$ that minimizes the principal's expected cost:

$$C(\lambda, \psi) \;=\; \vec{\Gamma}(\lambda)\,\vec{c} \;=\; U^A(\psi) + V(\lambda) + U^o + \vec{\Gamma}(\lambda)\,\vec{\delta}. \tag{2.16}$$

As will be shown, the unlimited liability assumption on the Agent allows us to always set $U^A(\psi) = 0$ at the optimal contract, even when there are truthful-reporting constraints to satisfy. Hence, the cost-minimizing solution to implement λ entails finding a contract ψ that minimizes the expected social loss $\vec{\Gamma}(\lambda)\,\vec{\delta}$.

2.4. **Information Revelation and Authority.** The timing of how information is revealed in our model is an important determinant of how authority is allocated. Our notion of authority is different from Aghion and Tirole (1997)[20] and forms the basis for our model of "guile" in the Williamsonian sense. We consider

[20]In Aghion and Tirole (1997), formal authority is the right to veto decisions while real authority belongs to the party who has the superior information. See also Baker *et al.* (1999).

two natural information revelation arrangements. The first case is an *authority relationship* in which the Principal reports his private signal t first and then the Agent responds with her report on s. We show that this timing implies that all optimal allocations can be implemented with an *authority contract* in which the Principal decides whether to pay bonuses or not, and then the Agent responds by imposing a conflict cost upon the Principal.

The second case we consider is a *sales relationship,* where the Agent reports her private signal s first and then the Principal responds with his report on t. All optimal allocations in this case can be implemented with a *sales contract* that has the Agent setting a price conditional upon only her information, followed by the Principal responding with a conflict cost on the Agent when he feels that he has been overcharged.

The sequence of moves for the contracting game is as follows:

(1) The Principal offers a contract $\psi \in \Psi$ to the Agent.
(2) The Agent accepts, or selects her outside option value of U^0.
(3) If the contract is accepted, the Agent privately selects effort $\vec{\lambda}$.
(4) The outcomes $o \in \{L\} \cup \{H\} \cup \mathbb{M}$ are realized, which in turn generate private signals t and s for the Principal and the Agent respectively.
(5) The timing of signal revelations are as follows:
    (a) Authority relationship: Principal reveals t first. Upon observing the Principal's report, the Agent reveals s.
    (b) Sales relationship: Agent reveals s first. Upon observing the Agent's report, the Principal reveals t.
(6) The Principal pays out c_{ts} and the Agent receives w_{ts} according to the report $ts \in S^2$.

At each stage parties are assumed to choose optimal strategies conditional upon having correct equilibrium beliefs regarding how the other player will play. We follow the norms of contract theory, and assume that the Principal can select his preferred sequential equilibrium. This means that we suppose he chooses his preferred contract subject to the constraints characterizing optimal choices at each stage.

2.5. **Benchmark Optimal Contract with Symmetric Information.** Before we characterize the optimal contracts with subjective evaluation, we first consider the case in which information is symmetric but imperfect - that is, the parties' information is verifiable by a third party. Here, in principle, the parties can use the courts or an arbitrator to implement the contract. A goal here is to understand how the possibility of malfeasance restricts contract formation in the absence of subjective evaluations, and how parties design a contract to implement an effort λ. We emphasize that information is symmetric by terming contracts here as *enforceable* contracts, as opposed to *self-enforcing* contracts in the next section where the parties' information is private and contracts then have to provide incentives for parties to truthfully reveal their information.

Because there is no need to provide incentives for parties to reveal their information in this case, conflict is unnecessary in an enforceable contract ($\vec{\delta} = \vec{0}$).[21] This implies that $c_{ts} = w_{ts}\ \forall ts \in S^2$, and we can thus let an enforceable contract be denoted by $\psi^E = \{\lambda, \vec{w}\} \in \Psi^E \equiv [0,1) \times \Re^{n^2}$. An enforceable contract, ψ^E, *implements* effort λ if it satisfies constraints PC (2.11), ICE (2.14) and ICM (2.15). The following proposition provides the condition for the implementation of an effort λ under the full support condition (FSC):

[21]Through the paper, $\vec{0}$ and $\vec{1}$ respectively denote a vector of all 0 and a vector of all 1.

Proposition 1. *Suppose that the full support condition FSC holds at effort level λ. There exists an enforceable contract, $\psi^E \in \Psi^E$, that implements λ if and only if the malfeasance-free condition (MFC) is satisfied:*

$$MF = \mathbb{H}^{++}\left(\vec{\hat{\Gamma}}^H\right) \cap \left\{\cap_{m\in\mathbb{M}} \mathbb{H}^{+}\left(\vec{\hat{\Gamma}}^H - \vec{\hat{\Gamma}}^m\right)\right\} \neq \emptyset. \tag{2.17}$$

Any wage vector $\vec{w}$ that implements λ satisfies:

$$\vec{\Gamma}(\lambda)\vec{w} = U^0 + V(\lambda), \tag{2.18}$$

$$\vec{\hat{\Gamma}}^H\vec{w} = V'(\lambda), \tag{2.19}$$

$$\vec{\hat{\Gamma}}^m\vec{w} \leq V'(\lambda),\ \forall m \in \mathbb{M}. \tag{2.20}$$

The Malfeasance-Free Condition (MFC) in (2.17) is defined using the set of hyperplanes supporting $\vec{x} \in \Re^{n^2}$: $\mathbb{H}^+(\vec{x}) = \left\{\vec{y} \in \Re^{n^2} | \vec{x}^T\vec{y} \geq 0\right\}$, where the superscript T denotes the transpose throughout this paper. $\mathbb{H}^{++}$ is defined by replacing the weak inequality with a strict inequality.[22]

Notice that the malfeasance-free condition (2.17) is independent of the effort choice. If malfeasance is not possible ($\mathbb{M} = \emptyset$), then a sufficient condition for the existence of a compensation scheme that induces effort is that the half-space (or blunt cone[23]) $P^H = \mathbb{H}^{++}\left(\vec{\hat{\Gamma}}^H\right)$ is non-empty. This in turn is equivalent to requiring that $\vec{\hat{\Gamma}}^H \neq \vec{0}$. Hence, in the absence of malfeasance, an enforceable contract can be written as long as there is even the slightest bit of information about the Agent's performance.

When malfeasance is possible ($\mathbb{M} \neq \emptyset$), one then needs to ensure that the compensation scheme does not encourage malfeasance. This requires that the wage vector $\vec{w}$ be in the following no-malfeasance pointed cone $P^{MF} = \left\{\cap_{m\in\mathbb{M}} \mathbb{H}^{+}\left(\vec{\hat{\Gamma}}^H - \vec{\hat{\Gamma}}^m\right)\right\}$ as well. Any wage vector in P^{MF} sets the marginal reward to malfeasance lower than that for the productive effort. This has some intuitive implications. Suppose that for each malfeasance task $m \in \mathbb{M}$, there is a state that is generated only by a "successful" outcome m but never by H.[24] If there is also some state other than these that provides information on outcome H, we can set punishments in these states to make the marginal reward to malfeasance sufficiently low and hence deter malfeasance. This implies:

Corollary 1. *Suppose malfeasance is detectable; namely, for every $m \in \mathbb{M}$, there exists a state $ts_m \in S^2$ such that $\Gamma^H_{ts_m} = 0$ and $\Gamma^m_{ts_m} > 0$. If there is also a state $ts \neq ts_m$ $\forall m \in \mathbb{M}$ such that $\hat{\Gamma}^H_{ts} \neq 0$, then for any $\lambda \in [0, 1)$, there exists an enforceable contract $\psi^E = \{\lambda, \vec{w}\} \in \Psi^E$ that implements λ.*

With regard to the first-best effort level, from Proposition 1, it is immediate that the MFC condition (2.17) provides conditions under which it can be implemented:

Corollary 2. *Suppose that the FSC holds at the efficient effort level λ^{FB}. There exists an enforceable contract $\psi^E \in \Psi^E$ that implements λ^{FB} if and only if the malfeasance-free condition (2.17) holds.*

Henceforth, we shall assume that condition MFC (2.17) is always satisfied so that any impossibility of contract formation or any inefficiency that arises is not (solely) due to the presence of malfeasance.

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[22] The set $\mathbb{H}^+$ is called a half-space when $\vec{x} \neq \vec{0}$. This is because $\mathbb{H}^+(\vec{x}) \cup \mathbb{H}^{++}(-\vec{x}) = \Re^{n^2}$ and $\mathbb{H}^+(\vec{x}) \cap \mathbb{H}^{++}(-\vec{x}) = \emptyset$. More generally, the intersection of a number of hyperplanes forms a *convex polytope* and represents the set of vectors that satisfies a set of inequalities.

[23] A cone $P \subset \Re^{n^2}$ is any set with the feature that for all $\vec{x} \in P$, and any $\alpha > 0$, $\alpha\vec{x} \in P$. A cone is blunt if $\vec{0} \notin P$ and pointed if $\vec{0} \in P$.

[24] FSC can still be satisfied by allowing outcome L to generate all possible states with strictly positive probability.

3. Subjective Evaluation

In this section, we consider a Principal and an Agent who privately observe their signals, and derive the necessary and sufficient conditions for the existence of an optimal contract under the authority and sale relationships. As before, it is without loss of generality to consider only contracts that induce the Agent to choose $\lambda_H = \lambda > 0$ with no malfeasance ($\lambda_m = 0\ \forall m \in \mathbb{M}$).

Like the enforceable contracts considered in the previous section, a contract implementing λ must satisfy constraints PC (2.11), ICE (2.14) and ICM (2.15). Moreover, because states ts are no longer verifiable by a third-party, implementable contracts have to be *self-enforcing* in the sense that the Principal and the Agent have an incentive to truthfully reveal their private information. We model this as in the relational contract theory, and suppose that parties can impose punishments upon each other via a reduced-form relaxed budget constraint (2.7). The cost and wage vectors of the contract completely determine the social conflict costs due to these punishments at each state via (2.8).

The non-triviality of the truthful-reporting constraints implies that conflict is necessary in general - there are no contracts that implement positive effort with no conflict. To see why, consider an authority contract in which the Agent gives her report on s only after observing the Principal's report on t. Since t is known, she will always report the signal that maximizes her wages. Hence, her truthful-reporting constraint can only be satisfied if her wages are independent of her reports (see Lemma 2 below). But if her wages are dependent on only the Principal's reports and $c_{ts} = w_{ts}\ \forall ts \in S^2$, then the Principal will always report the signal that minimizes his cost. Hence, the truthful-reporting constraints are satisfied simultaneously only when wages are independent of the information revealed, which in turn implies that it is optimal for the Agent to supply no effort.[25]

The theory of relational contracts was developed to model one way that parties implement efficient trade with incomplete contracts. The idea is the following. In a repeated game there are many possible equilibria, and parties can exploit this multiplicity by agreeing to play inefficient equilibria when one party is believed to have breached an agreement. From a technical perspective, the only ingredients that the repeated game structure adds are the ability of one party to impose conflict costs upon the other, and provide limits to the magnitude of these costs.

Within an organization, it is natural to have misunderstandings between individuals that may lead to costly conflicts (Pondy (1967)). There is also some direct evidence on these conflict costs arising due to contract disputes. Krueger and Mas (2004) and Mas (2008) provide evidence of disgruntled union workers providing low quality effort that resulted in defective products. Similarly, Mas (2006) documents how an unfavorable arbitration decision for a police union during wage bargaining in New Jersey is followed by an increase in the local crime rate. These results provide concrete evidence that employees can and do respond to perceived unfair treatment with actions that impose socially wasteful conflict costs upon the firm/Principal.

In the context of optimal contracting with asymmetric information, these conflict costs are part of the efficient contract design, an observation that goes back to Myerson and Satterthwaite (1983) and the repeated game analysis of Green and Porter (1984). The fact that parties would like to avoid conflict allows us to ignore the limits on the size of the conflict cost that is a central feature of the early literature on relational

[25] See MacLeod (2003) for a general proof for this point. The point that one cannot provide explicit incentives with two parties under subjective evaluation has been observed by Carmichael (1983) and Malcomson (1984). The same idea explains why it is not possible to have efficient and budget-balancing contracts in teams as pointed out by Holmström (1982) and Eswaran and Kotwal (1984).

contracts. In this model we allow for conflict via the relaxed budget constraint (2.7) and derive the contract that implements the agreed-upon effort λ with the least amount of expected conflict.

The conflict in state ts is given by $\delta_{ts} = c_{ts} - w_{ts}$. Given that parties care only about their wage (w_{ts}) or cost (c_{ts}), it follows that *who* imposes the conflict is indeterminate and thus we can choose who to impose the cost in a way that is more convenient for the analysis. This is implied by the following result:

Lemma 1. *In the absence of constraints on the size of the conflict $\vec{\delta}$, it is without loss of generality to consider contracts where only one party (the Principal or the Agent) is inflicting the conflict.*

Lemma 1 is an extension of the result in MacLeod and Malcomson (1989), who show that under sufficient gains from trade, there will be a continuum of possible contracts, from pure bonus-pay to an efficiency-wage, that implement the optimal allocation.

3.1. **The Authority Relationship.** An authority relationship is one in which the Principal first reports his subjective evaluation of the performance t. Upon observing the Principal's report, the Agent responds with her own report of s. Since effort is sunk and the performance has been realized, the Agent cares only about her net compensation. Thus the *Agent's truthful-reporting constraint (ATR)* is:

$$w_{ts} \geq w_{ts'}, \quad \forall t, s, s' \in S. \tag{3.1}$$

This immediately implies:

Lemma 2. *In an authority relationship, the Agent's truthful-reporting constraint ATR (3.1) requires that $w_{ts} = w_{ts'}$ $\forall t, s, s' \in S$.*

In this case the Agent's wages are independent of her report, which is a direct implication of having the Principal report his information first. In order to provide incentives for the Principal to report truthfully, the Agent must be able to inflict punishment on the Principal when the Agent feels that she is treated unfairly. In this case, conflict is the "natural" consequence of differences in opinion. Given Lemma 1, it is without loss of generality to let the Agent be the party who is inflicting all the conflict in an authority contract and denote the conflict cost by δ^A_{ts} (A for authority).

Under this behavior, w_{ts} varies only with t and not s. Thus, the authority contract can be defined by a wage-price that varies only with the Principal's report t, $\vec{p}^A = \left[p^A_0, ..., p^A_{n-1}\right]^T \in \Re^n$, and $w_{ts} \equiv p^A_t$ $\forall t, s \in S$. The Agent then chooses to impose a conflict cost $\delta^A_{ts} \geq 0$ on the Principal after she has received wage p^A_t and observes s. The net cost to the Principal in state ts is $c_{ts} = \delta^A_{ts} + p^A_t \geq p^A_t$. By assumption, imposing these conflicts are at no cost to the Agent, and hence they do not affect the Agent's truthful-reporting constraint (3.1). We can integrate the Agent's truthful-reporting constraint directly into the definition of an authority contract by replacing the $1 \times n^2$ wage vector $\vec{w}$ with the $1 \times n$ wage-price vector $\vec{p}^A$, and let the set of authority contracts be given by:

$$\psi^A = \left\{\lambda, \vec{p}^A, \vec{\delta}^A\right\} \in \Psi^A \equiv [0,1) \times \Re^n \times \Re^{n^2}_+.$$

The *Principal's truthful-reporting constraint (PTR)* requires that conditional upon the Agent exerting the effort obligation λ and upon observing a signal $t \in S$, he cannot reduce his costs by reporting a signal $t' \neq t$:

$$\left(p^A_t + \sum_{s\in S} q_{ts}(\lambda)\, \delta^A_{ts}\right) - \left(p^A_{t'} + \sum_{s\in S} q_{ts}(\lambda)\, \delta^A_{t's}\right) \leq 0, \quad \forall t, t' \in S, \tag{3.2}$$

where $q_{ts}(\lambda)$ is the probability of state s given t, as defined in (2.5).

Definition 2. The set of authority contracts that implements λ is defined by $\Psi^A(\lambda) \subset \Re^n \times \Re_+^{n^2}$, where RBC (2.7), PC (2.11), ICE (2.14), ICM (2.15), ATR (3.1) and PTR (3.2) are satisfied for $\vec{\lambda} = [\lambda, 0, ..., 0]$ for any $\left\{\vec{p}^A, \vec{\delta}^A\right\} \in \Psi^A(\lambda)$.

Given that $\Psi^A(\lambda)$ is defined by a set of linear inequalities, then if it is not empty, it must be a closed and convex set. We can now state the program for finding the optimal authority contract with subjective evaluation:

Program-AC:

$$C^{A*}(\lambda) = \begin{cases} \min_{\psi^A \in \Psi^A(\lambda)} C\left(\lambda, \psi^A\right) & , \text{ if } \Psi^A(\lambda) \neq \emptyset \\ \infty & , \text{ if } \Psi^A(\lambda) = \emptyset. \end{cases} \tag{3.3}$$

Notice that adding a constant, k, to each p_t^A $\forall t$ will not affect any of the incentive constraints. This implies that under the unlimited liability assumption on the Agent, her participation constraint (PC) will always bind at the optimum. Moreover, the Agent's truthful-reporting constraint ATR (3.1) implies that the Agent's information cannot be used to provide effort incentives for the Agent, and hence the appropriate malfeasance-free condition (2.17) for this case is:

Definition 3. The signal generating process satisfies the Strong Malfeasance-Free Condition (SMFC) if:

$$SMF = \mathbb{H}^{++}\left(\vec{\hat{\gamma}}^H\right) \cap \left\{\cap_{m \in \mathbb{M}} \mathbb{H}^+\left(\vec{\gamma}^H - \vec{\gamma}^m\right)\right\} \neq \emptyset. \tag{3.4}$$

Proposition 2. *Suppose that the full support condition FSC holds at λ. Then an optimal authority contract implementing λ exists if and only if the Strong Malfeasance-Free Condition SMFC (3.4) holds.*

Since program-AC (3.3) is a linear program, the solution can be fully characterized by the Kuhn-Tucker conditions. If a contract $\left\{\vec{p}^A, \vec{\delta}^A\right\} \in \Psi^A(\lambda)$ is a solution associated with an Agent's outside option U^0 and Principal's fixed gain from trade U^{P0}, then for any $k \in \Re$, the contract $\left\{\vec{p}^A + k\vec{1}, \vec{\delta}^A\right\}$ will be a solution associated with an Agent's outside option $U^0 + k$ and a Principal's fixed gain from trade $U^{P0} + k$. Hence, without loss of generality, we can assume that U^0 and U^{P0} are sufficiently high so that we may restrict attention to only $\vec{p}^A \in \Re_+^n$; $\vec{p}^A$ can be rescaled down later if necessary. The following proposition characterizes the solution to program-AC (3.3) under this assumption:

Proposition 3. *Suppose that the full support condition FSC holds at λ. A contract $\psi^{A*} = \left\{\lambda, \vec{p}^A, \vec{\delta}^A\right\}$ is an optimal authority contract implementing λ if and only if there exist non-negative Lagrangian multipliers μ_1^A (for ICE (2.14)), $\mu_m^{A(ICM)}$ for $m \in \mathbb{M}$ (for ICM (2.15)), and $\mu_{tt'}^A$ for $t, t' \in S$ and $t' \neq t$ (for PTR (3.2)) such that:*

$$-\mu_1^A \hat{\gamma}_t^H + \sum_{m \in \mathbb{M}} \mu_m^{A(ICM)} \hat{\gamma}_t^m + v_t^A = 0 \qquad , \forall t \tag{3.5}$$

$$\Gamma_{ts}(\lambda) + v_{ts}^A \geq 0 \qquad , \forall t, s \tag{3.6}$$

$$\delta_{ts}^A \left[\Gamma_{ts}(\lambda) + v_{ts}^A\right] = 0 \qquad , \forall t, s \tag{3.7}$$

$$\left(p_t^A + \sum_{s \in S} q_{ts}(\lambda)\, \delta_{ts}^A\right) - \left(p_{t'}^A + \sum_{s \in S} q_{ts}(\lambda)\, \delta_{t's}^A\right) \leq 0 \qquad , \forall t, t' \neq t \tag{3.8}$$

$$\mu_{tt'}^A \left[\left(p_t^A + \sum_{s \in S} q_{ts}(\lambda)\, \delta_{ts}^A\right) - \left(p_{t'}^A + \sum_{s \in S} q_{ts}(\lambda)\, \delta_{t's}^A\right)\right] = 0 \quad , \forall t, t' \neq t \tag{3.9}$$

$$\vec{\hat{\gamma}}^m \vec{p}^A - V'(\lambda) \leq 0 \qquad , \forall m \in \mathbb{M} \tag{3.10}$$

$$\mu_m^{A(ICM)} \left[\vec{\hat{\gamma}}^m \vec{p}^A - V'(\lambda)\right] = 0 \qquad , \forall m \in \mathbb{M} \tag{3.11}$$

$$V(\lambda) + U^0 - \vec{\gamma}(\lambda) \vec{p}^A = 0 \tag{3.12}$$

$$V'(\lambda) - \vec{\hat{\gamma}}^H \vec{p}^A \leq 0 \tag{3.13}$$

$$\mu_1^A \left[V'(\lambda) - \vec{\hat{\gamma}}^H \vec{p}^A\right] = 0 \tag{3.14}$$

where

$$\begin{aligned} v_{ts}^A &= \sum_{t' \neq t} \left(\mu_{tt'}^A q_{ts}(\lambda) - \mu_{t't}^A q_{t's}(\lambda)\right), \\ v_t^A &= \sum_{s \in S} v_{ts}^A = \sum_{t' \neq t} \left[\mu_{tt'}^A - \mu_{t't}^A\right]. \end{aligned}$$

Moreover, the expected social loss of implementation using the authority contract is:

$$Loss^A(\lambda) = \vec{\Gamma}(\lambda) \vec{\delta}^A = \mu_1^A V'(\lambda), \tag{3.15}$$

with $Loss^A(\lambda) > 0$ *whenever* $\lambda > 0$.

(3.5) is the first-order condition for p_t^A; it holds with equality because $p_t^A \geq 0\ \forall t$. (3.6) and (3.7) are the first-order and complementary slackness conditions for δ_{ts}^A. (3.8) and (3.9) are respectively constraint PTR (3.2) and its complementary slackness condition. (3.10) and (3.11) are respectively constraint ICM (2.15) and its complementary slackness condition. (3.12) is PC (2.11), and (3.13) and (3.14) are respectively the ICE (2.14) and its complementary slackness condition.

These conditions have some natural interpretations. Let $\vec{\mu}_{PTR}^A = \left\{\mu_{tt'}^A\right\}_{t \in S, t' \in S/\{t\}}$ be the vector of Lagrange multipliers for PTR (3.2). Define the value of the Principal's truthful-reporting constraint under an optimal authority contract ψ^A as:

$$TC\left(\psi^A, \vec{\mu}_{PTR}^A\right) = \sum_{t \in S} \sum_{t' \in S/\{t\}} \mu_{tt'}^A \Big[(p_t^A + \sum_{s \in S} q_{ts}(\lambda)\, \delta_{ts}^A) - (p_{t'}^A + \sum_{s \in S} q_{ts}(\lambda)\, \delta_{t's}^A)\Big]. \tag{3.16}$$

The marginal effect of conflict in state ts upon the constraints is given by:

$$v_{ts}^A = \frac{\partial TC\left(\psi^A, \vec{\mu}_{PTR}^A\right)}{\partial \delta_{ts}^A}. \tag{3.17}$$

When $v_{ts}^A < 0$, increasing δ_{ts}^A relaxes the truthful-reporting constraint. On the other hand, the direct marginal cost of increasing δ_{ts}^A is $\Gamma_{ts}(\lambda)$, the probability of state ts occurring. When $\Gamma_{ts}(\lambda) + v_{ts}^A > 0$, the marginal cost of increasing δ_{ts}^A outweighs it marginal benefit and hence, δ_{ts}^A should be made as small as possible ($\delta_{ts}^A = 0$); this is reflected in conditions (3.6) and (3.7). Conflict thus occurs only when the marginal benefit from conflict, $-v_{ts}^A$, is equal to the marginal cost, $\Gamma_{ts}(\lambda)$.

We can get a bit more insight into the optimal contract when the optimal contract is differentiable in an open ball around some effort level λ.[26] Let us also suppose that the no-malfeasance constraints ICM (2.15) do not bind at the optimal contract so that $\mu_m^{A(ICM)} = 0 \; \forall m \in \mathbb{M}$. By the envelope theorem, we have:

$$\begin{aligned}
\frac{d}{d\lambda} C^{A*}(\lambda) &= \frac{\partial}{\partial \lambda} L^A\left(\psi^A, \vec{\mu}^A\right) \\
&= V'(\lambda) + \mu_1^A V''(\lambda) && (3.18)\\
&\quad + \sum_{t,s \in S} \hat{\Gamma}_{ts}^H \delta_{ts}^A && (3.19)\\
&\quad + \sum_{t \in S} \sum_{t' \in S/\{t\}} \mu_{tt'}^A \sum_{s \in S} \frac{\partial q_{ts}(\lambda)}{\partial \lambda} \left(\delta_{ts}^A - \delta_{t's}^A\right). && (3.20)
\end{aligned}$$

Expression (3.18) is the effect upon $C^{A*}(\lambda)$ due to both the rising absolute (for PC (2.11)) and marginal cost of effort (for ICE (2.14)). The next two lines concern how $C^{A*}(\lambda)$ changes with effort due to its effect upon the probability of conflict at different states. In particular, expression (3.20) depends on the effect of effort on the correlation between the parties' signals.[27]

Proposition 3 characterizes the optimal authority contract under the full support condition FSC at λ. In the absence of the full support condition, it is possible that conflict never occurs in equilibrium, although it must remain as part of the contract terms. For example, suppose that $\Gamma_{ts}(\lambda) = 0$ whenever $t \neq s$. By setting $\delta_{ts}^A = 0$ for all $t = s$ and setting δ_{ts}^A sufficiently large whenever $t \neq s$, the players' truthful-reporting constraints are satisfied immediately. Since $t \neq s$ occurs with zero probability, the expected conflict is zero and we get implementation without conflict on the equilibrium path, with $\mu_1^A = 0$. The full support condition FSC implies that there is always some residual uncertainty and conflict in equilibrium then becomes unavoidable. From (2.16), the inefficiency in any contract is due entirely to these conflicts.

Next, since $V(\lambda)$ is unbounded as $\lambda \to 1$, there is a $\lambda^{\max}$ satisfying $\lambda^{\max} B_H - V(\lambda^{\max}) + U^{P0} < U^0$ and $V'(\lambda^{\max}) > B_H$, such that the Principal will never choose to implement any $\lambda > \lambda^{\max}$. Thus, without loss of generality, we can restrict the choice set for optimal effort to the closed set $[0, \lambda^{\max}]$. In that case, if the cost function is continuous in λ, then the optimal λ choice always exists.

Proposition 4. *Suppose that the full support condition FSC holds for all $\lambda \in [0, \lambda^{\max}]$ and the Strong Malfeasance-Free Condition SMFC (3.4) is satisfied. The solution to program-AC (3.3), $C^{A*}(\lambda)$, is continuous in $\lambda \in [0, \lambda^{\max}]$.*

Given that the cost function is continuous, there exists a solution to the optimal effort choice: $\lambda^{A*} \in \arg\max_{\lambda \in [0, \lambda^{\max}]} U^{P0} + \lambda B_H - C^{A*}(\lambda)$. The parties will then enter into an agreement $\psi^A\left(\lambda^{A*}\right) \in \Psi^{A*}\left(\lambda^{A*}\right)$ if and only if $U^{P0} + \lambda^{A*} B_H - C^{A*}\left(\lambda^{A*}\right) \geq 0$.

3.2. **The Sales Relationship and Guile.** Next, we consider contracting under a sales relationship. Here, the Agent reports her performance evaluation s first, and then the Principal reports his evaluation t upon observing the Agent's report. This type of contract is natural in situations where the Agent is an expert

[26]In general, the solution to a linear program is not unique, which complicates sensitivity analysis. The contract can be unique and continuous in parameters when the solution is at a regular extreme point of the constraint space. See Luenberger and Ye (2008).

[27]In Supplementary Appendix B, we explore the case where the correlation between the signals is independent of effort. This allows a clearer illustration on the effect of the correlation on the conflicts.

selling services to the Principal, such as expert advice. Analogous to ATR (3.1), the *Principal's truthful-reporting constraint (PTR)* in the sales relationship is:

$$c_{ts} \quad \leq \quad c_{t's}, \qquad \forall t, t', s \in S. \tag{3.21}$$

This immediately implies:

Lemma 3. *In a sales relationship, the Principal's truthful-reporting constraint PTR (3.21) implies that* $c_{t's} = c_{ts}$ $\forall t, t', s \in S$.

This corresponds to a sales contract whereby the Agent supplies a good or service to the Principal and informs him about the expected quality s. The Principal then has to pay according to the Agent's evaluation, but if he feels that he is short-changed, he can respond by inflicting a punishment on the Agent to discipline her. Hence, without loss of generality (Lemma 1), we let the Principal be the party imposing all the conflict costs under a sales contract.

Since c_{ts} varies only with s and not t, we define a cost-price vector $\vec{p}^S = \left[p_0^S, ..., p_{n-1}^S\right]^T \in \Re^n$ (S for sales contract) where $c_{ts} \equiv p_s^S$ $\forall t, s \in S$.[28] Given the conflict δ_{ts}^S imposed by the Principal on the Agent in state ts, the wage of the Agent under a sales contract is then $w_{ts} = p_s^S - \delta_{ts}^S \leq p_s^S$ $\forall t, s \in S$. Thus, the set of sales contracts that incorporate the Principal's truthful-reporting constraint takes the form:

$$\psi^S = \left\{\lambda, \vec{p}^S, \vec{\delta}^S\right\} \in \Psi^S \equiv [0,1) \times \Re^n \times \Re_+^{n^2}.$$

Next, the Agent's truthful-reporting constraint requires that after exerting effort λ and observing a signal $s \in S$, she cannot increase her expected wages by reporting a signal $s' \neq s$. The *Agent's truthful-reporting constraint (ATR)* conditional upon λ are:

$$\left(p_s^S - \sum_{t \in S} r_{ts}(\lambda)\, \delta_{ts}^S\right) - \left(p_{s'}^S - \sum_{t \in S} r_{ts}(\lambda)\, \delta_{ts'}^S\right) \geq 0, \quad \forall s, s' \in S, \tag{3.22}$$

where $r_{ts}(\lambda) = Pr\left[t \middle| s, \lambda\right]$, as defined in (2.6).

Unlike the authority contract, the Agent's payoffs can depend on her report under the sales contract. This introduces an additional form of opportunism because the Agent also has some control over the distribution of both parties' signals through her choice of effort $\vec{\lambda}$. In particular, the Agent can deviate from the effort obligation and then choose a (possibly) non-truthful reporting strategy to her advantage. We call this form of opportunism *guile* because the Agent knowingly alters the signal-generating process via reneging on the contractual effort terms, and then tries to cover it up by manipulating her reports accordingly.

A bit of matrix notation is required to formally write the guile constraint. Let N be the linear mapping from $\Re^n$ to $\Re^{n^2}$ with the feature that $\vec{c} = N\vec{p}^S \in \Re^{n^2}$, where $c_{ts} = p_s^S$ $\forall t, s \in S$.[29] We want to represent the Agent's state-contingent payoff as a mapping that depends on her reporting strategy. Since the dimension of the state space is n^2, we can view a reporting strategy, denoted by Π, as a linear transformation from $\Re^{n^2}$

[28]Note that in the authority-relationship analysis, prices refer to wages, whereas prices refer to costs here. To avoid confusion, one should think of a price vector $\vec{p}$ as always a $n \times 1$ vector while wage $\vec{w}$, cost $\vec{c}$ and conflict $\vec{\delta}$ are always $n^2 \times 1$ vectors. Under the authority contract, the wage vector $\vec{w}$ has only n degree of freedom due to ATR and hence, we let the wage be prices there. Under the sales contract, it is the cost vector $\vec{c}$ that has only n degree of freedom due to PTR and hence, we let the cost be prices here.

[29]N is a $n^2 \times n$ matrix with the property that $N_{\mathcal{I}(ts),s} = 1$ $\forall t, s \in S$ and 0 otherwise. It is intuitive to think about the complete wage schedule as a $n \times n$ square matrix in the (t, s)-space where the rows are t and the columns are s. Since costs are independent of t, every row of the square cost matrix is $(\vec{p}^s)^T$. Hence the linear transformation of N is essentially extending $(\vec{p}^s)^T$ along the row dimension before flattening it into a $n^2 \times 1$ column vector.

to $\Re^{n^2}$ as follows. A complete reporting strategy of the Agent can be represented by a $n \times n$ matrix π whose entries are either 1 or 0, each row has exactly one entry of 1, and $\pi_{ss'} = 1$ means that the Agent reports state s' when the true state is s; the truthful-reporting strategy is represented by the identity matrix I.[30] The transformation from π to Π is then as follows: for any $s, s' \in S$, $\Pi_{\mathcal{I}(ts),\mathcal{I}(ts')} = 1$ $\forall t \in S$ if $\pi_{ss'} = 1$, and 0 otherwise. Given this, the state-contingent wage vector associated with reporting strategy Π is:

$$\Pi\vec{w} \;=\; \Pi\big(N\vec{p}^S - \vec{\delta}^S\big) \in \Re^{n^2}. \tag{3.23}$$

In the absence of guile, the truthful-reporting strategy can be checked signal by signal. However, when there is guile, the Agent can consider an effort deviation to $\vec{\lambda}^g \neq [\lambda, 0, \ldots, 0]$ and then optimally misreport only some signals. The profitability of the deviation needs to be computed given the planned reporting strategy. Let Z be the set of possible reporting strategies of the Agent. For an allocation to be guile-free, it must be the case that the Agent cannot benefit from *jointly* deviating from the effort obligation and the truthful-reporting strategy:

Definition 4. A contract $\psi^S = \left\{\lambda, \vec{p}^S, \vec{\delta}^S\right\}$ is *guile-free (GF)* if $\forall \vec{\lambda}^g \in [0,1)^{\bar{m}+1}$, $\forall \Pi \in Z$:

$$\vec{\Gamma}(\lambda)\left(N\vec{p}^S - \vec{\delta}^S\right) - V(\lambda) \geq \vec{\Gamma}\left(\vec{\lambda}^g\right)\Pi\left(N\vec{p}^S - \vec{\delta}^S\right) - V\left(\vec{\lambda}^g\right). \tag{3.24}$$

The left-hand side of (3.24) is the Agent's ex-ante expected payoff of adhering to the contract effort obligation and then reporting truthfully; the right-hand side is her expected payoff under effort $\vec{\lambda}^g$ and then using reporting strategy Π.[31] Under an authority contract, $\Pi\vec{w}$ is constant for all $\Pi \in Z$ and hence, this constraint is already implied by the incentive constraint for effort ICE (2.14) and no-malfeasance ICM (2.15).

Definition 5. The set of sales contracts that implement λ is defined by $\Psi^S(\lambda) \subset \Re^n \times \Re_+^{n^2}$ where RBC (2.7), PC (2.11), ICE (2.14), ICM (2.15), ATR (3.22), PTR (3.21) and GF (3.24) are satisfied for $\vec{\lambda} = [\lambda, 0, ..., 0]$ for any $\left\{\vec{p}^S, \vec{\delta}^S\right\} \in \Psi^S(\lambda)$.

For any λ, the set of guile-free contracts (3.24) is convex.[32] Hence $\Psi^S(\lambda)$ is a convex set when it is not empty. The program for finding the optimal sales contract is:

Program-SC:

$$C^{S*}(\lambda) = \begin{cases} \min_{\psi^S \in \Psi^S(\lambda)} C\left(\lambda, \psi^S\right) & \text{, if } \Psi^S(\lambda) \neq \emptyset \\ \infty & \text{, if } \Psi^S(\lambda) = \emptyset. \end{cases} \tag{3.25}$$

It remains true here that adding a constant to p_s^S $\forall s$ will not affect any of the constraints and hence, under the unlimited liability assumption on the Agent, the Principal will always set PC to bind under the optimal sales contract.

3.2.1. *The Guile Constraint:* Notice that when $\vec{\lambda}^g$ in the guile constraint (3.24) is replaced by the contract effort obligation, we have ATR (3.22). Also, when Π is replaced by the identity matrix (but allowing $\vec{\lambda}^g$

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[30]Throughout the paper, I denotes the identity matrix (with the appropriate dimension).

[31]In essence, the Agent's ex-ante strategy here is a pair $\left\{\vec{\lambda}^g, \Pi\right\}$. This is related to the notion of "manipulative strategy" in Myerson (1986). Myerson studies dynamic games where agents receive private information along the game and there is communication with a mediator who helps to coordinate the players' actions. Incentive compatibility there then requires each player to have no profitable manipulative strategy via jointly mis-reporting her information *and* then disobeying the mediator's prescribed action.

[32]For each λ, the set of $\{\vec{p}^S, \vec{\delta}^S\}$ satisfying (3.24) for any $\vec{\lambda}^g$ and Π is convex, and the infinite intersection of convex sets is convex.

to vary now), (3.24) implies ICE (2.14) and ICM (2.15). Hence the guile constraint (3.24) subsumes the Agent's truthful-reporting constraint and her incentive-compatibility constraint for effort obligation and no-malfeasance.

The representation in (3.24) implies that the guile constraint is an infinite set of inequalities due to the need for (3.24) to be satisfied for all $\vec{\lambda}^g \in [0,1)^{\bar{m}+1}$. This can be reduced to a finite set of inequalities by observing that the Agent's optimal choice of effort conditional upon her reporting strategy is unique. Since the number of reporting strategies is finite, we then only have to check a finite number of inequalities under the hypothesis that the Agent anticipates how she will report.

To be precise, we first define the optimal effort function $\Lambda : \Re \to [0,1)$ as:

$$\Lambda(y) \quad = \quad \begin{cases} (V')^{-1}(y) & \text{, if } y > V'(0), \\ 0 & \text{, if } y \leq V'(0). \end{cases} \tag{3.26}$$

Let $y = \vec{\hat{\Gamma}}^{\tau}\Pi\vec{w}$ denote the *effort incentives* for task τ under reporting strategy Π; $\Lambda(y)$ thus defines the Agent's optimal effort level to be exerted on task τ. Next, given any wage vector $\vec{w}$ and reporting strategy Π, it is optimal for the Agent to load all effort onto task τ^* where:[33]

$$\tau^*(\Pi\vec{w}) \quad = \quad \arg\max_{\tau\in\{H\}\cup\mathbb{M}} \vec{\hat{\Gamma}}^{\tau}\Pi\vec{w}. \tag{3.27}$$

We can now define the "guile function". Let

$$\tilde{g}(y) \quad \equiv \quad \Lambda(y)\,y - V(\Lambda(y)). \tag{3.28}$$

It is readily verified that $\tilde{g}$ is strictly increasing and strictly convex for $y > V'(0)$.[34] The *guile-function* is defined as $g : Z \times \Re^{n^2} \to \Re$, where:

$$g(\Pi, \vec{w}) = \tilde{g}\left(\vec{\hat{\Gamma}}^{\tau^*(\Pi\vec{w})}\Pi\vec{w}\right). \tag{3.29}$$

Notice that $\forall\vec{\lambda}^g = [\lambda^g_H, \lambda^g_1, \ldots, \lambda^g_{\bar{m}}] \in [0,1)^{\bar{m}+1}$ and for any $\Pi \in Z$, we have:

$$g(\Pi, \vec{w}) \quad \geq \quad \sum_{\tau\in\{H\}\cup\mathbb{M}} \lambda^g_\tau \vec{\hat{\Gamma}}^{\tau}\Pi\vec{w} - V\left(\vec{\lambda}^g\right).$$

Thus we have the following result:

Proposition 5. *The guile constraint (3.24) consists of a finite set of inequalities. A sales contract* $\psi^S = \left\{\lambda, \vec{p}^S, \vec{\delta}^S\right\} \in \Psi^S$ *satisfies (3.24) for effort obligation* λ *if and only if:*

$$\vec{\Gamma}(\lambda)\vec{w} - V(\lambda) \geq \vec{\Gamma}^L\Pi\vec{w} + g(\Pi, \vec{w}), \quad \forall \Pi \in Z \tag{3.30}$$

where $\vec{w} = N\vec{p}^S - \vec{\delta}^S$*. ICE (2.14), ICM (2.15), ATR (3.22) are also satisfied when (3.30) is satisfied.*

Since program-SC (3.25) is a convex program with a finite number of constraints, its solutions can be characterized by the Kuhn-Tucker conditions. The following proposition provides an existence result for the optimal sales contracting problem. Let $G(\lambda) \subset \Psi^S$ be the set of contracts $\left\{\vec{p}^S, \vec{\delta}^S\right\}$ such that $\vec{w} = N\vec{p}^S - \vec{\delta}^S$ satisfies (3.30) for effort obligation λ.

[33] If there are more than one tasks that achieves the maximum, then pick the task with the lowest index with H indexing 0.

[34] Λ is differentiable for $y > V'(0)$. By the envelope theorem, $\tilde{g}'(y) = \Lambda(y) > 0$. Hence $\tilde{g}''(y) = \Lambda'(y) = \frac{1}{V''(y)} > 0$; the more convex V is, the less is the convexity of $\tilde{g}$.

Proposition 6. *Suppose that the full support condition FSC holds at λ. There exists an optimal sales contract that implements λ if and only if the set $G(\lambda)$ is non-empty.*

Whenever the optimal sales contract exists, analogous to (3.15), we define the expected social loss of implementing effort λ under the sales contract as:

$$Loss\,(\lambda) = \vec{\Gamma}\,(\lambda)\,\vec{\delta}^{S}, \tag{3.31}$$

where $\psi^S = \left\{\lambda, \vec{p}^S, \vec{\delta}^S\right\}$ is an optimal sales contract.

3.2.2. *The Relaxed-Sales Contracting Problem:* Before proceeding further, it is useful to define a *relaxed-version* of the sales contracting problem that considers only the *ex post* constraints, as in the case of the authority contract. In the Supplementary Appendix B, we use this relaxed problem to derive a "duality" relationship between the authority and the sales contract. In section 4, we compare the optimal sales contract with the optimal relaxed-sales contract; this allows us to illustrate when the set of guile-free sales contracts is strictly smaller than the set of sales contracts that satisfy only the Agent's truthful-reporting constraints.

Definition 6. The set of *relaxed-sales* contracts that implement λ is defined by $\Psi^{SR}(\lambda) \subset \Re^n \times \Re_+^{n^2}$, where RBC (2.7), PC (2.11), ICE (2.14), ICM (2.15), ATR (3.22) and PTR (3.21) are satisfied for $\vec{\lambda} = [\lambda, 0, ..., 0]$ for any $\left\{\vec{p}^S, \vec{\delta}^S\right\} \in \Psi^{SR}(\lambda)$.

The relaxed-sales program is:

Program-SC-R:

$$C^{SR*}(\lambda) = \begin{cases} \min_{\psi^{SR}\in\Psi^{SR}(\lambda)} C\left(\lambda, \psi^{SR}\right) & \text{, if } \Psi^{SR}(\lambda) \neq \emptyset \\ \infty & \text{, if } \Psi^{SR}(\lambda) = \emptyset. \end{cases} \tag{3.32}$$

3.3. **Authority or Sales Contract: Complexity Considerations.** Besides the potential efficiency gains from using one contract over another, there is also the practicality concern of writing each contract. The presence of the guile constraint in the sales contract makes it potentially more complex than writing an authority contract. We provide a heuristic comparison of complexity between the two contracts by considering the number of incentive constraints that each contract has to satisfy.

TABLE 1. Number of Constraints for the Authority and Sales Contracting Problems

Number of Signals	Authority Contract	Sales Contract
2	2+m+2	4
5	20+m+2	3125
10	90+m+2	10 billion

For a signal space of size n with m possible malfeasance tasks, the authority contracting problem has a total of $n^2 - n + m + 2$ constraints to satisfy.[35] On the other hand, from Proposition 5, the sales contract has only the guile and participation constraints to satisfy. The number of constraints associated with the guile constraint is the number of possible deviating reporting strategy which is given by $|Z| - 1 = n^n - 1$. Together with PC (2.11), there are thus a total of n^n constraints. This implies that as n increases, the

[35]There are m constraints for ICM (2.15), 1 for ICE (2.14), $n(n-1)$ truth-telling constraints for PTR (3.2), and 1 for PC (2.11).

number of constraints for the sales contracting problem increases exponentially faster than that for the authority contracting problem.

Table 1 illustrates the point that there is a profound effect upon the constraint space and complexity by merely changing the order of information revelation in a Principal-Agent problem. Moreover, this has not taken into account that the authority contracting problem is linear while the sales contracting problem is non-linear because of the guile constraint; we know that algorithms for solving linear programs are very efficient in general. This complexity observation is consistent with the intuition of Williamson (1975) that guile and opportunism have serious implications for organizational design. Besides this apparent complexity, the guile constraint by itself can be very restrictive on the feasible set of contracts. We study this in more detail in section 4

3.4. **Informed-Principal and Expert-Agent.** Our general information structure covers the special cases which we call the "*informed-Principal*" and the "*expert-Agent*" environments.

Definition 7. The information structure is an *informed-Principal (IP)* environment if for all outcomes $o \in \{L\} \cup \{H\} \cup \mathbb{M}$, the probability of each state occurring can be represented by $\Gamma^o_{ts} = \gamma^o_t q_{ts} \quad \forall t, s \in S$, where $\gamma^o_t = \sum_{s \in S} \Gamma^o_{ts}$, and $q_{ts} = Pr[s|t]$ is the conditional probability of the Agent observing signal s when the Principal observes t.

This implies that $\Gamma_{ts}(\lambda) = \gamma_t(\lambda) q_{ts} \ \forall \lambda$, and the conditional probability q_{ts}, as defined in (2.5), is independent of the Agent's effort. The IP environment includes the information structure of cases where the Agent has no information about the performance (Levin (2003) and Fuchs (2007)), and also cases where the Agent's information is a noisy signal of the Principal's information (MacLeod (2003), Chan and Zheng (2011) and Maestri (2012)).

The flipped side of the IP environment is the expert-Agent environment:

Definition 8. The information structure is an *expert-Agent (EA)* environment if for all outcomes $o \in \{L\} \cup \{H\} \cup \mathbb{M}$, the probability of each state occurring can be represented by $\Gamma^o_{ts} = \beta^o_s r_{ts} \quad \forall t, s \in S$, where $\beta^o_s = \sum_{t \in S} \Gamma^o_{ts}$, and $r_{ts} = Pr[t|s]$ is the conditional probability of the Principal observing signal t when the Agent observes s.

The EA environment corresponds to models of "credence goods" (Darby and Karni (1973), Emons (1997) and Dulleck and Kerschbamer (2006)), such as contracting for expert advice from physicians and consultants.

A detailed analysis of the IP and EA contracting environments is provided in Supplementary Appendix B. There, we show that in the EA environment, the set of optimal sales contracts corresponds to the set of optimal relaxed-sales contracts. This illustrates that the problem of guile in the sales contract is not merely an issue of asymmetric information, but arises in conjunction with the Agent's ability to manipulate the Principal's information flow.

We also develop a duality relationship between the authority and sales contracts. This relationship arises because after the parties observe their private information, they are effectively playing a zero-sum game in which the payoffs are determined by the correlation between their signals. We show that every optimal sales contract in an EA environment can be mapped to an optimal authority contract in the dual IP environment. However, despite the apparent symmetry in information structure between the EA and IP environments, the optimal sales contract in the EA environment is not perfectly symmetric to the optimal authority contract in the IP environment. This illustrates a difference in how information is utilized in the two types of contracts:

the authority contract uses only the Principal's information to provide effort incentives for the Agent, whereas the sales contract uses both the Agent's and the Principal's information to provide effort incentives.

Finally, an important theme in organizational economics is the role of authority in the presence of asymmetric information. A number of papers have developed the intuition that authority should be given to the party with the superior information.[36] We use the IP and EA environments to illustrate that this is not necessarily the case here. When the cardinality of the signal space is greater than 2, it is possible that the authority contract is more efficient than the sales contract in the EA environment in which the Agent has the superior information about the performance, and vice versa. Existing models on credence goods typically consider only binary signals, and MacLeod (2003) has also shown that the authority contract is always more efficient than the sales contract in the IP environment with only 2 signals.[37] However, in practice, parties to an agreement have access to a large number of signals of performance, ranging from peer reports to random monitoring. These results illustrate that adding more signals is not an insignificant extension of the Principal-Agent model.

4. Guile

We now study the issue of guile in the sales contract in more detail. We begin with two examples to illustrate the detrimental effects of guile on the efficiency of the sales contract. Section 4.1 considers a 2-signal, no-malfeasance and incentive-neutral (to be defined) environment. We solve for both the optimal authority and sales contracts there and show that the guile constraint has an adverse effect on both the complexity and efficiency of the contract. Next, section 4.2 provides an example illustrating the interplay of guile and malfeasance. In that example, pure guile does not worsen the inefficiency of the sales contract but it does restrict the contract form, while pure malfeasance also has no effect by itself. However, when guile interplays with malfeasance, both efficiency and contract form are affected. We then provide a general analysis of guile in section 4.3 and provide some general conditions under which guile is a binding constraint.

4.1. **Example 1: Incentive-Neutral Information Structure with Two Signals.**

We put aside malfeasance (let $\mathbb{M} = \emptyset$) and consider a simple example with two signals. Suppose that $S = \{U, E\}$ with U denoting an "unacceptable" performance, and E for an "excellent" performance. We assume full support in the low outcome, $\Gamma^L_{ts} \in (0, 1)\ \forall t, s \in \{U, E\}$, with an *incentive-neutral* information structure where:

$$\hat{\Gamma}^H_{EU} = \hat{\Gamma}^H_{UE} = 0 \quad \text{and} \quad \hat{\Gamma}^H_{EE} = \rho > 0. \tag{4.1}$$

This then implies that $\hat{\Gamma}^H_{UU} = -\rho$. Such a signal structure is fully parametrized by ρ under the restriction that: $0 < \hat{\Gamma}^H_{EE} = -\hat{\Gamma}^H_{UU} = \rho < \min\left\{\Gamma^L_{UU}, \left(1 - \Gamma^L_{EE}\right)\right\} < 1$.[38] The incentive-neutral assumption means that the Agent's effort incentives are generated only via payments at states where the players agree on the outcome. We will solve for optimal authority and sales contracts that implement an effort $\lambda > 0$ for a fixed value of ρ.

[36] Gibbons (1987) illustrates that when the uninformed Principal has authority, it gives rise to an inefficient outcome and more conflict. Kanemoto and MacLeod (1992) show that this can be solved by allocating power to the informed agent. Milgrom (1988) makes this point regarding discretion in an organization, while Aghion and Tirole (1997) highlight the role that information plays in determining real authority.

[37] See the appendix of MacLeod (2003).

[38] This restriction ensures that the probability distribution of the states under the high outcome $\vec{\Gamma}^H$ is well-defined and given by $\Gamma^H_{ts} = \hat{\Gamma}^H_{ts} + \Gamma^L_{ts}\ \forall ts \in \{U, E\}^2$.

4.1.1. *Optimal Authority Contract.* Let w_U and w_E be the wages for the Agent when the Principal reports U and E respectively under the authority contract. ICE (2.14) implies:

$$\begin{aligned} & \rho w_E - \rho w_U = V'(\lambda) \\ \Longrightarrow \quad & b^A \equiv w_E - w_U = \tfrac{V'(\lambda)}{\rho}. \end{aligned}$$

The low payment w_U is then pinned down by the binding PC (2.11):

$$\begin{aligned} & w_U + Pr\left[t = E\right] b^A - V(\lambda) - U^0 = 0 \\ \Longrightarrow \quad & w_U = V(\lambda) + U^0 - \left(\Gamma^L_{EU} + \Gamma^L_{EE} + \lambda\rho\right) \tfrac{V'(\lambda)}{\rho}. \end{aligned}$$

The conflict vector $\vec{\delta}^A$ is determined by the Principal's truthful reporting constraint PTR (3.2). One can verify that PTR is more stringent when the Principal sees an excellent performance ($t = E$), but wants to lie that the performance is unacceptable to save on paying the bonus b^A. To deter this, conflict has to occur at state UE where the Principal believes performance is unacceptable but the Agent disagrees with this assessment. The PTR constraint at $t = E$ is:

$$\begin{aligned} & \left(\Gamma^L_{EU} + \Gamma^L_{EE} + \lambda\rho\right)\left(w_U + b^A\right) \leq \Gamma^L_{EU} w_U + \left(\Gamma^L_{EE} + \lambda\rho\right)\left(w_U + \delta^A_{UE}\right) \\ \Longrightarrow \quad & \delta^A_{UE} \;\geq\; \tfrac{\Gamma^L_{EU} + \Gamma^L_{EE} + \lambda\rho}{\Gamma^L_{EE} + \lambda\rho} b^A \;=\; \left(1 + \tfrac{\Gamma^L_{EU}}{\Gamma^L_{EE} + \lambda\rho}\right) \tfrac{V'(\lambda)}{\rho}. \end{aligned}$$

The optimal contract requires conflict to be as low as possible, and hence the above constraint must bind. From this, the total expected deadweight-loss under an authority contract is:

$$Loss^{A(in)}(\lambda) \;=\; \Gamma^L_{UE}\delta^A_{UE} \;=\; \Gamma^L_{UE}\left(1 + \frac{\Gamma^L_{EU}}{\Gamma^L_{EE} + \lambda\rho}\right)\left(\frac{V'(\lambda)}{\rho}\right) \tag{4.2}$$

4.1.2. *Optimal Relaxed-Sales Contract.* Before considering the optimal sales contract, we first consider the optimal relaxed-sales contract (solution to program-SC-R (3.32)), and then illustrate how guile constrains it. Let c_U and c_E be the costs that the Principal pays when the Agent reports U and E respectively. One can verify that since $\rho > 0$, the Agent's truthful-reporting constraint ATR (3.22) is more stringent at $s = U$; that is, when she observes that her performance is unacceptable but wants to report that it is excellent to get a higher price. To deter this behavior, conflict needs to occur at state UE where the Agent claims that her performance is excellent but the Principal believes otherwise. Under these observations, the Agent's ICE (2.14) is:

$$\begin{aligned} & \rho c_E - \rho c_U = V'(\lambda) \\ \Longrightarrow \quad & b^{SR} \equiv c_E - c_U = \tfrac{V'(\lambda)}{\rho} = b^A. \end{aligned} \tag{4.3}$$

The Agent's truthful-reporting constraint ATR (3.22) at $s = U$ is:

$$\begin{aligned} & \left(\Gamma^L_{UU} - \lambda\rho + \Gamma^L_{EU}\right) c_U \geq \left(\Gamma^L_{UU} - \lambda\rho\right)\left(c_E - \delta^{SR}_{UE}\right) + \Gamma^L_{EU} c_E \\ \Longrightarrow \quad & \delta^{SR}_{UE} \;\geq\; \tfrac{\Gamma^L_{UU} - \lambda\rho + \Gamma^L_{EU}}{\Gamma^L_{UU} - \lambda\rho} b^{SR} \;=\; \left(1 + \tfrac{\Gamma^L_{EU}}{\Gamma^L_{UU} - \lambda\rho}\right) \tfrac{V'(\lambda)}{\rho} \end{aligned} \tag{4.4}$$

Setting this to bind gives the optimal relaxed-sales contract. The term $\Gamma^L_{UE}\delta^{SR}_{UE}$ is the expected deadweight loss of the optimal relaxed-sales contract, and it is greater than $Loss^{A(in)}(\lambda)$ in (4.2) if $\frac{\Gamma^L_{EU}}{\Gamma^L_{UU} - \lambda\rho} > \frac{\Gamma^L_{EU}}{\Gamma^L_{EE} + \lambda\rho}$. Since the optimal relaxed-sales contract must be weakly more efficient that the optimal sales contract with the guile constraint considered, we have:

Proposition 7. *Under the incentive-neutral information structure (4.1), the optimal authority contract is more efficient than the optimal sales contract whenever* $\lambda > \frac{\Gamma^L_{UU} - \Gamma^L_{EE}}{2\rho}$.

This suggests that the authority contract is better than the sales contract when the effort obligation λ is higher than the ratio of the information content of the low signal $(\Gamma^L_{UU} - \Gamma^L_{EE})$ relative to the high signal (2ρ). In particular, if the ratio is negative, then it is never optimal to use a sales contract.

4.1.3. *Optimal Sales Contract.* Solving for the optimal authority and the optimal relaxed-sales contracts here has been relatively easy. We consider the optimal sales contract with the guile constraint considered now. We first show that the optimal relaxed-sales contract derived above is not guile-free and then illustrate the additional layers of complexity that the guile constraint presents.

To take into account guile (3.30), we have to consider all possible deviating reporting strategies of the Agent, each of which is represented by a matrix Π as described in (3.23). We denote the Agent's three possible deviating reporting strategies by:

- Π_1: always report E.
- Π_2: always report U.
- Π_3: always mis-report (reports E when sees U, and reports U when sees E).

The truthful-reporting strategy is denoted by the identity matrix I.

To see why the optimal relaxed-sales sales contract in (4.3) and (4.4) is not guile-free, we first let $\vec{w}^{SR}$ be the Agent's wage vector under the optimal relaxed-sales contract. The Agent chooses her effort level in anticipation of the reporting strategy that she uses later. Her expected payoff for reporting strategy Π is $\vec{\Gamma}^L \Pi \vec{w}^{SR} + g\left(\Pi, \vec{w}^{SR}\right)$ where the guile function g is defined in (3.29). Under $\vec{w}^{SR}$, the effort incentives under the truthful-reporting strategy is $\vec{\hat{\Gamma}}^H I \vec{w}^{SR} = \rho b^{SR}$. The effort incentives under Π_1 is $\vec{\hat{\Gamma}}^H \Pi_1 \vec{w}^{SR} = \rho \delta^{SR}_{UE}$. We then have:

$$\begin{aligned} \vec{\Gamma}^L \vec{w}^{SR} + \lambda \vec{\hat{\Gamma}}^H \vec{w}^{SR} - V(\lambda) &= \vec{\Gamma}^L \Pi_1 \vec{w}^{SR} + \lambda \vec{\hat{\Gamma}}^H \Pi_1 \vec{w}^{SR} - V(\lambda) && (4.5) \\ &< \vec{\Gamma}^L \Pi_1 \vec{w}^{SR} + g\left(\Pi_1, \vec{w}^{SR}\right). && (4.6) \end{aligned}$$

The equality in (4.5) follows from the binding ATR at U under the optimal relaxed-sales contract. This implies that, conditional on exerting the effort obligation λ, the Agent's expected payoff under Π_1 is the same as that under the truthful-reporting strategy. The strict inequality in (4.6) follows from $b^{SR} \neq \delta^{SR}_{UE}$; this implies that Π_1 and the truthful-reporting strategy have different effort incentives and hence, the Agent can do better by using an effort level that is different from λ under Π_1.

We now compute a sales contract that is guile-free against Π_1. Notice that under the optimal sales contract, δ^S_{EE} will be 0, since the highest payoff for the Agent is at state EE. Let $b^S \equiv c_E - c_U > 0$; the optimal sales contract must then take the following form:

<u>Agent's Wage:</u>

	$s = U$	$s = E$
$t = U$	$c_U - \delta^S_{UU}$	$c_U + b^S - \delta^S_{UE}$
$t = E$	$c_U - \delta^S_{EU}$	$c_U + b^S$

Let $\vec{w}$ denote the Agent's wage vector under this sales contract. Consider the Agent's truthful-reporting constraint ATR (3.22) at U:

$$\begin{aligned} \left(\Gamma^L_{UU} - \lambda\rho\right)\left(c_U - \delta^S_{UU}\right) + \Gamma^L_{EU}\left(c_U - \delta^S_{EU}\right) &\geq \left(\Gamma^L_{UU} - \lambda\rho\right)\left(c_U + b^S - \delta^S_{UE}\right) + \Gamma^L_{EU}\left(c_U + b^S\right) \\ \iff \qquad 0 &\geq \left(\Gamma^L_{UU} - \lambda\rho\right)\left(b^S + \delta^S_{UU} - \delta^S_{UE}\right) + \Gamma^L_{EU}\left(b^S + \delta^S_{EU}\right) \end{aligned}$$

Since $\Gamma^L_{EU} > 0$, this necessarily implies that $b^S + \delta^S_{UU} - \delta^S_{UE} < 0$ and hence:

$$\delta^S_{UE} \quad > \quad b^S + \delta^S_{UU} \; > \; 0. \tag{4.7}$$

Next, the effort incentive for Π_1 is $\vec{\hat{\Gamma}}^H \Pi_1 \vec{w} = \rho\delta^S_{UE}$, and the effort incentives for the truthful-reporting strategy is $\vec{\hat{\Gamma}}^H \vec{w} = \rho\left(b^S + \delta^S_{UU}\right)$. The Agent's ICE (2.14) requires that $\vec{\hat{\Gamma}}^H \vec{w} = V'(\lambda)$, and (4.7) then implies that $\vec{\hat{\Gamma}}^H \Pi_1 \vec{w} > \vec{\hat{\Gamma}}^H \vec{w} > V'(0)$. Hence $g\left(I, \vec{w}\right) = \tilde{g}\left(\hat{\Gamma}^H \vec{w}\right)$ and $g\left(\Pi_1, \vec{w}\right) = \tilde{g}\left(\hat{\Gamma}^H \Pi_1 \vec{w}\right)$, where $\tilde{g}$ is defined in (3.28). For the contract to be guile-free against Π_1, it is required that:

$$\vec{\Gamma}^L \vec{w} + \tilde{g}\left(\hat{\Gamma}^H \vec{w}\right) \quad \geq \quad \vec{\Gamma}^L \Pi_1 \vec{w} + \tilde{g}\left(\hat{\Gamma}^H \Pi_1 \vec{w}\right), \tag{4.8}$$

where:

$$\vec{\Gamma}^L \vec{w} \quad = \quad c_U - \Gamma^L_{UU}\delta^S_{UU} - \Gamma^L_{EU}\delta^S_{EU} + \Gamma^L_{UE}\left(b^S - \delta^S_{UE}\right) + \Gamma^L_{EE} b^S, \tag{4.9}$$

$$\vec{\Gamma}^L \Pi_1 \vec{w} \quad = \quad c_U + \left(\Gamma^L_{UU} + \Gamma^L_{UE}\right)\left(b^S - \delta^S_{UE}\right) + \left(\Gamma^L_{EU} + \Gamma^L_{EE}\right) b^S. \tag{4.10}$$

Notice that δ^S_{EU} decreases $\vec{\Gamma}^L \vec{w}$ but does not affect $\Gamma^L \Pi_1 \vec{w}$ nor the effort incentives of both Π_1 and the truthful-reporting strategy. Hence the most efficient way to maintain guile-free against Π_1 entails setting $\delta^S_{EU} = 0$. δ^S_{UU} and δ^S_{UE} are then set to minimize the expected inefficiency:

$$\left(\Gamma^L_{UU} - \lambda\rho\right)\delta^S_{UU} + \Gamma^L_{UE}\delta^S_{UE}, \tag{4.11}$$

while ensuring that the guile constraint against Π_1 (4.8) holds.

We relegate the rest of the details to Supplementary Appendix C.1. It is shown there that if:

$$\left(\Gamma^L_{UU} - \Lambda\left(\rho\delta^S_{UE}\right)\rho\right)^2 \quad \geq \quad \Gamma^L_{UE}\Gamma^L_{EU}, \tag{4.12}$$

where $\Lambda\left(\rho\delta^S_{UE}\right)$ is the optimal effort exerted under effort incentives $\rho\delta^S_{UE}$ (see (3.26)), then the expected inefficiency (4.11) is minimized by setting $\delta^S_{UU} = \delta^S_{EU} = 0$, and δ^S_{UE} to satisfy:

$$\tilde{g}\left(\rho\delta^S_{UE}\right) - \Gamma^L_{UU}\delta^S_{UE} \quad = \quad \tilde{g}\left(V'(\lambda)\right) - \left(\Gamma^L_{UU} + \Gamma^L_{EU}\right)\frac{V'(\lambda)}{\rho}. \tag{4.13}$$

with $b^S = \frac{V'(\lambda)}{\rho}$.

Although this sales contract is guile-free against Π_1, we still need to consider if it is also guile-free against both Π_2 and Π_3. Moreover, when δ^S_{UE} gets too high, the Agent's truthful-reporting constraint at E might be violated in which case, we might need to add conflict at state UU or EU. Without the explicit probabilities and cost function, it is in general very difficult to determine if this sales contract is indeed feasible. This illustrates that even in such a simple 2-signal environment, the issue of guile itself dramatically increases the complexity of the design of sales contracts, which in turn may explain why it is so difficult to design compensation schemes in sales relationship in practice! Nevertheless, we provide sufficient conditions for the above contract to be feasible and hence optimal.

Proposition 8. *Consider the 2-signal incentive-neutral information structure with effort obligation λ. Consider the sales contract $b^S = \frac{V'(\lambda)}{\rho}$, $\delta^S_{UU}, \delta^S_{EU} = 0$, $\delta^S_{UE} > 0$ and $c_U = U^o + V(\lambda) + \Gamma^L_{UE}\delta^S_{UE} - \left(\Gamma^L_{UE} + \Gamma^L_{EE} + \lambda\rho\right) b^S$. Suppose that the following four conditions for δ^S_{UE} hold:*

(1) *δ^S_{UE} satisfies (4.13), and (4.12) holds.*
(2) $\left(\Gamma^L_{UE} + \Gamma^L_{EE} + \lambda\rho\right) b^S - \Gamma^L_{UE}\delta^S_{UE} - V(\lambda) - U^o \geq 0.$
(3) $\delta^S_{UE} \leq \left(\min\left\{1 + \frac{\Gamma^L_{EE}}{\Gamma^L_{UE}}, 2\right\}\right) \times b^S.$
(4) $\left(\Gamma^L_{UE} + \Gamma^L_{EE} + \lambda\rho\right) c_U \leq \left(\Gamma^L_{UE} + \Gamma^L_{EE} + \lambda\rho\right) b^S - \Gamma^L_{UE}\delta^S_{UE}.$

Then this sales contract is optimal.

The proof of Proposition 8 is in Supplementary Appendix C.1. Condition 1 of Proposition 8 characterizes the optimal sales contract that is guile-free against Π_1. Conditions 2 and 3 are respectively sufficient conditions that ensure that the contract is guile-free against Π_2 and Π_3, while condition 4 is the ATR at E.

What is particularly interesting about this result is that guile manifests itself with *higher* effort: the reporting strategy Π_1 in which guile binds induces the Agent to exert a higher effort level than the contract obligation λ. This nicely fits into the example of the healthcare industry where there is a concern that physicians might provide unnecessary procedures.

The final question we address with this example is under what conditions will a sales contract be preferred to an authority contract. Given that characterizing the optimal sales contract requires more information about the explicit cost function, a general result that depends only upon the signal probabilities is not possible. However, when the optimal sales contract takes the form characterized in Proposition 8, the comparison is feasible. Moreover, from Proposition 7, the authority contract is always better with high effort. Thus we only have to consider low effort levels:

Proposition 9. *Suppose that $V'(0) > 0$. Let $Loss^{S(in)}(\lambda)$ be the expected inefficiency of the sales contract that satisfies the conditions in Proposition 8. If $\Gamma^L_{UU} > \Gamma^L_{EE}$, there exists $\epsilon > 0$ such that $Loss^{S(in)}(\lambda) < Loss^{A(in)}(\lambda)$ for all $\lambda \in (0, \epsilon)$.*

Recall from Proposition 7 that under neutral incentives, $\Gamma^L_{UU} > \Gamma^L_{EE}$ is a necessary condition for the sales contract to be more efficient than the authority contract. Thus Proposition 9 illustrates that when this necessary condition is satisfied, the sales contract is more efficient than the authority contract when the effort obligation is sufficiently low.

4.2. **Example 2: The Interplay of Guile and Malfeasance.** We now consider an example that includes malfeasance and show that the interplay between guile and malfeasance can lead to changes in both the efficiency and form of the optimal sales contract. The detailed computations for this example are found in Supplementary Appendix C.2.

Suppose there are three possible signals now: $S = \{U, A, E\}$, where the signals U and E represent "unacceptable" and "excellent" as before, and A represents a moderate signal that the performance is "acceptable". Representing the signal distribution via a 3×3 matrix in the (t, s)-space, we assume that the distribution of states under outcomes L and H are respectively:

$$\Gamma^L = \begin{bmatrix} \varepsilon & \varepsilon & \varepsilon \\ \varepsilon & \eta & \varepsilon \\ \varepsilon & \varepsilon & 0 \end{bmatrix} \quad \Gamma^H = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \eta & 0 \\ 0 & 0 & 7\varepsilon \end{bmatrix}, \quad \Longrightarrow \quad \hat{\Gamma}^H = \begin{bmatrix} -\varepsilon & -\varepsilon & -\varepsilon \\ -\varepsilon & 0 & -\varepsilon \\ -\varepsilon & -\varepsilon & 7\varepsilon \end{bmatrix},$$

where the signals U, A, E are indexed in this order from top to bottom and left to right, with the assumption that $0 < \varepsilon < \eta(= 1 - 7\epsilon) < 7\varepsilon$.[39] We consider implementing an effort level $\lambda > 0$ with a sales contract in this setting in the absence of malfeasance first. Notice that all states except for (A, A) and (E, E) indicate that the outcome is more likely to be the low outcome L. Hence incentives should only be provided when s is A or E.

It can be verified that in the absence of malfeasance, a bonus is required to be given only when $s = E$. To deter the Agent from constantly reporting E to obtain this bonus which we denote by b_E, there must be conflict when the Agent reports E while the Principal reports otherwise (i.e. $\delta^S_{UE}, \delta^S_{AE} > 0$). Ignoring the guile constraint for the moment, the optimal relaxed-sales contract minimizes the expected inefficiency due to δ^S_{UE} and δ^S_{AE}, subject to the Agent's truthful-reporting constraint ATR (3.22). This is achieved by the set:

$$\left\{ \{\delta^S_{AE}, \delta^S_{UE}\} \middle| \delta^S_{AE} \geq b_E \text{ and } \delta^S_{AE} + \delta^S_{UE} = 3b_E \right\}, \tag{4.14}$$

where b_E is then pinned down by ICE (2.14).

We consider the Agent's guile constraint now. Recall the argument in (4.6) in the previous example that a sales contract can be susceptible to guile if there is another reporting strategy that gives the Agent different effort incentives than the truthful-reporting strategy. Under the contract in (4.14), if the Agent were to report E when she actually observes U, her effort incentive is altered by an amount of:

$$-\varepsilon(b_E - \delta^S_{UE}) - \varepsilon(b_E - \delta^S_{AE}) - \varepsilon b_E. \tag{4.15}$$

This extra (dis-)incentive is 0 and hence is not a problem. But if the Agent were to report E when she actually observes $s = A$, her effort incentive is altered by an amount of:

$$-\varepsilon(b_E - \delta^S_{UE}) - 0(b_E - \delta^S_{AE}) - \varepsilon b_E \quad = \quad -\varepsilon(b_E - \delta^S_{UE}) - \varepsilon b_E. \tag{4.16}$$

This extra (dis-)incentive is non-zero if $\delta^S_{UE} \neq 2b_E$, which will then alter the Agent's effort incentive. In this case, the Agent might benefit from decreasing effort slightly from the effort obligation λ and then reporting E whenever she receives $s = A$.

To ensure that the Agent's guile constraint is always satisfied, we need to shift some conflict from δ^S_{AE} to δ^S_{UE}. In particular, setting:

$$\delta^S_{AE} = b_E, \quad \delta^S_{UE} = 2b_E \tag{4.17}$$

satisfies (4.14) and will always be guile-free since the difference in effort incentives from the truthful-reporting strategy is always 0 for (4.17). This illustrates how guile can restrict the type of sales contract observed, even though there are other contracts (any contract that satisfies (4.14)) that achieves the same level of efficiency in the absence of guile.

Suppose now that there is also a seemingly "harmless" malfeasance task m with distribution of states given by:

$$\Gamma^m = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

Conditional on a "successful" malfeasance outcome m, the state is (E, U) with certainty; that is, the Principal believes that the performance is excellent while the Agent knows that it is unacceptable. This malfeasance

[39] In particular, this implies $7/14 > \epsilon > 1/14$.

task is "harmless" because under the guile-free incentive scheme derived in (4.17), the Agent will never engage in pure malfeasance (exert effort on m and then report her signal truthfully) since she has zero chance of getting the bonus at outcome m, while effort on m decreases the probability of reaching outcome L.

However, the Agent can benefit from engaging in a combination of malfeasance and guile. This involves the Agent reporting E more often after exerting effort on task m, to fool the Principal that the state is (E, E) when the true state is actually (E, U). Intuitively, such interplay of malfeasance and guile is an example of the Agent gaming the system to produce an excellent performance signal for the Principal and then lying ex-post to cover it up. The ability of the Agent to create a signal $t = E$ for the Principal via an activity (task m) that the Principal does not value makes it difficult to load incentives at E now. This illustrates the point that if a signal is easily gamed, it cannot be used to provide incentives. In such instances, some incentives have to be provided via a less informative signal that is harder to game. In this case, incentive has to be provided via the less informative signal A as well, which decreases the efficiency of the sales contract.

Notice that this is not another example of the multi-tasking problem; instead it is one of information manipulation via off-equilibrium play. Along the equilibrium path, there is indeed no gain from malfeasance: if the Agent is going to be truthful, then it is optimal for her to set $\lambda_m = 0$ in which case, being truthful is indeed optimal for her. It is only when the Agent explores deviation from the equilibrium that she receives a benefit from engaging in malfeasance. This resonates well with the way that performance pay fails in practice. Initially, the incentive scheme often works well until a party tries to explore deviation (engage in malfeasance) *and* subsequently "fine-tune" it with guile. Such a form of gaming the system then implies that incentives cannot always be loaded on the most informative signal and thus stands in contrast to the conventional wisdom in Principal-Agent theory.

4.3. **Guile and Performance Pay.**

4.3.1. *Guile and Performance Pay.* Section 3.2 shows that the optimal sales contracting problem is convex - plainly, the optimal sales contract can be characterized by its Kuhn-Tucker conditions. However, these conditions might be difficult to interpret and thus unhelpful. It might then pay dividends to solve the (easier) relaxed-sales contracting problem (3.32) and then check (and hope) that the guile constraint is not binding. But even doing this can be difficult, as the two previous examples have illustrated.

The purpose of this section is to explore general and easy-to-check conditions under which guile is a binding constraint for a given sales contract. These conditions also provide a direction to approximate a guile-free sales contract when the guile constraint is violated. For clarity of exposition, we fix the effort obligation to be λ^* throughout this section.

Consider a feasible relaxed-sales contract $\left\{\vec{p}^S, \vec{\delta}^S\right\} \in \Psi^{SR}(\lambda^*)$ and let $\vec{w} = \vec{p} - N\vec{\delta}^S$ be the associated wage vector; thus $\vec{w}$ satisfies ICE (2.14) for effort λ^* and the Agent's truthful-reporting constraint ATR (3.22). We put aside the issues of malfeasance for the moment and illustrate the possibility of the Agent engaging in guile when faced with $\vec{w}$.

Define:

$$WB(\vec{w}) = \left\{(wage, bonus) \mid wage = \vec{\Gamma}^L \Pi \vec{w},\ bonus = \vec{\hat{\Gamma}}^H \Pi \vec{w},\quad \Pi \in Z\right\},$$

as the set of possible $(wage, bonus)$-pairs under $\vec{w}$ that arise from different reporting strategies. Since the set of reporting strategies Z is finite, $WB(\vec{w})$ contains a finite number of points. Notice that by decomposing the Agent's compensation into a fixed component ($wage$) and an effort-dependent component ($bonus$), we can write the Agent's ex-ante expected payoff under effort λ and $(wage, bonus)$ as:

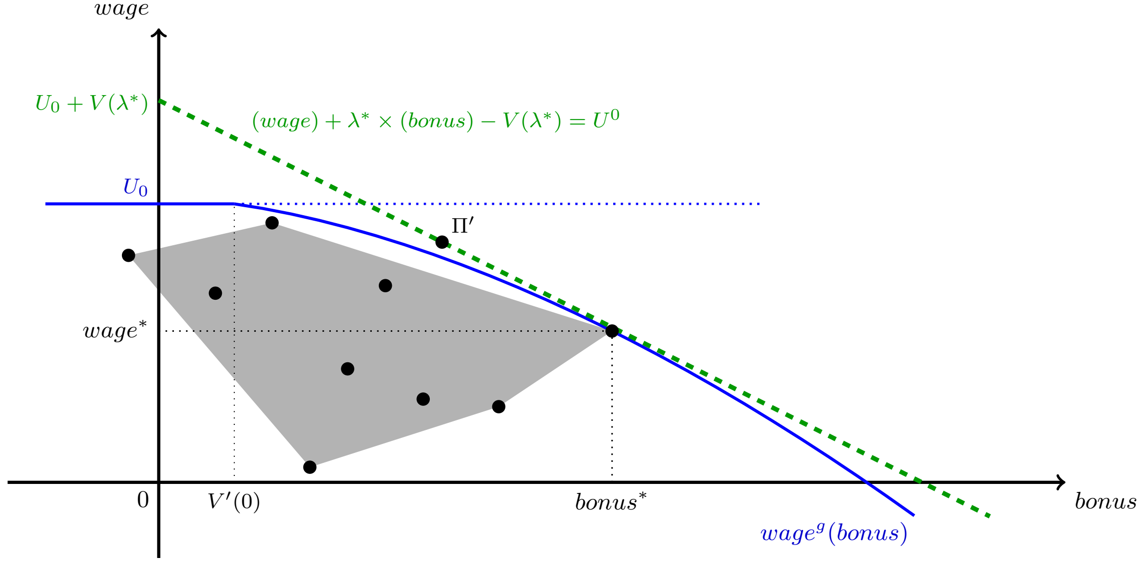
$$U\left(wage, bonus, \lambda\right) = wage + \lambda \times bonus - V\left(\lambda\right).$$

The choice of reporting strategy Π then determines the $(wage, bonus)$-pair that the Agent receives. Denote the corresponding payoffs from truthful-reporting by:

$$\begin{aligned} wage^* &= \vec{\Gamma}^L \vec{w}, \\ bonus^* &= \hat{\vec{\Gamma}}^H \vec{w} = V'\left(\lambda^*\right). \end{aligned}$$

Misrepresentation of information is thus equivalent to choosing a $(wage, bonus)$-pair in $WB(\vec{w})$ that is different from $(wage^*, bonus^*)$. If both parties truthfully reveal their information, the Agent's optimal effort is λ^* by construction.

Figure 4.1. Guile



Guile occurs when the Agent combines information misrepresentation with a change in effort. Referring to Figure 4.1, the horizontal axis represents *bonus* and the vertical axis represents *wage*. Each $(wage, bonus)$-pair associated to a reporting strategy is represented by a dot. Ignoring the dot denoted by Π' for now, the shaded area is the convex hull of $WB(\vec{w})$. First, the Agent's truthful-reporting constraint ATR (3.22) requires that the Agent cannot gain from any reporting strategy holding effort fixed at λ^*:

$$U\left(wage^*, bonus^*, \lambda^*\right) \quad \geq \quad wage + \lambda^* \times bonus - V\left(\lambda^*\right), \quad \forall \left(wage, bonus\right) \in WB\left(\vec{w}\right).$$

This corresponds to requiring all points in $WB\left(\vec{w}\right)$ to be below the green dotted line in Figure 4.1.

The guile constraint is more severe and requires that:

$$U\left(wage^*, bonus^*, \lambda^*\right) \geq wage + \lambda^g \times bonus - V\left(\lambda^g\right), \quad \forall \left(wage, bonus\right) \in WB\left(\vec{w}\right), \quad \forall \lambda^g \in [0, 1). \tag{4.18}$$

From Proposition 5, it is sufficient to check condition (4.18) for $\lambda^g = \Lambda\left(bonus\right)$, the optimal effort given the *bonus* level - see (3.26). For each *bonus* level, there is thus an associated fixed wage $wage^g\left(bonus\right)$ that makes the Agent indifferent between the equilibrium payoff $U\left(wage^*, bonus^*, \lambda^*\right) = U^0$, and engaging in guile:

$$wage^{g}\left(bonus\right)=U^{0}-\Lambda\left(bonus\right)\times bonus+V\left(\Lambda\left(bonus\right)\right). \tag{4.19}$$

The $wage^g$-curve is the solid concave curve in Figure 4.1. If the convex hull of $WB\left(\vec{w}\right)$ lies below this curve, as is the case in Figure 4.1 (ignoring Π'), then the contract is guile-free. The following result is immediate:

Proposition 10. *Compensation $\vec{w}$ is not guile-free if there exists $(wage, bonus) \in WB(\vec{w})$ such that $wage > U^0$.*

The following proposition provides a condition under which guile is more restrictive than the set of feasible relaxed-sales contracts. We first introduce some terminologies for the proposition. We say that a reporting strategy $\Pi \in Z$ allows the Agent to *misrepresent information at no cost* if:

$$\vec{\Gamma}\left(\lambda^{*}\right)\Pi\vec{w}=\vec{\Gamma}\left(\lambda^{*}\right)\vec{w}. \tag{4.20}$$

We say that Π *alters effort incentives* if:

$$\vec{\tilde{\Gamma}}^{H}\Pi\vec{w}\neq V'\left(\lambda^{*}\right). \tag{4.21}$$

Proposition 11. *Let $\psi^{SR}\left(\lambda^*\right) \in \Psi^{SR}\left(\lambda^*\right)$ be a feasible contract for the relaxed-sales program (Definition 6) for λ^*. If there exists a reporting strategy $\Pi \in Z$ that allows the Agent to misrepresent information at no cost (4.20) and alters effort incentives (4.21), then $\psi^{SR}\left(\lambda^*\right)$* is not guile-free.

Proposition 11 can be readily understood from Figure 4.1. In the absence of malfeasance, a reporting strategy Π that allows the Agent to misrepresent information at no cost (4.20) implies that the corresponding $(wage, bonus)$-pair lies on the green dotted line. If it also alters effort incentives (4.21), then it must be a different point from $(wage^*, bonus^*)$. An example of such a strategy is depicted by Π' in Figure 4.1; it necessarily lies above the $wage^g$-curve which thus allows the Agent to benefit from guile.

Next we consider the effect of malfeasance. Analogous to the case for effort on the productive task H, we say that Π *provides strong malfeasance-effort incentives* if:

$$\exists m\in\mathbb{M}\;\text{ such that }\;\vec{\tilde{\Gamma}}^{m}\Pi\vec{w}>V'\left(\lambda^{*}\right). \tag{4.22}$$

Proposition 12. *Let $\psi^{SR}\left(\lambda^*\right) \in \Psi^{SR}\left(\lambda^*\right)$ be a feasible contract of the relaxed-sales program (Definition 6) for λ^*. If there exists a reporting strategy $\Pi \in Z$ that allows the Agent to misrepresent information at no cost (4.20) and provides strong malfeasance-effort incentives (4.22), then $\psi^{SR}\left(\lambda^*\right)$* is not guile-free.

This result shows that malfeasance can increase the potential for guile, even if the contract is guile-free relative to the effort incentives on the productive task. Moreover, whenever the Agent has an incentive to choose malfeasance, the result implies that total effort will be *higher* than effort upon the productive task (since $\vec{\tilde{\Gamma}}^{m}\Pi\vec{w} > V'\left(\lambda^*\right)$). Again, our result resonates well with the observation that in healthcare markets, there is a tendency for physicians to oversupply redundant services due to the additional compensation they receive for such services (see Dafny (2005) and Chandra *et al.* (2012)).

5. Discussion

This paper extends the theory of optimal contracting with subjective evaluation to a more general class of information structures. The model includes, as special cases, situations where the principal is better informed and uses an authority contract (Levin (2003), MacLeod (2003) and Fuchs (2007)), and the expert-Agent environment that uses a sales contract, corresponding to the case that has been studied in the credence good literature (Darby and Karni (1973), Emons (1997) and Dulleck and Kerschbamer (2006)). This approach yields a number of insights.

First, it provides a way to integrate Williamson's (1975) notion of guile into agency theory. Guile arises when the Agent's compensation can depend on her information about performance. This gives rise to opportunistic behavior by the Agent in the form of deviation from the effort obligation (self-interest), followed by mis-reporting her information ex-post (guile).

Second, we find that authority contracts - ones that give the Principal the task of evaluating performance - are computationally less complex than sales contracts - contracts in which the terms are set by the Agent. In particular, when the signal space is large, the number of potential constraints for a sales contract is astronomical - with just 10 signals, one has 10 billion constraints to consider! Our result may help to explain why designing contracts for the efficient supply of services from professionals such as physicians and financial advisors is so difficult. For example, for C-section procedures, a basic hospital record contains more than 20 separate recorded signals regarding patient condition, and the physician has to make a decision based upon these and other unrecorded information. Not surprisingly, there is a great deal of worry regarding what is the optimal C-section rate.

Third, we show that guile is distinct from malfeasance. Guile can arise in the absence of malfeasance, but malfeasance can exacerbate guile, particularly when it is not anticipated by the Principal. One avenue for future research is to extend our analysis of malfeasance to allow for an interaction of objective measures of performance with subjective evaluations, as in Baker *et al.* (1994) and Zabojnik (2014).

Fourth, our results highlight the importance of *modulating* organizational conflicts. The early literature on efficiency wages (Shapiro and Stiglitz (1984)) supposes that the efficient effort level can be elicited with a simple dismissal threat. Levin (2003) extends this to a contract where the dismissal threat is given by a fixed threshold for a one-dimensional performance metric. In contrast, the optimal conflict in our model is a function of the correlation in signals that has no simple *a priori* structure. The marginal cost of conflict in state ts is given by the probability of that state, $\Gamma_{ts}(\lambda)$, while the marginal deterrence benefit from conflict is given by $-v_{ts}^A$ (3.17). To minimize inefficiency, conflict should occur only in specific states where $\Gamma_{ts}(\lambda) + v_{ts}^A = 0$. Lazear (1989) has shown that the potential for conflict can explain some features of organizational form. Given the complexity of determining when conflict should occur to minimize inefficiency, our result may help to explain why there is such great variation in organizational performance. It also highlights the importance of work concerning the techniques that firms can use as a substitute for internal conflicts (Dequiedt and Martimort (2015) and Khalil *et al.* (2015)).

The results in this paper can be viewed as a call for more research. Using a reduced-form model of relational contracting has allowed us to better understand how guile works. Future work includes integrating this work into the theory of relational contracts as in Baker *et al.* (1994) and Levin (2003). One straightforward extension would be to add constraints to the size of conflict and see how this affects the optimal contract form. A more challenging item on the agenda would be to look at the dynamics of information feedback in the relational contract as in Fuchs (2007), but allowing for the Agent to have information as well. Chan and Zheng (2011) and Maestri (2012) have made progress on this front for the two-signal informed-Principal environment. Our results suggest that extending this work to a more general information structure is likely to be a challenge.

Appendix A. Omitted Proofs

Proof of Proposition 1.

Proof. Condition (2.18) is the binding PC, while (2.19) and (2.20) are respectively the binding ICE (2.14), and ICM (2.15). We prove the MFC now. Suppose that $\vec{w}$ implements λ. Since $V'(\lambda) > 0$, (2.19) implies that $\vec{\hat{\Gamma}}^H \vec{w} > 0$ and hence $\vec{w} \in \mathbb{H}^{++}\left(\hat{\Gamma}^H\right)$. (2.19) and (2.20) imply that $(\vec{\hat{\Gamma}}^H - \vec{\hat{\Gamma}}^m)\vec{w} \geq 0$ for all $m \in M$ and therefore $\vec{w} \in \mathbb{H}^+\left(\vec{\Gamma}^H - \vec{\Gamma}^m\right)$ $\forall m \in \mathbb{M}$. Thus we get the MFC as a necessary condition.

Conversely, suppose that the MFC condition is satisfied. Choose $\vec{w}^0 \in MF$. This implies that $\vec{\hat{\Gamma}}^H \vec{w}^0 > 0$, and hence we can choose $b > 0$ such that $b\vec{\hat{\Gamma}}^H \vec{w}^0 = V'(\lambda)$ so that $b\vec{w}^o$ satisfies ICE (2.14). Since $b > 0$, we also have $b\vec{w}^0 \in \left\{\cap_{m\in\mathbb{M}}\mathbb{H}^+\left(\vec{\Gamma}^H - \vec{\Gamma}^m\right)\right\}$ since this set is the intersection of positive cones. This implies that $b\vec{\hat{\Gamma}}^m \vec{w}^0 = b\vec{\hat{\Gamma}}^H \vec{w}^0 - b\left(\vec{\Gamma}^H - \vec{\Gamma}^m\right)\vec{w}^0 \leq V'(\lambda)$. $b\vec{w}^0$ thus satisfies ICM (2.15). Let $\vec{1}$ be a vector whose entries are all 1. Observe that $\vec{\Gamma}^\tau \vec{1} = 1$ $\forall \tau$ since these are probability vectors. Thus, for all $a \in \Re$, $(\vec{\Gamma}^H - \vec{\Gamma}^m)\vec{1}a = 0$, while $a\vec{\hat{\Gamma}}^H \vec{1} = 0$. Let $\vec{w}(a) = a\vec{1} + b\vec{w}^0$; $\vec{w}(a)$ thus satisfies both ICE (2.14) and ICM (2.15), and hence implements λ. Thus we have $U^A(\{\lambda, \vec{w}\}) = \vec{\Gamma}(\lambda)\vec{w} - V(\lambda) - U^o = a + b\vec{\Gamma}(\lambda)\vec{w}^0 - V(\lambda) - U^o$, and we can choose a to satisfy the PC (2.11). □

Proof of Lemma 1.

Proof. Consider a contract where at state $ts \in S^2$, x_{ts} is what the Principal pays out before the conflicts take place, and let $d^A_{ts} > 0$ and $d^P_{ts} > 0$ be the conflicts inflicted by the Agent and the Principal respectively. Under this contract, $c_{ts} = x_{ts} + d^A_{ts}$, $w_{ts} = x_{ts} - d^P_{ts}$ and $\delta_{ts} = c_{ts} - w_{ts} = d^A_{ts} + d^P_{ts}$. Next, consider a contract where $x'_{ts} = x_{ts} + d^A_{ts}$, $d^{P'}_{ts} = d^A_{ts} + d^P_{ts}$, and $d^{A'}_{ts} = 0$; this contract has only the Principal inflicting all the conflicts. It is readily verified that under this contract, $c'_{ts} = x'_{ts} + d^{A'}_{ts} = c_{ts}$, $w'_{ts} = x'_{ts} - d^{P'}_{ts} = w_{ts}$, and $\delta'_{ts} = d^{A'}_{ts} + d^{P'}_{ts} = \delta_{ts}$, and hence, the social loss and both parties' payoffs are left unchanged. A contract that has only the Agent inflicting all the conflicts can be constructed analogously. □

Proof of Proposition 2.

Proof. Suppose a solution to program-AC (3.3) exists. Since $w_{ts} = p^A_t$, constraints ICE (2.14), which must bind, and ICM (2.15) can be rewritten respectively as $\vec{\hat{\gamma}}^H \vec{p}^A = V'(\lambda)$ and $\vec{\hat{\gamma}}^m \vec{p}^A \leq V'(\lambda)$ $\forall m \in \mathbb{M}$. An argument similar to the proof of Proposition (1) implies the SMFC (3.4) as a necessary condition.

Conversely, suppose SMFC (3.4) is satisfied and let $\vec{p}^0 \in SMF$. There exists $b > 0$ such that $b\vec{\hat{\gamma}}^H \vec{p}^0 = V'(\lambda)$; $b\vec{p}^0$ thus satisfies ICE (2.14). Notice also that $b\vec{p}^0 \in SMF$ and hence satisfies ICM (2.15). Next choose $a \in \Re$ such that $\vec{p}^1 = a\vec{1} + \vec{p}^0$ satisfies the PC (2.11). Adding a unit vector $\vec{1}$ does not affect the satisfaction of the ICE and ICM constraints. Next, let $\bar{p} = \max_t p^1_t$ and set $\delta^A_{ts} = \bar{p} - p^1_t \geq 0$. With this, we now have $c_{ts} = \bar{p}$ for all $ts \in S^2$ and hence PTR (3.2) is satisfied trivially. This demonstrates that the feasible set $\Psi^A(\lambda)$ is non-empty. Let $\hat{C}$ be the cost under this contract. Since there are a finite number of states, the set of solutions with costs less than or equal to $\hat{C}$ can be restricted to a bounded set. The linearity of the payoff function, combined with the fact that $\Psi^A(\lambda)$ is a closed and convex set then implies that a solution $0 \leq C^{A*}(\lambda) \leq \hat{C}$ to program-AC exists. □

Proof of Proposition 3.

Proof. We write all the incentive constraints in "$\leq$"-inequality form. This is a linear-programming problem and so, the first-order conditions, along with the complementary-slackness conditions for multipliers and

$\delta_{ts}^A \geq 0$, provide necessary and sufficient conditions for the optimum. The Lagrangian of the problem is:

$$
\begin{aligned}
L^A\left(\psi^A, \vec{\mu}^A\right) = \quad & \sum_{t,s\in S} \gamma_t(\lambda)\left(p_t^A + q_{ts}(\lambda)\,\delta_{ts}^A\right) + \mu_0^A \left(\underbrace{U^0 + V(\lambda) - \vec{\gamma}(\lambda)\vec{p}^A}_{PC}\right) + \mu_1^A \Big(\underbrace{V'(\lambda) - \vec{\tilde{\gamma}}^H \vec{p}^A}_{ICE}\Big) \\
+ \quad & \sum_{m\in\mathbb{M}} \mu_m^{A(ICM)} \Big(\underbrace{\vec{\tilde{\gamma}}^m \vec{p}^A - V'(\lambda)}_{ICM}\Big) \\
+ \quad & \sum_{t\in S}\sum_{t'\in S/\{t\}} \mu_{tt'}^A \left[\underbrace{\left(p_t^A + \sum_{s\in S} q_{ts}(\lambda)\,\delta_{ts}^A\right) - \left(p_{t'}^A + \sum_{s\in S} q_{ts}(\lambda)\,\delta_{t's}^A\right)}_{PTR}\right].
\end{aligned}
\tag{A.1}
$$

Using the duality theorem of linear-programming (see Lemma 4 in Supplementary Appendix D), $\mu_0^A = 1$ and $C^{A*}(\lambda) = U^0 + V(\lambda) + \mu_1^A V'(\lambda)$. After taking into account that $\mu_0^A = 1$, (3.5) to (3.14) are the first-order conditions and corresponding complementary slackness conditions as described in the main text. These conditions are necessary and sufficient for optimality (see Theorem 1 in Appendix). $v_t^A = \sum_{s\in S} v_{ts}^A$ comes from the observation that $\sum_{s\in S} q_{ts}(\lambda) = 1\ \forall t$. From (2.16) and $C^{A*}(\lambda)$ above, we have $Loss^A(\lambda) = \mu_1^A V'(\lambda)$. In order for the Principal to make pay vary with performance it must be the case that $\delta_{ts}^A > 0$ for some ts. This combined with the full support assumption implies that the loss is strictly positive for $\lambda > 0$, and hence ICE binds with $\mu_1^A > 0$. □

Proof of Proposition 4.

Proof. From Proposition 2, there exists a solution to program-AC. The FSC for $\lambda \in [0, \lambda^{\max}]$ and the fact that the SMFC condition is independent of effort λ implies that we can find a uniform bound on contract terms for all effort levels. Hence, there exists a compact set $X \subset \Re^n \times \Re^{n^2}$ such that attention can be restricted to contracts in $\Psi^{A*}(\lambda) = X \cap \Psi^A(\lambda)$. Consider any sequence $\lambda_k \to \lambda$ and let $\left\{\vec{p}_k^A, \vec{\delta}_k^A\right\} \in \Psi^{A*}(\lambda_k)$ with $\left\{\vec{p}_k^A, \vec{\delta}_k^A\right\} \to \left\{\vec{p}^A, \vec{\delta}^A\right\}$. $\vec{p}^A \in \Re^n$ implies $\vec{p}^A$ satisfies ATR (3.1). By noting that all other constraints are continuous, we can conclude that $\left\{\vec{p}^A, \vec{\delta}^A\right\} \in \Psi^{A*}(\lambda)$. Hence $\Psi^{A*}(\lambda)$ is upper-hemicontinuous.

Next, any contract $\left\{\vec{p}^A, \vec{\delta}^A\right\} \in \Psi^{A*}(\lambda)$ satisfies ICE and ICM for λ. For $\lambda_k \to \lambda \in [0, \lambda^{\max}]$, we can define b_k so that $b_k\vec{p}^A$ satisfy ICE and ICM for λ_k and $b_k \to 1$. Let $a_k\vec{1}$ be the corresponding value that ensures that the PC (2.11) is satisfied for $\vec{p}_k^A = b_k\vec{p} + a_k\vec{1}$, with $a_k \to 0$. Let $\vec{\delta}_k^{A'}$ be such that $\delta_{k,ts}^{A'} = \delta_{ts}^A + (p_t^A - p_{k,t}^A)$ for all $t, s \in S$, where $\delta_{k,ts}^{A'}$ is the entry of $\vec{\delta}_k^{A'}$ corresponding to state ts, $p_{k,t}^A$ is the entry of $\vec{p}_k^A$ corresponding to signal t. All entries of $\vec{\delta}_k^{A'}$ are bounded above because of FSC. To ensure the non-negativity of the conflicts, let $\delta_{k,ts}^A = \delta_{k,ts}^{A'} - \min\{\delta_{k,ts}^{A'}\}$. It is immediate that $\left\{\vec{p}_k^A, \vec{\delta}_k^A\right\} \in \Psi^A(\lambda_k)$. Hence $\Psi^{A*}(\lambda)$ is lower-hemicontinuous. By the maximum theorem, $C^{A*}(\lambda)$ is continuous in λ. □

Proof of Proposition 6.

Proof. The "only if" direction is trivial. For the "if" direction, take $\left\{\vec{p}^S, \vec{\delta}^S\right\} \in G(\lambda)$; by Proposition 5, $\left\{\vec{p}^S, \vec{\delta}^S\right\}$ satisfies the guile-free constraint (3.24) together with ICE (2.14), ICM (2.15), ATR (3.22). Next, notice that for any $a \in \Re$, $\left\{\vec{p}^S + a\vec{1}, \vec{\delta}^S\right\} \in G(\lambda)$. The Agent's expected payoff from contract $\left\{\vec{p}^S + a\vec{1}, \vec{\delta}^S\right\}$ is $\vec{\Gamma}(\lambda) + a - V(\lambda)$ and a can be set to satisfy PC (2.11). This implies that $\Psi^S(\lambda)$ is non-empty. Since the constraint set $IC - Sales$ for any λ is closed and convex in the contract terms, with the same argument as in Proposition 2, a solution exists. $\square$

Proof of Proposition 9.

Proof. Recall that $Loss^{A(in)}(\lambda) = \Gamma_{UE}^L \left(1 + \frac{\Gamma_{EU}^L}{\Gamma_{EE}^L + \lambda\rho}\right) \frac{V'(\lambda)}{\rho}$ from (4.2). Next, consider the sales contract that satisfies the conditions in Proposition 8 for an effort obligation λ and let $\delta_{UE}^S(\lambda)$ be the associated conflict. Denote $\lambda^{\Pi_1}(\lambda) = \Lambda\left(\rho\delta_{UE}^S(\lambda)\right)$, the Agent's optimal effort choice under reporting strategy Π_1, where Λ is defined in (3.26). It is readily verified that $\lim_{\lambda\to 0} \lambda^{\Pi_1}(\lambda) = 0$. $\delta_{UE}^S(\lambda)$ satisfies equation (4.13) and hence:

$$\underbrace{\left[c_U + \frac{V'(\lambda)}{\rho} - \left(\Gamma_{UU}^L + \Gamma_{UE}^L\right)\delta_{UE}^S(\lambda)\right]}_{\vec{\Gamma}^L \Pi_1 \vec{w}} + \underbrace{\left[\lambda^{\Pi_1}(\lambda)\right]\rho\delta_{UE}^S(\lambda) - V\left(\lambda^{\Pi_1}(\lambda)\right)}_{g(\Pi_1, \vec{w})} = U^o$$

By noting that $c_U = U^o + V(\lambda) + \Gamma_{UE}^L \delta_{UE}^S(\lambda) - \left(\Gamma_{UE}^L + \Gamma_{EE}^L + \lambda\rho\right)\frac{V'(\lambda)}{\rho}$, we have

$$\begin{aligned}
\delta_{UE}^S(\lambda) &= \left(\frac{1 - \left(\Gamma_{UE}^L + \Gamma_{EE}^L + \lambda\rho\right)}{\Gamma_{UU}^L - \left[\lambda^{\Pi_1}(\lambda)\right]\rho}\right)\frac{V'(\lambda)}{\rho} + \frac{V(\lambda) - V\left(\lambda^{\Pi_1}(\lambda)\right)}{\Gamma_{UU}^L - \left[\lambda^{\Pi_1}(\lambda)\right]\rho} \\
&= \left(\frac{\Gamma_{UU}^L + \Gamma_{EU}^L - \lambda\rho}{\Gamma_{UU}^L - \left[\lambda^{\Pi_1}(\lambda)\right]\rho}\right)\frac{V'(\lambda)}{\rho} + \frac{V(\lambda) - V\left(\lambda^{\Pi_1}(\lambda)\right)}{\Gamma_{UU}^L - \left[\lambda^{\Pi_1}(\lambda)\right]\rho}
\end{aligned}$$

where the second equality follows from $\Gamma_{UE}^L + \Gamma_{EE}^L + \Gamma_{UU}^L + \Gamma_{EU}^L = 1$. Hence

$$\begin{aligned}
&\lim_{\lambda\to 0}\left(Loss^{S(in)}(\lambda) - Loss^{A(in)}(\lambda)\right) \\
&= \lim_{\lambda\to 0}\left(\Gamma_{UE}^L \delta_{UE}^S(\lambda) - \Gamma_{UE}^L\left(1 + \frac{\Gamma_{EU}^L}{\Gamma_{EE}^L + \lambda\rho}\right)\frac{V'(\lambda)}{\rho}\right) \\
&= \Gamma_{UE}^L\left(1 + \frac{\Gamma_{EU}^L}{\Gamma_{UU}^L}\right)\frac{V'(0)}{\rho} - \Gamma_{UE}^L\left(1 + \frac{\Gamma_{EU}^L}{\Gamma_{EE}^L}\right)\frac{V'(0)}{\rho} \\
&= \Gamma_{UE}^L \frac{V'(0)}{\rho}\left(\frac{\Gamma_{EU}^L}{\Gamma_{UU}^L} - \frac{\Gamma_{EU}^L}{\Gamma_{EE}^L}\right).
\end{aligned}$$

Hence, if $\Gamma_{UU}^L > \Gamma_{EE}^L$, then $\lim_{\lambda\to 0}\left(Loss^{S(in)}(\lambda) - Loss^{A(in)}(\lambda)\right) < 0$. $Loss^{A(in)}(\cdot)$ is clearly continuous. By noting that $\Lambda(\cdot)$ and $\tilde{g}(\cdot)$ are continuous, $\delta_{UE}^S(\cdot)$ is continuous and hence, $Loss^{S(in)}(\cdot)$ is also continuous. The continuity of $Loss^{S(in)}(\lambda) - Loss^{A(in)}(\lambda)$ thus establishes the result. $\square$

Proof of Proposition 11.

Proof. Suppose Π allows the Agent to misrepresent information at no cost and alters effort incentives which implies that $\vec{\hat{\Gamma}}^H \Pi \vec{w} \neq \vec{\hat{\Gamma}}^H \vec{w}$. Let $\tilde{\lambda}$ be set such that $\tilde{\lambda} = \Lambda\left(\vec{\hat{\Gamma}}^H \Pi \vec{w}\right)$; $\tilde{\lambda} \neq \lambda^*$ is the optimal effort level exerted by the Agent when choosing task H and reporting strategy Π. Since Π allows the Agent to misrepresent information at no cost, we have

$$\begin{aligned}
0 &= \left[\vec{\Gamma}^L \Pi \vec{w} + \lambda^* \vec{\hat{\Gamma}}^H \Pi \vec{w} - V\left(\lambda^*\right)\right] - \left[\vec{\Gamma}^L \vec{w} + \lambda^* \vec{\hat{\Gamma}}^H \vec{w} - V\left(\lambda^*\right)\right], \\
&< \left[\vec{\Gamma}^L \Pi \vec{w} + \tilde{\lambda} \vec{\hat{\Gamma}}^H \Pi \vec{w} - V\left(\tilde{\lambda}\right)\right] - \left[\vec{\Gamma}^L \vec{w} + \lambda^* \vec{\hat{\Gamma}}^H \vec{w} - V\left(\lambda^*\right)\right],
\end{aligned}$$

and hence the contract is not guile free. $\square$

Proof of Proposition 12.

Proof. Suppose Π allows the Agent to misrepresent information at no cost and provides strong malfeasance-effort incentives. If $\vec{\hat{\Gamma}}^H \Pi \vec{w} \neq V'(\lambda^*)$ then from Proposition 11 the contract is not guile free, and we are done. Consider now the case in which $\vec{\hat{\Gamma}}^H \Pi \vec{w} = V'(\lambda^*)$. Since information can be misrepresented at no cost, this implies $\vec{\Gamma}^L \Pi \vec{w} = \vec{\Gamma}^L \vec{w}$. Thus we have:

$$\begin{aligned}
\vec{\Gamma}^L \vec{w} + \lambda^* \vec{\hat{\Gamma}}^H \vec{w} - V(\lambda^*) &= \vec{\Gamma}^L \Pi \vec{w} + \lambda^* \vec{\hat{\Gamma}}^H \Pi \vec{w} - V(\lambda^*), \\
&< \vec{\Gamma}^L \Pi \vec{w} + \lambda^* \vec{\hat{\Gamma}}^m \Pi \vec{w} - V(\lambda^*) \\
&\leq \vec{\Gamma}^L \Pi \vec{w} + \lambda^{m*} \vec{\hat{\Gamma}}^m \Pi \vec{w} - V(\lambda^{m*}),
\end{aligned}$$

where m is the malfeasance task that provides strong malfeasance-effort incentives (4.22), and $\lambda^{m*} = \Lambda\left(\vec{\hat{\Gamma}}^m \Pi \vec{w}\right)$ where $\Lambda(\cdot)$ is as defined in (3.26). In other words, putting all her effort into malfeasance rather than the productive task makes the agent strictly better off, and hence the contract is not guile-free. $\square$

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Appendix B. Informed-Principal and Expert-Agent (For Online Publication Only)

In this Supplementary Appendix section, we provide a detailed analysis on the informed-Principal (IP, definition 7) and the expert-Agent (EA, definition 8) environments. We first show in section B.1 that the Agent's guile constraint, which is synonymous to the sales contract, is easily handled under the EA environment. We fully characterize the optimal sales contract in the EA environment, and then consider an example of the EA environment with symmetric correlation (to be defined) where we can obtain a closed-form solution for both the optimal sales and optimal authority contract. This example has the intuitive property that as the correlation in the parties' signal approaches perfect correlation, the expected inefficiency of the contract approaches zero.

Next, in section B.2, we define a duality relationship between the two environments and show that there is a one-to-one mapping between the optimal sales contract in an EA environment, with an optimal authority contract in the dual IP environment. From this, we learn that even if the information structures are symmetric, these contracts have quite different properties.

Finally, in section B.3, we provide an example to illustrate that, perhaps counter-intuitively, the optimal sales contract is not always more efficient than the optimal authority contract in the EA environment. This illustrates that the informed-party need not always be allocated decision rights to improve contractual efficiency.

Additional details and omitted proofs of this section are found in section B.4.

B.1. **The Expert-Agent and the Sales Contract.** The following proposition characterizes the optimal sales contract under the EA environment.

Proposition 13. *Under the expert-Agent environment (Definition 8), any solution to the relaxed-sales program (program-SC-R (3.32)) also satisfies the guile constraint GF (3.30). If the full support condition FSC holds at $\lambda > 0$, then a contract $\psi^{S*} = \left\{\lambda, \vec{p}^S, \vec{\delta}^S\right\}$ is an optimal sales contract implementing λ here if and only if there exist non-negative Lagrangian multipliers μ_1^S (for ICE (2.14)), $\mu_m^{S(ICM)}$, $m \in \mathbb{M}$ (for ICM*

(2.15)) and $\mu^S_{ss'}$ for $s,s'\in S$ and $s'\neq s$ (for ATR (3.22)) such that:

$$-\mu_1^S\hat{\beta}_s^H+\textstyle\sum_{m\in\mathbb{M}}\mu_m^{S(ICM)}\hat{\beta}_s^m+v_s^S=0,\qquad\forall s\tag{B.1}$$

$$\beta_s(\lambda)r_{ts}+\mu_1^S\hat{\beta}_s^Hr_{ts}-\textstyle\sum_{m\in\mathbb{M}}\mu_m^{S(ICM)}\hat{\beta}_s^m+v_{ts}^S\geq 0,\qquad\forall t,s\tag{B.2}$$

$$\delta_{ts}^S\left(\beta_s(\lambda)r_{ts}+\mu_1^S\hat{\beta}_s^Hr_{ts}-\textstyle\sum_{m\in\mathbb{M}}\mu_m^{S(ICM)}\hat{\beta}_s^m+v_{ts}^S\right)=0,\quad\forall t,s\tag{B.3}$$

$$\left[\left(p_{s'}^S-\textstyle\sum_{t\in S}r_{ts}\delta_{ts'}^S\right)-\left(p_s^S-\textstyle\sum_{t\in S}r_{ts}\delta_{ts}^S\right)\right]\leq 0\qquad,\ \forall s,s'\neq s\tag{B.4}$$

$$\mu_{ss'}^S\left[\left(p_{s'}^S-\textstyle\sum_{t\in S}r_{ts}\delta_{ts'}^S\right)-\left(p_s^S-\textstyle\sum_{t\in S}r_{ts}\delta_{ts}^S\right)\right]=0\qquad,\ \forall s,s'\neq s\tag{B.5}$$

$$\textstyle\sum_{s\in S}\hat{\beta}_s^{\ m}\left(p_s^S-\sum_{t\in S}r_{ts}\delta_{ts}^S\right)-V'(\lambda)\leq 0\qquad,\ \forall m\in\mathbb{M}\tag{B.6}$$

$$\mu_m^{S(ICM)}\left[\textstyle\sum_{s\in S}\hat{\beta}_s^{\ m}\left(p_s^S-\sum_{t\in S}r_{ts}\delta_{ts}^S\right)-V'(\lambda)\right]=0\qquad,\ \forall m\in\mathbb{M}\tag{B.7}$$

$$V(\lambda)+U^0-\textstyle\sum_{s\in S}\beta_s\left(\lambda^S\right)\left(p_s^S-\sum_{t\in S}r_{ts}\delta_{ts}^S\right)=0\tag{B.8}$$

$$\textstyle\sum_{s\in S}\hat{\beta}_s^{\ H}\left(p_s^S-\sum_{t\in S}r_{ts}\delta_{ts}^S\right)-V'(\lambda)\geq 0\tag{B.9}$$

$$\mu_1^S\left[\textstyle\sum_{s\in S}\hat{\beta}_s^{\ H}\left(p_s^S-\sum_{t\in S}r_{ts}\delta_{ts}^S\right)-V'(\lambda)\right]=0\tag{B.10}$$

where

$$\begin{aligned}v_{ts}^S &= \sum_{s'\neq s}\left[\mu_{ss'}^Sr_{ts}-\mu_{s's}^Sr_{ts'}\right],\\ v_s^S &= -\sum_{t\in S}v_{ts}^S=-\sum_{s'\neq s}\left[\mu_{ss'}^S-\mu_{s's}^S\right]\end{aligned}$$

The expected social loss of implementing effort λ using the sales contract is:

$$Loss^S(\lambda)=\quad\vec{\Gamma}(\lambda)\,\vec{\delta}^S=\quad\mu_1^SV'(\lambda),\tag{B.11}$$

with $Loss^S(\lambda)>0$ whenever $\lambda>0$.

Moreover, if the FSC holds for all $\lambda\in[0,\lambda_{\max}]$, the cost of the optimal sales contract, $C^{S*}(\lambda)$, is continuous in $\lambda\in[0,\lambda^{\max}]$.

The proof of Proposition 13 is found in section B.4.1. The proposition illustrates that the problem of guile in the sales contract is not merely one of asymmetric information. Guile arises only in conjunction with the Agent's ability to manipulate the Principal's information flow.

B.1.1. *An Example of Expert-Agent with Symmetric Correlation.* As an illustrative example, we consider an expert-Agent environment with symmetric correlation (to be defined) next. Under this environment, a closed-form solution for both types of contracts can be obtained. We solve for them and show that the optimal sale contract is always more efficient than the optimal authority contract here.

Consider an expert-Agent environment (EA - Definition 8) with a correlation information structure satisfying the *symmetric correlation* condition:

$$Pr\left[t|s\right]=r_{ts}=\begin{cases}1-\epsilon & ,\ \text{if } t=s\\ \frac{\epsilon}{n-1} & ,\ \text{if } t\neq s\end{cases},\tag{B.12}$$

with $1-\epsilon > \frac{\epsilon}{n-1}$; this is equivalent to $\epsilon < 1-\frac{1}{n}$. This assumption implies that the Principal is more likely to agree with the Agent than not. When $\epsilon \to 0$, the signals are perfectly correlated. For simplicity, we assume that malfeasance is not possible here ($\mathbb{M} = \emptyset$).

Optimal Sales Contract. From Proposition 13, the optimal sales contract is characterized by (B.1) - (B.5) and (B.8) - (B.9) while setting $\mathbb{M} = \emptyset$. Let $S^+ = \left\{ s \in S | \hat{\beta}_s^H > 0 \right\}$ and $S^- = \left\{ s \in S | \hat{\beta}_s^H \leq 0 \right\}$. S^+ is the set of signals indicating that the outcome is more likely to be H while S^- is the set of signals indicating that the outcome is more likely to be L. Next, let $k = |S^-|$, the cardinality of set S^-; this then implies that $|S^+| = n-k$. Since $\sum_{s\in S} \hat{\beta}_s^H = 0$, both S^+ and S^- are non-empty sets and hence, $1 \leq k \leq n-1$. Finally, let $\hat{\beta}^+ = \sum_{s \in S^+} \hat{\beta}_s^H > 0$.

Proposition 14. *Consider the expert-Agent environment (EA - Definition 8) that satisfies the symmetric correlation condition (B.12). The following sales contract* $\left\{ \vec{p}^S, \vec{\delta}^S \right\}$ *is an optimal sales contract that implements effort* λ*:*

$$p_s^S = \begin{cases} \bar{p}^S + \bar{b}^S & , \text{ if } s \in S^+ \\ \bar{p}^S & , \text{ if } s \in S^-, \end{cases} \qquad \delta_{ts}^S = \begin{cases} \bar{\delta}^S & , \text{ if } t \in S^-, s \in S^+ \\ 0 & , \text{ if otherwise,} \end{cases} \tag{B.13}$$

where:

$$\begin{aligned} \bar{p}^S &= U^0 + V(\lambda) - \frac{\beta^+(\lambda)}{\hat{\beta}^+} V'(\lambda) \\ \bar{b}^S &= \left(1 + \frac{k\epsilon}{n-1-n\epsilon} \right) \frac{V'(\lambda)}{\hat{\beta}^+} \\ \bar{\delta}^S &= \left(\frac{n-1}{n-1-n\epsilon} \right) \frac{V'(\lambda)}{\hat{\beta}^+} \end{aligned}$$

Proposition 14 characterizes an optimal sales contract which has the intuitive feature of the Agent getting a bonus $\bar{b}^S$ whenever she reports that the outcome is more likely to be H, and conflict $\bar{\delta}^S$ occurs when the Principal disagrees with this assessment. The proof consists of a tedious process of checking the optimality conditions in (B.1) to (B.9), and is found in section B.4.2 below.

Importantly, given the form of the optimal sales contract in (B.13), it is without loss to consider just a binary signal space $S = \{0, 1\}$, and let $Pr[t=0|s=0] = Pr[t=1|s=1] = 1-\epsilon$. It follows that when $s = 1$, the Agent receives a bonus, and conflict occurs only at state $ts = 01$:

Corollary 3. *In an expert-Agent environment (EA - Definition 8) that satisfies the symmetric correlation condition (B.12), the optimal sales contracting problem (program SC - 3.25) for any signal space S is always equivalent to a problem with signal space $S' = \{0, 1\}$, where $s' = 1$ is the "good" signal with $Pr[s' = 1|o] = \sum_{s\in S^+} \beta_s^o$, and $s' = 0$ is the "bad" signal with $Pr[s' = 0|o] = \sum_{s \in S^-} \beta_s^o$, for $o \in \{L, H\}$. Under the optimal sales contract, the Agent receives a bonus if and only if she observes signal $s' = 1$, and the Principal punishes the Agent if and only if he observes the bad signal and the Agent reports the good signal ($ts = 01$).*

The corresponding optimal sales contract for the two-signal problem consists of a fixed wage and a bonus paid to the Agent when he reports $s = 1$:

$$\begin{aligned} \bar{p}^S &= U^0 + V(\lambda) - \frac{\beta_1(\lambda)}{\hat{\beta}_1^H} V'(\lambda), \\ \bar{b}^S &= \frac{(1-\epsilon)}{(1-2\epsilon)} \frac{V'(\lambda)}{\hat{\beta}_1^H}, \end{aligned}$$

and the Principal inflicts a conflict $\bar{\delta}^S$ at state $ts = 01$:

$$\bar{\delta}^S = \frac{1}{(1-2\epsilon)} \frac{V'(\lambda)}{\hat{\beta}_1^H}$$

Under this contract, the expected inefficiency is:

$$Loss^S(\lambda) = \epsilon \beta_1(\lambda) \frac{1}{(1-2\epsilon)} \frac{V'(\lambda)}{\hat{\beta}_1^H}.$$

MacLeod (2003) shows that when only the Principal is informed, which is defined formally in Definition 7 later, the optimal authority contract converges to the first-best as the signals become more correlated. Here, we provide a similar result for the optimal sales contract in the expert-Agent case: as the degree of correlation in signals increases ($\epsilon \to 0$), the expected inefficiency approaches zero $\left(Loss^S(\lambda) \to 0\right)$.

Optimal Authority Contract. For this two-signal problem, it is straightforward to compute the optimal authority contract as the following (the details are found in section B.4.2): the Principal pays a bonus $\bar{b}^A$ to the Agent when he observes the good signal ($t = 1$), and the Agent inflicts a conflict $\bar{\delta}^A$ when she sees $s = 1$ but is not paid the bonus (i.e. at $ts = 01$), with:

$$\begin{aligned} \bar{b}^A &= \frac{V'(\lambda)}{(1-2\epsilon)\hat{\beta}_1^H} \\ \bar{\delta}^A &= \left[1 + \frac{\beta_0(\lambda)\epsilon}{\beta_1(\lambda)(1-\epsilon)}\right] \frac{V'(\lambda)}{(1-2\epsilon)\hat{\beta}_1^H}, \end{aligned}$$

and resulting in an expected inefficiency of:

$$Loss^A(\lambda) = \left[1 + \frac{\beta_0(\lambda)\epsilon}{\beta_1(\lambda)(1-\epsilon)}\right] Loss^S(\lambda)$$

Thus, we see that here, it is more costly to implement an effort λ under the authority contract than under the sales contract. This follows from the fact that the quality of the Agent's information is better and hence, harnessing her information is less expensive. However, although intuitive, we caution that this result does *not* carry over in general when the problem cannot be reduced to a 2-signal environment. We elaborate more on this in section B.3.

B.2. **Duality between the IP and the EA Environments.** We explore how the structures of the two contracts compare by establishing a duality relationship between them - namely, by holding the relationship between effort and productivity fixed while switching the signals. More precisely, we begin with the optimal authority contract in an informed-Principal (IP) environment, and then ask if there is a "similar" sales contract in the analogous expert-Agent (EA) environment. We show that there is indeed a "dual" (to be defined) EA environment, but it involves a bit more than simply switching the signals. Our result thus illustrates some fundamental differences between the authority and sales contracts in terms of how the information of each party is utilized for effort provision. For simplicity, we assume no malfeasance ($\mathbb{M} = \emptyset$) throughout this section. The duality relationship in the two environments is defined as the following:

Definition 9. Consider an expert-Agent environment (Definition 8, with $\vec{\beta}^o,\ o = H, L$ and $r_{ts},\ t, s \in S$), and an informed-Principal environment (Definition 7, with $\vec{\gamma}^o,\ o = H, L$ and $q_{ts},\ t, s \in S$). The two environments are the *dual environment* for each other if (i) $\vec{\gamma}^L = \vec{\beta}^H$, (ii) ,$\vec{\gamma}^H = \vec{\beta}^L$, and (iii) $q_{ts} = r_{st}$ $\forall t, s \in S$.

The assumption on the conditional probabilities imply that the signals that the Principal and the Agent receive are switched in the two environments. For example, the state $ts = 10$ in the primal environment, where the Principal observes 1 and the Agent observes 0, corresponds to the state in the dual environment where the Principal observes 0 and the Agent observes 1 instead. The duality conditions for the outcome probabilities also implies that $\vec{\tilde{\beta}}^H = -\vec{\tilde{\gamma}}^H$. Hence, when an effort λ is exerted on the dual EA environment, the probability vector of the states is given by:

$$
\begin{aligned}
\vec{\beta}(\lambda) &= \vec{\beta}^L + \lambda\vec{\tilde{\beta}}^H \\
&= \vec{\gamma}^H - \lambda\vec{\tilde{\gamma}}^H \\
&= \vec{\gamma}\left(1-\lambda\right), \qquad \text{(B.14)}
\end{aligned}
$$

which is the probability vector of the states in the primal IP environment under effort $1-\lambda$ instead. This relationship implies a corresponding duality in payoffs as well. The payoff for the Principal in the IP environment is:

$$U^{P(IP)}\left(\psi\right) = U^{P0} + \lambda B_H - \sum_{t,s\in S}\gamma_t\left(\lambda\right) q_{ts}c_{ts},$$

while her payoff in the dual EA environment is given by:[40]

$$U^{P(EA)}\left(\psi\right) = U^{P0} - \left(1-\lambda\right) B_H - \sum_{t,s\in S}\beta_s\left(\lambda\right) r_{ts}c_{ts}.$$

Notice that the goal of effort in the dual EA environment is to reduce the probability of a loss B_H rather than increasing the probability of a gain; the marginal return to effort remains to be B_H. The relationship between the signals and whether or not B_H occurs is the same, except that H now refers to an outcome of a high loss rather than of a high reward. In other words, while H is the good performance in the IP primal environment, L becomes the good performance in the EA dual environment.

The duality relationship we wish to establish is with regards to the states in which a conflict occurs. More precisely we first define a notion for two contracts to have the same *pattern:*

Definition 10. A sales contract $\psi^S = \left\{\lambda^S, \vec{p}^S, \vec{\delta}^S\right\}$ has the same *pattern* as an authority contract $\psi^A = \left\{\lambda^A, \vec{p}^A, \vec{\delta}^A\right\}$ if there exits $\theta > 0$ and $\alpha \in \Re$ such that:

$$p_s^S = -\theta p_s^A + \alpha \quad , \forall s \in S, \qquad \text{(B.15)}$$

$$\delta_{ts}^S = \theta\delta_{st}^A, \quad , \forall t, s \in S. \qquad \text{(B.16)}$$

When the contracts have the same pattern, conflicts occur in the same states, and modulo the fixed term α, relative prices in the two cases are the same. Under the assumption that there exist optimal authority and sales contracts for the IP and the EA environment respectively, we have the following duality result:

Proposition 15. *(Duality) Let $\psi^A = \left\{\lambda^A, \vec{p}^A, \vec{\delta}^A\right\}$ be an optimal authority contract that implements $\lambda^A > 0$ in the informed-Principal environment (IP - Definition 7) and suppose that effort satisfies $1-\lambda^A \geq \frac{Loss^A(\lambda^A)}{V'(\lambda^A)}$, the ratio of the deadweight loss to the marginal cost of effort. There exists an optimal sales contract, $\psi^s = \left\{\lambda^S, \vec{p}^s, \vec{\delta}^s\right\}$, with the same pattern (as defined in Definition 10) that implements effort λ^S*

[40] We have modified the Principal's payoffs in $U^{P(EA)}(\cdot)$ from the original definition in (2.9) to provide a more natural interpretation about the problem. Notice that this interpretation does not alter any of the analysis previously since we have been looking at the cost-minimization problem of implementing an effort level.

in the corresponding dual (as defined in definition 9) expert-Agent environment (EA - Definition 8) , with:

$$\lambda^S = 1 - \frac{Loss^A(\lambda^A)}{V'(\lambda^A)} - \lambda^A, \tag{B.17}$$

$$\theta = \frac{V'(\lambda^S)}{V'(\lambda^A) + DL^A}, \tag{B.18}$$

$$\alpha = U^0(1+\theta) + V(\lambda^S) + \theta V(\lambda^A) + \theta Loss^A(\lambda^A)\left(2 + \frac{DL^A}{V'(\lambda^A)}\right), \tag{B.19}$$

where $DL^A = \sum_{ts\in S^2} \hat{\gamma}_t^H q_{ts}\delta_{ts}^A$.[41] *The mapping from* ψ^A *to* ψ^S *is summarized in Table (2).*

Table 2. Contract Duality

	IP, Authority (Primal)	*EA, Sales (Dual)*
$Pr[o = H]$	λ^A	$1 - \lambda^S$
Principal's Revenue	$U^{P0} + \lambda^A B_H$	$U^{P0} - (1-\lambda^S) B_H$
Signals	$t, s \in S$	$t \to s, s \to t$
Conditional Probability	$Pr[s\|t] = q_{ts}$	$Pr[t\|s] = r_{ts} = q_{st}$
$Pr[ts\|\lambda]$	$(\gamma_t^L + \lambda^A\hat{\gamma}_t^H) q_{ts}$	$(\beta_s^L + \lambda^S\hat{\beta}_s^H) r_{ts} = (\gamma_s^H - \lambda^S\hat{\gamma}_s^H) q_{st}$
Price term	p_t^A	$p_s^S = -\theta p_s^A + \alpha$
Conflict	δ_{ts}^A	$\delta_{ts}^S = \theta\delta_{st}^A$
Wage	$w_{ts}^A = p_t^A$	$w_{ts}^S = p_s^S - \delta_{ts}^S = -\theta c_{st}^A + \alpha$
Cost	$c_{ts}^A = p_t^A + \delta_{ts}^A$	$c_{ts}^S = p_s^S = -\theta w_{st}^A + \alpha$
Return to Effort	$V'(\lambda^A) = \sum_{t\in S}\hat{\gamma}_t^H p_t^A$	$V'(\lambda^S) = \sum_{t,s\in S}\hat{\beta}_s^H r_{ts} w_{ts}^S = \theta(V'(\lambda^A) + DL^A)$
Truthful-Reporting Multipliers	$\mu_{tt'}^A$	$\mu_{ss'}^S = \mu_{ss'}^A$
ICE Multipliers	μ_1^A	$\mu_1^S = \mu_1^A$
$\partial TC/\partial\delta_{ts}$	v_{ts}^A	$v_{ts}^S = v_{st}^A$
$\partial TC/\partial p$	v_t^A	$v_s^S = -v_s^A$

Superscript A denotes terms of the authority contract; superscript S denotes terms of the sales contract.

The proof of Proposition 15 is found in section B.4.3. In constructing the dual sales contract from the primal authority contract, we set the Lagrangian multiplier for ICE to be the same across the two contracting problem (i.e. $\mu_1^A = \mu_1^S$) which then implies that $\frac{Loss^A(\lambda^A)}{V'(\lambda^A)} = \frac{Loss^S(\lambda^S)}{V'(\lambda^S)}$. Hence, we have:

Corollary 4. *Consider the optimal authority contract* $\psi^A = \left\{\lambda^A, \vec{p}^A, \vec{\delta}^A\right\}$ *in the informed-Principal environment and suppose that the optimal sales contract in the corresponding dual expert-Agent environment (as characterized in Proposition 15) exists and is* $\psi^S = \left\{\lambda^S, \vec{p}^S, \vec{\delta}^S\right\}$. *Then* $Loss^A(\lambda^A) \le Loss^S(\lambda^S)$ *if and only if* $\lambda^A \le \lambda^S$.

The duality result of Proposition 15 focuses on the pattern of conflicts; the quality of information on the performance at states where conflicts take place are the same across the two environments. Recall from (3.17) that $v_{ts}^A = \frac{\partial TC(\psi^A, \vec{\mu}_{PTR}^A)}{\partial\delta_{ts}^A}$ where $TC(\psi^A, \vec{\mu}_{PTR}^A)$ is the value of the Principal's truthful-reporting constraint under an optimal authority contract ψ^A; v_{ts}^A is thus the marginal effect of conflict at state ts on

[41]Notice that from (3.15), $Loss^A(\lambda^A) = \sum_{ts\in S^2}\gamma_t^L q_{ts}\delta_{ts}^A + \lambda^A DL^A$ and so $DL^A = \frac{d}{d\lambda^A}Loss^A(\lambda^A)$.

the constraint. Notice that $v_t^A = \frac{\partial TC\left(\psi^A, \vec{\mu}^A_{PTR}\right)}{\partial p_t^A}$; analogously, v_t^A is the marginal effect of wage-price p_t^A on the constraint.

We can similarly define v_{ts}^S and v_s^S as respectively the marginal effects of δ_{ts}^S and p_s^S on the Agent's truthful-reporting constraint constraint in the sales contract.[42] The duality result of Proposition 15 (last two rows in table 2) shows that the marginal effects of conflicts on the truthful-reporting constraints are the same across the two contracts; the marginal effects of prices on the constraint work in opposite direction but have the same magnitude as well.

Moreover, in both environments, the effort incentives are provided based on the reports of the party who has the superior information. That the two contracts are not perfectly symmetric (in the sense that we do not have $\delta_{ts}^S = \delta_{st}^A$) suggests that the way each contract uses information to give incentives is different. This difference is not due to guile; we have shown in Proposition 13 that the guile constraint is always satisfied in the expert-Agent environment. Instead, the difference arises because the authority contract uses the Principal's information to provide effort incentives for the Agent, whereas the sales contract uses the Agent's information to provide effort incentives for herself! Notice that when conflict is high under the authority contract such that $\frac{Loss^A(\lambda^A)}{V'(\lambda^A)} \geq 1 - \lambda^A$, the dual sales contract does not exist. This arises because high conflict in the authority contract implies that the quality of the information is very low which then limits the Principal's ability to discipline the Agent under the sales contract.

B.3. **Sales or Authority?** The literature on organizational economics suggests that the more informed party should be allocated decision rights (Kanemoto and MacLeod (1992) and Aghion and Tirole (1997)). In this section we show that this intuition does not generalize in our model in the sense that the sales contract is not necessarily more efficient than the authority contract in an expert-Agent environment, and vice-versa in an informed-Principal environment.

Consider an expert-Agent environment with $S = \{0, 1, 2\}$ and, for simplicity, no possibility of malfeasance ($\mathbb{M} = \emptyset$). Let $\vec{\beta}^H = \left[0, 0, 1\right]$ and $\vec{\beta}^L = \left[\frac{1}{2}, \frac{1}{2}, 0\right]$, and hence $\vec{\hat{\beta}} = \left[-\frac{1}{2}, -\frac{1}{2}, 1\right]$; when the outcome is H, the Agent receives signal $s = 2$ with probability 1, and when the outcome is L, she receives signals 0 and 1 with equal probability but never receives signal 2. Next, let r_{ts}, the probability of the principal observing signal t when the Agent observes s, be given by the following:

$$\begin{array}{lll} r_{00} = \frac{2}{3}, & r_{01} = \frac{\varepsilon}{3}, & r_{02} = \frac{1}{6} \\ r_{10} = \frac{\varepsilon}{3}, & r_{11} = \frac{2}{3}, & r_{12} = \frac{1}{6} \\ r_{20} = \frac{1-\varepsilon}{3}, & r_{21} = \frac{1-\varepsilon}{3} & r_{22} = \frac{2}{3} \end{array}$$

where $\varepsilon > 0$ assures that the full support assumption is satisfied.

Since signal 2 is the only signal informative of outcome H, incentives should be loaded at signal 2. With details found in section B.4.4, to implement $\lambda > 0$, the optimal sales contract is to pay the Agent a bonus of $b^S = \frac{2+\varepsilon}{1+\varepsilon} V'(\lambda)$ when the Agent reports $s = 2$, and conflicts occur only at states 02 and 12, with $\delta_{02}^S = \delta_{12}^S = \frac{3}{1+\varepsilon} V'(\lambda)$. The resulting expected social loss is then $\frac{\lambda}{1+\varepsilon} V'(\lambda)$.

On the other hand, the same effort level under this expert-agent information structure can be implemented by an authority contract that pays the Agent a bonus $b^A = \frac{3}{1+\varepsilon} V'(\lambda)$ only when the Principal reports $t = 2$,

[42]That is, $v_{ts}^S = \frac{\partial TC\left(\psi^S, \vec{\mu}^S_{ATR}\right)}{\partial \delta_{ts}^S}$ and $v_s^S = \frac{\partial TC\left(\psi^S, \vec{\mu}^S_{ATR}\right)}{\partial p_s^S}$ where $TC\left(\psi^S, \vec{\mu}^S_{ATR}\right) = \sum_{s \in S} \sum_{s' \in S/\{s\}} \mu_{ss'}^S \left[\left(p_{s'}^S - \sum_{t \in S} r_{ts} \delta_{ts'}^S\right) - \left(p_s^S - \sum_{t \in S} r_{ts} \delta_{ts}^S\right)\right]$ and $\vec{\mu}^S_{ATR} = \left\{\mu_{ss'}^S\right\}_{s \in S, s' \in S/\{s\}}$ is the vector of Lagrangian multipliers for the Agent's truthful-reporting constraint.

and conflicts happen only at states 10 and 01 with $\delta_{10}^A = \delta_{01}^A = \left(1 + \frac{2\lambda}{(1-\varepsilon)(1-\lambda)}\right)\left(\frac{6}{1+\varepsilon}V'(\lambda)\right)$.[43] The resulting expected social loss is then $2\varepsilon\left(\frac{(1-\varepsilon)(1-\lambda)+2\lambda}{1-\varepsilon^2}V'(\lambda)\right)$, which can be verified to be smaller than $\frac{\lambda}{1+\varepsilon}V'(\lambda)$, the expected loss from the optimal sales contract, for small enough ε.

While computing and understanding these contracts take a bit of work, the intuition behind can be readily seen by taking ε to be 0.[44] For a sales contract, to prevent the Agent from always reporting $s = 2$ to claim the bonus, conflict needs to occur when the Principal does not observe $t = 2$ as well. Since states 02 and 12 occur with positive probability, the expected social loss is always non-zero. On other hand, λ can be implemented with zero expected social loss via an authority contract that gives the Agent a bonus when the Principal reports $t = 2$. To see how, first notice that when $\varepsilon = 0$, the probability of states 10 and states 01 actually occurring is 0. Hence, δ_{10}^A and δ_{01}^A can be set arbitrarily large without causing any expected social loss. Next, when the Principal observes $t = 2$, the probabilities of the Agent observing $s = 0$ and $s = 1$ are both strictly positive. By setting δ_{10}^A sufficiently large, the Principal is deterred from reporting $t = 1$. Similarly, by setting δ_{01}^A sufficiently large, the Principal is deterred from reporting $t = 0$. The Principal's truthful-reporting constraint is thus satisfied with the threat of punishments that never occur on the equilibrium path.

An example illustrating that the sales contract is more efficient than the authority contract in an informed-principal environment can be constructed analogously. In a 2-signal environment, MacLeod (2003) demonstrates that the sales contract cannot be more efficient than the authority contract in the informed-Principal environment.[45] Thus, these examples rely upon having at least 3 signals. What this illustrates is that adding more signals is not an insignificant extension of the model.

B.4. **Additional Details and Omitted Proofs of Supplementary Appendix B.** We provides the omitted details and proofs of this section here.

B.4.1. *Details for Section B.1.*

Proof of Proposition 13.

Proof. We first prove the first statement that the relaxed-sales program solution is guile-free here. Notice that the Agent's truthful-reporting constraint ATR (3.22) here is:

$$\left(p_s - \sum_{t\in S} r_{ts}\delta_{ts}^S\right) - \left(p_{s'} - \sum_{t\in S} r_{ts}\delta_{ts'}^S\right) \geq 0, \quad \forall s, s' \neq s, \tag{B.20}$$

which is independent of the Agent's effort. Next, let $\left\{\vec{p}^S, \vec{\delta}^S\right\}$ be an optimal relaxed-sales contract and suppose, for a contradiction, that there exists a reporting strategy $\Pi \in Z$ that violates the guile constraint under $\left\{\vec{p}^S, \vec{\delta}^S\right\}$. Let $\vec{\lambda}^\Pi$ be the optimal effort level that attains the maximum expected payoff for the Agent under reporting strategy Π; $\vec{\lambda}^\Pi$ allows for positive effort on the malfeasance task. Let $\bar{U}\left(\vec{\lambda}, \Pi\right)$ be the Agent's expected payoff for using an effort vector $\vec{\lambda}$ together with reporting strategy Π. Since adhering to

[43] We note that this is just a feasible authority contract which is not necessarily optimal.
[44] We have taken $\varepsilon > 0$ in order to satisfy the full support condition (FSC).
[45] See the appendix of MacLeod (2003).

the contract terms gives the Agent an expected payoff of U^o, we have:

$$U^o < \bar{U}\left(\vec{\lambda}^{\Pi}, \Pi\right) \tag{B.21}$$
$$\leq \bar{U}\left(\vec{\lambda}^{\Pi}, I\right) \tag{B.22}$$
$$\leq \bar{U}\left([\lambda, 0, \ldots, 0], I\right) \tag{B.23}$$
$$= U^o,$$

where the first inequality in (B.21) follows from the assumption that the guile constraint is violated for Π, the second inequality in (B.22) follows from (B.20) that the Agent is always weakly better off by truthfully reporting at every signal regardless of the exerted effort, and the third inequality in (B.23) follows from ICE and ICM being satisfied for $\left\{\vec{p}^S, \vec{\delta}^S\right\}$ under truthful-reporting. We thus have a contradiction.

We have thus shown that the solution to program-SC-R suffices for the optimal sales contract. Program-SC-R is a linear program and the Lagrangian of the problem is:

$$\begin{aligned}
L^{SR} = \;& \vec{\beta}(\lambda)\vec{p}^S + \mu_0^S\left(V(\lambda) + U^o - \sum_{s\in S}\beta_s(\lambda)\left(p_s^S - \sum_{t\in S} r_{ts}\delta_{ts}^S\right)\right) \\
& + \mu_1^S\left(V'(\lambda) - \sum_{s\in S}\hat{\beta}_s^{\;H}\left(p_s^S - \sum_{t\in S} r_{ts}\delta_{ts}^S\right)\right) \\
& + \sum_{m\in\mathbb{M}}\mu_m^{S(ICM)}\left(\sum_{s\in S}\hat{\beta}_s^{\;m}\left(p_s^S - \sum_{t\in S} r_{ts}\delta_{ts}^S\right) - V'(\lambda)\right) \\
& + \sum_{s\in S}\sum_{s'\in S/\{s\}}\mu_{ss'}^S\left[\left(p_{s'}^S - \sum_{t\in S} r_{ts}\delta_{ts'}^S\right) - \left(p_s^S - \sum_{t\in S} r_{ts}\delta_{ts}^S\right)\right]
\end{aligned}$$

The first-order conditions and their corresponding complementary slackness conditions provide necessary and sufficient conditions for optimality. The rest of the proof is then analogous to Proposition 3 and is thus omitted.

To prove continuity, for a same argument as in Proposition 4, we can restrict attention to contracts in a compact set $\Psi^{SR*}(\lambda) = X \cap \Psi^{SR}(\lambda)$ where $X \subset \Re^n \times \Re^{n^2}$, and $\Psi^{SR*}(\lambda)$ is upper-hemicontinuous.

Next, let $\left\{\vec{p}^S, \vec{\delta}^S\right\} \in \Psi^{SR*}(\lambda)$ and denote $\vec{w} = N\vec{p} - \vec{\delta}^S$. For any sequence $\lambda_k \to \lambda$, we define $\vec{p}_k = b_k\vec{p} + \vec{a}_k$ and $\vec{\delta}_k^S = b_k\vec{\delta}^s$, with $b_k \to 1$ and $\vec{a}_k \to \vec{0}$. Denote $\vec{w}_k = b_k\vec{w} + N\vec{a}_k$. b_k is set such that $b_k\vec{\hat{\Gamma}}^H\vec{w} = V'(\lambda_k)$. This implies $\vec{\hat{\Gamma}}^H\vec{w}_k = V'(\lambda_k)$ and hence satisfies ICE for λ_k. It is immediate that it also satisfies ICM. $\vec{a}_k$ is set such that $\vec{\Gamma}(\lambda_k)\vec{w}_k - V(\lambda_k) = U^o$ which thus satisfies PC. As for ATR, let $p_{k,s}^S$ be the cost-price for report s under $\vec{p}_k^S$, and $\delta_{k,ts}^S$ be the conflict in state ts under $\vec{\delta}_k^S$. ATR is satisfied for $\left\{\vec{p}^S, \vec{\delta}^S\right\}$ which then implies that $\forall t, s, s' \in S$:

$$\begin{aligned}
& p_s^S - \textstyle\sum_{t\in S} r_{ts}\delta_{ts}^S \geq p_{s'}^S - \sum_{t\in S} r_{ts}\delta_{ts'}^S \\
\iff\quad & b_k p_s^S + a_k - \textstyle\sum_{t\in S} r_{ts} b_k\delta_{ts}^S \geq b_k p_{s'}^S + a_k - \sum_{t\in S} r_{ts} b_k\delta_{ts'}^S \\
\iff\quad & p_{k,s}^S - \textstyle\sum_{t\in S} r_{ts}\delta_{k,ts}^S \geq p_{k,s'}^S - \sum_{t\in S} r_{ts}\delta_{k,ts'}^S
\end{aligned}$$

Hence ATR is also satisfied for $\left\{\vec{p}_k^S, \vec{\delta}_k^S\right\}$. We thus have $\left\{\vec{p}_k^S, \vec{\delta}_k^S\right\} \in \Psi^{SR*}(\lambda_k)$ for all k. This implies that $\Psi^{SR*}(\lambda)$ is lower-hemicontinuous By the maximum theorem, $C^{S*}(\lambda)$ is continuous in λ. □

B.4.2. *Details for Section B.1.1.*

Proof of Proposition 14 and Optimal Sales Contract for the EA Environment with Symmetric Correlation. From Proposition 13, the optimal sales contract is characterized by (B.1) - (B.5) and (B.8) - (B.9) while setting $\mathbb{M} = \emptyset$. Substituting in (B.1), we can rewrite (B.2) and (B.3) as respectively:

$$\beta_s(\lambda) r_{ts} + \textstyle\sum_{s' \in S/\{s\}} \mu^S_{s's}(r_{ts} - r_{ts'}) \geq 0 \quad , \forall t, s \in S, \tag{B.24}$$

$$\left[\beta_s(\lambda) r_{ts} + \textstyle\sum_{s' \in S/\{s\}} \mu^S_{s's}(r_{ts} - r_{ts'})\right] \delta^S_{ts} = 0 \quad , \forall t, s \in S. \tag{B.25}$$

Notice that when $t = s$, the left-hand side of (B.24) becomes:

$$\beta_s(\lambda)(1-\epsilon) + (1 - \epsilon - \frac{\epsilon}{n-1}) \sum_{s' \in S/\{s\}} \mu^S_{s's}, \tag{B.26}$$

which is strictly positive for any choice of multiplier vector $\vec{\mu}^S \geq \vec{0}$, because $\beta_s(\lambda) > 0 \; \forall s \in S$ and $1 - \epsilon - \frac{\epsilon}{n-1} \geq 0$. From (B.25), δ^S_{ts} must then be 0 when $t = s$ which establishes the following result:

Proposition 16. *In the Agent-informed environment (EA - Definition 8) where there is symmetric correlation satisfying (B.12), there is no conflict ($\delta^S_{ts} = 0$) when the Principal and the Agent agree on the performance ($t = s$).*

When $t \neq s$, the left-hand side of (B.24), instead, becomes:

$$\begin{aligned} & \beta_s(\lambda)\frac{\epsilon}{n-1} + \mu^S_{s's}\Big(\frac{\epsilon}{n-1} - (1-\epsilon)\Big)\Big|_{s'=t} \\ = \;& \beta_s(\lambda)\frac{\epsilon}{n-1} + \Big(\frac{\epsilon}{n-1} - (1-\epsilon)\Big)\mu^S_{ts}. \end{aligned} \tag{B.27}$$

If $\delta^S_{ts} > 0$, then (B.27) must be 0 under (B.25). In this case, μ^S_{ts} is uniquely pinned down by:

$$\mu^S_{ts} \;=\; \beta_s(\lambda)\Big(\frac{\epsilon}{(1-\epsilon)n - 1}\Big). \tag{B.28}$$

We are now ready to provide a solution to the program and prove Proposition 14. Consider a sales contract $\left\{\vec{p}^S, \vec{\delta}^S\right\}$ of the form in (B.13) with $\bar{b}^S > 0$ (to be derived), and let

$$\bar{\delta}^S = \Big(\frac{(k-1)\epsilon}{n-1} + (1-\epsilon)\Big)^{-1} \bar{b}^S > 0. \tag{B.29}$$

The corresponding multiplier vector for the contract will be a $\vec{\mu}^S$ vector where $\mu^S_{ss'}$ is set according to (B.28) if $ss' \in S^- \times S^+$, and $\mu^S_{ss'} = 0$ otherwise.

We now show that this multiplier vector $\vec{\mu}^S$, together with this contract $\left\{\vec{p}^S, \vec{\delta}^S\right\}$, satisfy all the optimality conditions. From the analysis in (B.26) and (B.27), (B.24) is satisfied. Consider (B.25) now. When $\delta^S_{ts} = 0$, (B.25) is trivially satisfied. When $\delta^S_{ts} > 0$, then $t \in S^-$ and $s \in S^+$. Given that μ^S_{ts} is set according to (B.28), the term in the bracket of (B.25) is 0 and hence, (B.25) is still satisfied.

We consider the ATR (B.4) now. When $ss' \in S^+ \times S^+$ or $ss' \in S^- \times S^-$:

$$\big(p^S_s - p^S_{s'}\big) - \sum_{t \in S} r_{ts}\big(\delta^S_{ts} - \delta^S_{ts'}\big) = 0. \tag{B.30}$$

When $ss' \in S^+ \times S^-$:

$$\begin{aligned}
\left(p_s^S - p_{s'}^S\right) - \sum_{t\in S} r_{ts}\left(\delta_{ts}^S - \delta_{ts'}^S\right) &= \bar{b}^S - \sum_{t\in S^-} r_{ts}\bar{\delta}^S \\
&= \bar{b}^S - \frac{k\epsilon}{n-1}\bar{\delta}^S \\
&> \bar{b}^S - \left[\frac{(k-1)\epsilon}{n-1} + (1-\epsilon)\right]\bar{\delta}^S \\
&= 0. \qquad \text{(B.31)}
\end{aligned}$$

$\sum_{t\in S^-} r_{ts} = \frac{k\epsilon}{n-1}$ because $s \in S^+$ and hence, each $t \in S^-$ happens with probability $\frac{\epsilon}{n-1}$. The inequality comes from $1-\epsilon > \frac{\epsilon}{n-1}$, and the last equality follows from $\bar{\delta}^S = \left(\frac{(k-1)\epsilon}{n-1} + (1-\epsilon)\right)^{-1}\bar{b}^S$. When $ss' \in S^- \times S^+$:

$$\begin{aligned}
\left(p_s^S - p_{s'}^S\right) - \sum_{t\in S} r_{ts}\left(\delta_{ts}^S - \delta_{ts'}^S\right) &= -\bar{b}^S + \sum_{t\in S^-} r_{ts}\bar{\delta}^S \\
&= -\bar{b}^S + \left[\frac{(k-1)\epsilon}{n-1} + (1-\epsilon)\right]\bar{\delta}^S \\
&= 0 \qquad \text{(B.32)}
\end{aligned}$$

$\sum_{t\in S^-} r_{ts} = \frac{(k-1)\epsilon}{n-1} + (1-\epsilon)$ because $s' \in S^-$ so there exists $t = s$ which happens with probability $1-\epsilon$, and the rest of $t \in S^-$ (there are $k-1$ of them) happens with probability $\frac{\epsilon}{n-1}$ each. (B.30) to (B.32) thus implies ATR (B.4) always holds.

As for (B.5), from what we have just done, the term in the square bracket is 0 except when $ss' \in S^+ \times S^-$, but $\mu_{ss'}^S = 0$ when $ss' \in S^+ \times S^-$. Hence (B.5) holds. Thus we have shown that the contract $\left\{\vec{p}^S, \vec{\delta}^S\right\}$, together with the proposed multiplier vector $\vec{\mu}^S$, satisfy the optimality conditions (B.1) - (B.5) . We are left to pin down $\bar{p}^S$, $\bar{b}^S$ and $\bar{\delta}^S$ using the PC (B.8) and ICE (B.9).

We first determine $\bar{b}^S$ using the ICE. Let $\hat{\beta}^+ = \sum_{s\in S^+} \hat{\beta}_s^H > 0$. The ICE constraint implies that:

$$\hat{\beta}^+ \left(\bar{b}^S - \bar{\delta}^S \frac{k\epsilon}{n-1}\right) = V'(\lambda).$$

Combining with (B.29), we thus have:

$$\bar{b}^S = \left(1 + \frac{k\epsilon}{n-1-n\epsilon}\right)\frac{V'(\lambda)}{\hat{\beta}^+} \qquad \text{(B.33)}$$

$$\bar{\delta}^S = \left(\frac{n-1}{n-1-n\epsilon}\right)\frac{V'(\lambda)}{\hat{\beta}^+} \qquad \text{(B.34)}$$

where $\bar{b}^S, \bar{\delta}^S \in (0,\infty)$.[46] Finally, let $\beta^+(\lambda) = \sum_{s\in S^+} = \beta(\lambda)$, we can determine $\bar{p}^S$ using the PC:

$$\begin{aligned}
\bar{p}^S + \beta^+(\lambda)\left(\bar{b}^S - \bar{\delta}^S\left(\frac{k\epsilon}{n-1}\right)\right) &= U^0 + V(\lambda). \\
\Longrightarrow \bar{p}^S &= U^0 + V(\lambda) - \frac{\beta^+(\lambda)}{\hat{\beta}^+}V'(\lambda). \qquad \text{(B.35)}
\end{aligned}$$

Optimal Authority Contract for the EA Environment with Symmetric Correlation. Consider a contract where the Principal pays a bonus $\bar{b}^A$ to the Agent when he observes the good signal ($t = 1$). $\bar{b}^A$ is obtained

[46] $\epsilon < 1 - \frac{1}{n}$ implies that $n-1-n\epsilon > 0$. Hence $\bar{b}^S, \bar{\delta}^S \in (0,\infty)$.

immediately from the ICE:

$$\begin{aligned} & \left[\hat{\beta}_1^H(1-\epsilon)+\hat{\beta}_0^H\epsilon\right]\bar{b}^A = V'(\lambda) \\ \Longrightarrow \quad & \bar{b}^A = \tfrac{V'(\lambda)}{(1-2\epsilon)\hat{\beta}_1^H}. \end{aligned}$$

where the second line uses $\hat{\beta}_0^H = -\hat{\beta}_1^H$. Next, for $\epsilon < \frac{1}{2}$, it is readily verified that the PTR (3.2) is more stringent at $t=1$ and conflict needs to occur only at state $ts = 01$. Having PTR bind at $t=1$ and noting that $q_{11}(\lambda) = \frac{\beta_1(\lambda)(1-\epsilon)}{\beta_0(\lambda)\epsilon+\beta_1(\lambda)(1-\epsilon)}$, the PTR at $t=1$ can be written as

$$\bar{b}^A \leq \tfrac{\beta_1(\lambda)(1-\epsilon)}{\beta_0(\lambda)\epsilon+\beta_1(\lambda)(1-\epsilon)}\bar{\delta}^A$$

which implies that

$$\begin{aligned} \bar{\delta}^A &= \left[1+\frac{\beta_0(\lambda)\epsilon}{\beta_1(\lambda)(1-\epsilon)}\right]\bar{b}^A \\ &= \left[1+\frac{\beta_0(\lambda)\epsilon}{\beta_1(\lambda)(1-\epsilon)}\right]\frac{V'(\lambda)}{(1-2\epsilon)\,\hat{\beta}_1^H} \end{aligned}$$

The corresponding expected level of conflict is then:

$$\begin{aligned} Loss^A(\lambda) &= \epsilon\beta_1(\lambda)\,\bar{\delta}^A \\ &= \left[1+\frac{\beta_0(\lambda)\epsilon}{\beta_1(\lambda)(1-\epsilon)}\right]Loss^S(\lambda) \end{aligned}$$

B.4.3. *Details for Section B.2.*

Proof of Proposition 15.

Proof. First note that under the assumption on λ^A, λ^S as defined in (B.17), is non-negative. θ is also non-negative which implies that $\delta_{ts}^S \geq 0$.

Let vectors $\vec{\mu}^A$ be the full vector of Lagrange multipliers for the optimal authority contract $\left\{\lambda^A, \vec{p}^A, \vec{\delta}^A\right\}$; $\vec{\mu}^A$ together with $\left\{\lambda^A, \vec{p}^A, \vec{\delta}^A\right\}$ thus satisfies the optimality conditions (3.5) to (3.14) in the IP environment. Consider the sales contract $\left\{\lambda^S, \vec{p}^s, \vec{\delta}^s\right\}$ that satisfies the conditions in the proposition. Set $\vec{\mu}^S = \vec{\mu}^A$. The proof entails showing that $\left\{\lambda^S, \vec{p}^s, \vec{\delta}^s\right\}$ together with $\vec{\mu}^S$ satisfy the sales contract optimality conditions (B.1) to (B.10) for the dual EA environment. First notice that $\mu_{ss'}^S = \mu_{ss'}^A\ \forall s, s' \in S$ implies that:

$$\begin{aligned} v_{ts}^S &= \sum_{s'\neq s}\left(\mu_{ss'}^S r_{ts} - \mu_{s's}^S r_{ts'}\right) \\ &= \sum_{s'\neq s}\left(\mu_{ss'}^S q_{st} - \mu_{s's}^S q_{s't}\right) \\ &= \sum_{s'\neq s}\left(\mu_{ss'}^A q_{st} - \mu_{s's}^A q_{s't}\right) \\ &= v_{st}^A \qquad \text{(B.36)} \end{aligned}$$

The second line comes from the dual environment condition that $r_{ts} = q_{st}$, and the third line follows from setting $\vec{\mu}^S = \vec{\mu}^A$. By the same argument, we also have $v_s^S = -v_s^A$.

We begin checking the optimality conditions (B.1) to (B.10) now. (3.5) gives:

$$-\mu_1^A\hat{\gamma}_t^H + v_t^A = 0 \ \ \forall t \in S.$$

Using $\mu_1^A = \mu_1^S$, $\hat{\gamma}_t^H = -\hat{\beta}_t^H$ (the dual environment condition) and $v_t^A = -v_t^S$, and then transposing the signals from t to s under the dual environment condition, we get

$$\mu_1^S \hat{\beta}_s^H - v_s^S = 0 \quad \forall s \in S,$$

which is (B.1).

Next, (B.14) implies that:

$$\begin{aligned}
\vec{\gamma}\left(\lambda^A\right) &= \vec{\beta}\left(1-\lambda^A\right) \\
&= \vec{\beta}\left(\lambda^S + \frac{Loss^A\left(\lambda^A\right)}{V'\left(\lambda^A\right)}\right) \\
&= \vec{\beta}\left(\lambda^S\right) + \mu_1^S \vec{\hat{\beta}}^H, \qquad \text{(B.37)}
\end{aligned}$$

where the second line follows from (B.17), and the last line follows from $\mu_1^S = \mu_1^A = \frac{Loss^A\left(\lambda^A\right)}{V'\left(\lambda^A\right)}$ from (3.15). The left-hand side of (3.6) is:

$$\gamma_t\left(\lambda^A\right) q_{ts} + v_{ts}^A = \gamma_t\left(\lambda^A\right) r_{st} + v_{st}^S,$$

and transposing the signals under the dual environment condition and using (B.37), we have:

$$\gamma_s\left(\lambda^A\right) r_{ts} + v_{ts}^S = \beta_s\left(\lambda^S\right) r_{ts} + \mu_1^S \hat{\beta}_s^H r_{ts} + v_{ts}^S,$$

which is the left-hand side of (B.2). (B.2) is thus satisfied. Given that $\delta_{ts}^S = \theta \delta_{st}^A$ and $\theta > 0$, (3.7) implies that (B.3) is also satisfied.

Next, (3.8) implies that:

$$\left(p_t^A + \sum_{s \in S} q_{ts}\delta_{ts}^A\right) - \left(p_{t'}^A + \sum_{s \in S} q_{ts}\delta_{t's}^A\right) \leq 0, \quad \forall t, t' \in S.$$

Notice that if we multiply the above by $-\theta < 0$, add the constant α to p_t^A (which does not affect the inequality) and then transpose all s to t, we get:

$$\left(-\theta p_s^A + \alpha - \sum_{s \in S} q_{st}\theta\delta_{st}^A\right) - \left(-\theta p_{s'}^A + \alpha - \sum_{s \in S} q_{st}\theta\delta_{s't}^A\right) \geq 0, \quad \forall s, s' \in S.$$

Using (B.15) and (B.16), and the dual environment condition that $r_{ts} = q_{st}$, we get:

$$\left(p_s^S - \sum_{t \in S} r_{ts}\delta_{ts}^S\right) - \left(p_{s'}^S - \sum_{t \in S} r_{ts}\delta_{ts'}^S\right) \geq 0, \quad \forall s, s' \in S$$

which is exactly (B.4). $\mu_{ss'}^S = \mu_{ss'}^A$ $\forall s, s' \in S$ and (3.9) then imply that (B.5) is also satisfied.

(B.6) and (B.7) are vacuous since we assume that $\mathbb{M} = \emptyset$. The ICE condition (B.9) is satisfied by the appropriate choice of θ. (B.9) holds if:

$$\begin{aligned}
& \textstyle\sum_{s \in S} \hat{\beta}_s^H \left(p_s^S - \sum_{t \in S} r_{ts}\delta_{ts}^S\right) - V'\left(\lambda^S\right) = 0 \\
\iff \quad & \textstyle\sum_{s \in S} \hat{\beta}_s^H \left(-\theta p_s^A + \alpha - \sum_{t \in S} r_{ts}\theta\delta_{st}^A\right) - V'\left(\lambda^S\right) = 0 \\
\iff \quad & \textstyle\theta \sum_{t \in S} \left(-\hat{\gamma}_t^H\right)\left(-p_t^A - \sum_{s \in S} q_{ts}\delta_{ts}^A\right) - V'\left(\lambda^S\right) = 0 \\
\iff \quad & \theta = \frac{V'\left(\lambda^S\right)}{\sum_{t \in S}\hat{\gamma}_t^H p_t^A + \sum_{t,s \in S}\hat{\gamma}_t^H q_{ts}\delta_{ts}^A} \\
\iff \quad & \theta = \frac{V'\left(\lambda^S\right)}{V'\left(\lambda^A\right) + \sum_{t,s \in S}\hat{\gamma}_t^H q_{ts}\delta_{ts}^A}
\end{aligned}$$

where the second line comes from (B.15) and (B.16), the third line follows from the dual environment conditions and noting that $\sum_{t\in S}\hat{\gamma}_t^H\alpha=0$, and the last line follows from (3.13) binding which thus implies that $\sum_{t\in S}\hat{\gamma}_t^H p_t^A=V'\left(\lambda^A\right)$.

The last thing to check is the PC condition (B.8) which is satisfied by the appropriate choice of α:

$$\begin{aligned} & \textstyle\sum_{s\in S}\beta_s\left(\lambda^S\right)\left(p_s^S-\sum_{t\in S}r_{ts}\delta_{ts}^S\right)=U^0+V\left(\lambda^S\right) \\ \iff\quad & \textstyle\sum_{s\in S}\beta_s\left(\lambda^S\right)\left(-\theta p_s^A+\alpha-\sum_{t\in S}r_{ts}\theta\delta_{st}^A\right)=U^0+V\left(\lambda^S\right) \\ \iff\quad & \textstyle\alpha=U^0+V\left(\lambda^S\right)+\theta\sum_{s\in S}\beta_s\left(\lambda^S\right)\left(p_s^A+\sum_{t\in S}r_{ts}\delta_{st}^A\right)\end{aligned}$$

Notice that (B.37) also implies $\vec{\beta}\left(\lambda^S\right)=\vec{\gamma}\left(\lambda^A\right)-\mu_1^S\vec{\hat{\beta}}^H=\vec{\gamma}\left(\lambda^A\right)+\mu_1^A\vec{\hat{\gamma}}^H$. Hence:

$$\begin{aligned}\alpha &= U^0+V\left(\lambda^S\right)+\theta\sum_{t\in S}\left(\gamma_t\left(\lambda^A\right)+\mu_1^A\hat{\gamma}_t^H\right)\left(p_t^A+\sum_{s\in S}q_{ts}\delta_{ts}^A\right) \\ &= U^0+V\left(\lambda^S\right)+\theta\left(\underbrace{\sum_{t\in S}\gamma_t\left(\lambda^A\right)p_t^A}_{=U^o+V\left(\lambda^A\right)}+\underbrace{\mu_1^A\sum_{t\in S}\hat{\gamma}_t^H p_t^A}_{=Loss^A\left(\lambda^A\right)}+\underbrace{\sum_{t,s\in S}\gamma_t\left(\lambda^A\right)q_{ts}\delta_{ts}^A}_{=Loss^A\left(\lambda^A\right)}+\underbrace{\mu_1^A\sum_{t,s\in S}\hat{\gamma}_t^H q_{ts}\delta_{ts}^A}_{=DL^A}\right) \\ &= U^0(1+\theta)+V\left(\lambda^S\right)+\theta V\left(\lambda^A\right)+\theta Loss^A\left(\lambda^A\right)\left(2+\frac{DL^A}{V'\left(\lambda^A\right)}\right),\end{aligned}$$

where the second line on $\sum_{t\in S}\gamma_t\left(\lambda^A\right)p_t^A=U^o+V\left(\lambda^A\right)$ comes from (3.12) and $\mu_1^A\sum_{t\in S}\hat{\gamma}_t^H p_t^A=\mu_1^A V'\left(\lambda^A\right)=Loss^A\left(\lambda^A\right)$ from (3.15). □

B.4.4. *Details for Section B.3.*

Optimal Sales Contract for Section B.3. Let b^S be the bonus paid when the Agent reports $s=2$. To deter lying at $s=1$, the following must hold:

$$\begin{aligned} & b^S-r_{01}\delta_{02}^S-r_{11}\delta_{12}^S\geq 0 \\ \iff\quad & b^S-\tfrac{\varepsilon}{3}\delta_{02}^S-\tfrac{2}{3}\delta_{12}^S\geq 0\end{aligned}$$

To deter lying at $s=0$, the following must hold:

$$\begin{aligned} & b^S-r_{00}\delta_{02}^S-r_{10}\delta_{12}^S\geq 0 \\ \iff\quad & b^S-\tfrac{2}{3}\delta_{02}^S-\tfrac{\varepsilon}{3}\delta_{12}^S\geq 0\end{aligned}$$

Since $\Gamma_{02}(\lambda)=\Gamma_{12}(\lambda)$, the condition can be satisfied by setting $\delta_{02}^S=\delta_{12}^S=\delta^S$ with

$$\begin{aligned} & \delta^S\left(\tfrac{2+\varepsilon}{3}\right)=b^S \\ \iff\quad & \delta^S=\tfrac{3}{2+\varepsilon}b^S\end{aligned}$$

The effort incentives are then satisfied by:

$$\begin{aligned} & \tfrac{1}{6}(b^S-\delta^S)+\tfrac{1}{6}(b^S-\delta^S)+\tfrac{2}{3}b^S=V'(\lambda) \\ \iff\quad & b^S\left(\tfrac{\varepsilon-1}{6(2+\varepsilon)}+\tfrac{\varepsilon-1}{6(2+\varepsilon)}+\tfrac{2}{3}\right)=V'(\lambda)\end{aligned}$$

which implies that:

$$b^S = \tfrac{2+\varepsilon}{1+\varepsilon} V'(\lambda),$$
$$\delta^S = \tfrac{3}{1+\varepsilon} V'(\lambda)$$

The expected social loss is then

$$\begin{aligned} 2\left(\frac{\lambda}{6}\right)\delta^S &= \frac{\lambda}{3}\left(\frac{3}{1+\varepsilon}V'(\lambda)\right) \\ &= \frac{\lambda}{1+\varepsilon}V'(\lambda) \end{aligned}$$

Optimal Authority Contract for Section B.3. We consider an authority contract where the Principal pays a bonus b^A when he reports $t = 2$, and conflicts only occurs at states 10 and 01. To satisfy the effort incentives, b^A must satisfy:

$$\begin{aligned} & \left(\tfrac{2}{3} - \tfrac{1-\varepsilon}{6} - \tfrac{1-\varepsilon}{6}\right) b^A = V'(\lambda) \\ \Longleftrightarrow \quad & b^A = \tfrac{3}{1+\varepsilon} V'(\lambda) \end{aligned}$$

To deter the Principal from lying to $t = 1$ when $t = 2$, δ^A_{10} must be set such that:

$$\begin{aligned} & \textstyle\sum_{s\in S} \Gamma_{2s}(\lambda) b^A \leq \Gamma_{20}(\lambda)\delta^A_{10} \\ \Longleftrightarrow \quad & \left[\tfrac{(1-\varepsilon)(1-\lambda)}{6} + \tfrac{(1-\varepsilon)(1-\lambda)}{6} + \tfrac{2\lambda}{3}\right] b^A \leq \left[\tfrac{(1-\varepsilon)(1-\lambda)}{6}\right] \delta^A_{10} \\ \Longleftrightarrow \quad & \delta^A_{10} \geq \left(1 + \tfrac{2\lambda}{(1-\varepsilon)(1-\lambda)}\right)\left(\tfrac{6}{1+\varepsilon}V'(\lambda)\right) \end{aligned}$$

To deter the Principal from lying to $t = 0$ when $t = 2$, δ^A_{01} must be set such that:

$$\begin{aligned} & \textstyle\sum_{s\in S} \Gamma_{2s}(\lambda) b^A \leq \Gamma_{21}(\lambda)\delta^A_{01} \\ \Longleftrightarrow \quad & \left[\tfrac{(1-\varepsilon)(1-\lambda)}{6} + \tfrac{(1-\varepsilon)(1-\lambda)}{6} + \tfrac{2\lambda}{3}\right] b^A \leq \left[\tfrac{(1-\varepsilon)(1-\lambda)}{6}\right] \delta^A_{01} \\ \Longleftrightarrow \quad & \delta^A_{01} \geq \left(1 + \tfrac{2\lambda}{(1-\varepsilon)(1-\lambda)}\right)\left(\tfrac{6}{1+\varepsilon}V'(\lambda)\right) \end{aligned}$$

Hence, we set

$$\delta^A_{10} = \delta^A_{01} = \left(1 + \frac{2\lambda}{(1-\varepsilon)(1-\lambda)}\right)\left(\frac{6}{1+\varepsilon}V'(\lambda)\right)$$

and the expected loss is then:

$$\begin{aligned} & 2\left(\frac{\varepsilon(1-\lambda)}{6}\right)\left(\frac{(1-\varepsilon)(1-\lambda)+2\lambda}{(1-\varepsilon)(1-\lambda)}\right)\left(\frac{6}{1+\varepsilon}V'(\lambda)\right) \\ = \quad & 2\varepsilon\left(\frac{(1-\varepsilon)(1-\lambda)+2\lambda}{1-\varepsilon^2}V'(\lambda)\right) \end{aligned}$$

Appendix C. Additional Details for Examples in Section 4 (For Online Publication Only)

C.1. **Details for Section 4.1.** We provide the details for condition (4.13) which characterizes the optimal δ^S_{UE} first. From (4.8), (4.9) and (4.10), the most efficient way to maintain guile-free against Π_1 entails setting $\delta^S_{EU} = 0$. δ^S_{UU} and δ^S_{UE} are then set to minimize the expected inefficiency $\left(\Gamma^L_{UU} - \lambda\rho\right)\delta^S_{UU} + \Gamma^L_{UE}\delta^S_{UE}$ in (4.11), while ensuring that the guile constraint against Π_1 holds:

$$\left(\vec{\Gamma}^L\vec{w} + \tilde{g}\left(\hat{\Gamma}^H\vec{w}\right)\right) - \left(\vec{\Gamma}^L\Pi_1\vec{w} + \tilde{g}\left(\hat{\Gamma}^H\Pi_1\vec{w}\right)\right) \geq 0$$
$$\iff \quad \tilde{g}\left(\rho\delta^S_{UE}\right) - \tilde{g}\left(\rho\left(b^S + \delta^S_{UU}\right)\right) + \Gamma^L_{UU}\left(b^S - \delta^S_{UE} + \delta^S_{UU}\right) + \Gamma^L_{EU}b_S \leq 0$$

Using $b^S + \delta^S_{UU} = \frac{V'(\lambda)}{\rho}$ from the ICE, this can then be written as

$$\tilde{g}\left(\rho\delta^S_{UE}\right) - \tilde{g}\left(V'(\lambda)\right) + \Gamma^L_{UU}\left(\frac{V'(\lambda)}{\rho} - \delta^S_{UE}\right) + \Gamma^L_{EU}\left(\frac{V'(\lambda)}{\rho} - \delta^S_{UU}\right) \leq 0. \tag{C.1}$$

We thus minimize (4.11) subject to (C.1). The Lagrangian of this minimization problem is:

$$\begin{aligned}\mathcal{L} \;=\;& \left(\Gamma^L_{UU} - \lambda\rho\right)\delta^S_{UU} + \Gamma^L_{UE}\delta^S_{UE} \\ &+\mu\left\{\tilde{g}\left(\rho\delta^S_{UE}\right) - \tilde{g}\left(V'(\lambda)\right) + \Gamma^L_{UU}\left(\frac{V'(\lambda)}{\rho} - \delta^S_{UE}\right) + \Gamma^L_{EU}\left(\frac{V'(\lambda)}{\rho} - \delta^S_{UU}\right)\right\}\end{aligned}$$

where μ is the Lagrange multiplier. The first-order conditions are:

$$[\delta^S_{UE}]: \qquad \Gamma^L_{UE} + \mu\left[\tilde{g}'\left(\rho\delta^S_{UE}\right)\rho - \Gamma^L_{UU}\right] = 0 \tag{C.2}$$

$$[\delta^S_{UU}]: \qquad \left(\Gamma^L_{UU} - \lambda\rho\right) - \mu\Gamma^L_{EU} \geq 0 \tag{C.3}$$

(C.2) holds with equality since $\delta^S_{UE} > 0$ from (4.7); we thus have $\mu = -\frac{\Gamma^L_{UE}}{\tilde{g}'\left(\rho\delta^S_{UE}\right)\rho - \Gamma^L_{UU}}$. Substituting this into (C.3) gives us:

$$\left(\Gamma^L_{UU} - \lambda\rho\right) + \frac{\Gamma^L_{UE}}{\tilde{g}'\left(\rho\delta^S_{UE}\right)\rho - \Gamma^L_{UU}}\Gamma^L_{EU} \quad \geq \quad 0. \tag{C.4}$$

If (C.4) holds with strict inequality, then $\delta^S_{UU} = 0$. In this case, the most efficient sales contract that is guile-free against Π_1 is the one that sets $\delta^S_{UU}, \delta^S_{EU} = 0$ and δ^S_{UE} to have (C.1) binding, which can then be written as (4.13):

$$\tilde{g}\left(\rho\delta^S_{UE}\right) - \Gamma^L_{UU}\delta^S_{UE} \quad = \quad \tilde{g}\left(V'(\lambda)\right) - \left(\Gamma^L_{UU} + \Gamma^L_{EU}\right)\frac{V'(\lambda)}{\rho}.$$

To understand when (C.4) holds with strict inequality, first recall that $\tilde{g}'\left(\rho\delta^S_{UE}\right) = \Lambda\left(\rho\delta^S_{UE}\right)$, the effort exerted by the Agent under effort incentives $\rho\delta^S_{UE}$ (see fn. 34); this is thus the Agent's guile effort for Π_1. Since $\mu > 0$,[47] we know that $\Lambda\left(\rho\delta^S_{UE}\right)\rho - \Gamma^L_{UU} < 0$ and thus, (C.4) holds with strict inequality if and only if:

$$\left(\Gamma^L_{UU} - \lambda\rho\right)\left(\Gamma^L_{UU} - \Lambda\left(\rho\delta^S_{UE}\right)\rho\right) \quad > \quad \Gamma^L_{UE}\Gamma^L_{EU}. \tag{C.5}$$

Since $\Lambda\left(\rho\delta^S_{UE}\right) > \lambda$[48] and $\Gamma^L_{UU} - \lambda\rho > 0$, a necessary condition for (C.5) to hold is that:

$$\left(\Gamma^L_{UU} - \lambda\rho\right)^2 > \Gamma^L_{UE}\Gamma^L_{EU}, \tag{C.6}$$

[47] We know that $\mu > 0$ because the guile-free constraint against Π_1 binds.

[48] This comes from (4.7) which implies that the effort incentives for Π_1 is strictly greater than that for truth-telling.

while a sufficient condition is the condition given in (4.12):

$$\left(\Gamma_{UU}^{L}-\Lambda\left(\rho\delta_{UE}^{S}\right)\rho\right)^{2}\geq\Gamma_{UE}^{L}\Gamma_{EU}^{L}.$$

Suppose the necessary condition (C.6) holds; the sufficient condition (4.12) then requires that the Agent's guile effort $\Lambda\left(\rho\delta_{UE}^{S}\right)$ is not too much higher than the effort obligation λ. This will be the case when the cost function is very convex such that $\Lambda'(\cdot)$ is small (see fn. 34).

Proof of Proposition 8.

Proposition. *8: Consider the 2-signal incentive-neutral information structure with effort obligation λ. Consider the sales contract $b^S=\frac{V'(\lambda)}{\rho}$, $\delta_{UU}^{S},\delta_{EU}^{S}=0$, $\delta_{UE}^{S}>0$ and $c_U=U^o+V(\lambda)+\Gamma_{UE}^{L}\delta_{UE}^{S}-\left(\Gamma_{UE}^{L}+\Gamma_{EE}^{L}+\lambda\rho\right)b^S$. Suppose that the following four conditions for δ_{UE}^{S} hold:*

(1) *δ_{UE}^{S} satisfies (4.13) and (4.12) holds.*
(2) $\left(\Gamma_{UE}^{L}+\Gamma_{EE}^{L}+\lambda\rho\right)b^S-\Gamma_{UE}^{L}\delta_{UE}^{S}-V(\lambda)-U^o\geq 0.$
(3) $\delta_{UE}^{S}\leq\left(\min\left\{1+\frac{\Gamma_{EE}^{L}}{\Gamma_{UE}^{L}},2\right\}\right)\times b^S.$
(4) $\left(\Gamma_{UE}^{L}+\Gamma_{EE}^{L}+\lambda\rho\right)c_U\leq\left(\Gamma_{UE}^{L}+\Gamma_{EE}^{L}+\lambda\rho\right)b^S-\Gamma_{UE}^{L}\delta_{UE}^{S}.$

Then this sales contract is optimal.

Proof. First note that the Agent's effort incentives from each possible reporting strategies are respectively:

$$\text{(C.7)}\qquad \vec{\hat{\Gamma}}^{H}I\vec{w}=\vec{\hat{\Gamma}}^{H}\vec{w}=\rho\left(b^S+\delta_{UU}^{S}\right)$$

$$\text{(C.8)}\qquad \vec{\hat{\Gamma}}^{H}\Pi_1\vec{w}=\rho\delta_{UE}^{S}$$

$$\text{(C.9)}\qquad \vec{\hat{\Gamma}}^{H}\Pi_2\vec{w}=\rho\left(\delta_{UU}^{S}-\delta_{EU}^{S}\right)$$

$$\text{(C.10)}\qquad \vec{\hat{\Gamma}}^{H}\Pi_3\vec{w}=\rho\left(-b^S+\delta_{UE}^{S}-\delta_{EU}^{S}\right).$$

b^S and c_U are respectively set such that the ICE holds and PC binds. As explained in the main text and the observations above, the first condition implies that this sales contract is the most efficient among all sales contract that is guile-free against Π_1.

As for the second condition, notice that under the proposed sales contract, the effort incentives for reporting strategy Π_2, $\vec{\hat{\Gamma}}^{H}\Pi_2\vec{w}$ in (C.9), is 0. Hence the Agent chooses 0 effort under Π_2 and obtains c_U for sure. The second condition thus ensures that the expected payoff from doing so is less than U^o, the expected payoff of adhering to the contract terms. Hence it is guile-free against Π_2.

For the third condition, notice that under the proposed contract,

$$\text{(C.11)}\qquad \vec{\Gamma}^{L}\Pi_3\vec{w}=c_U+\Gamma_{UU}^{L}\left(b^S-\delta_{UE}^{S}\right)+\Gamma_{EU}^{L}b^S.$$

$\delta_{UE}^{S}\leq\left(1+\frac{\Gamma_{EE}^{L}}{\Gamma_{UE}^{L}}\right)b^S$ (from condition 3) then implies that $\Gamma_{UE}^{L}\left(b^S-\delta_{UE}^{S}\right)+\Gamma_{EE}^{L}b^S\geq 0$. This, together with (4.10) and (C.11), implies that $\Gamma^L\Pi_3\vec{w}\leq\Gamma^L\Pi_1\vec{w}$. Moreover, we also have $\Gamma^L\Pi_1\vec{w}<\Gamma^L\vec{w}$. This is due to the first condition which implies that (4.8) binds, and that $g\left(\Pi_1,\vec{w}\right)>g\left(I,\vec{w}\right)$; this last inequality comes from the effort incentives under Π_1 (C.8) being higher than that of the truth-telling reporting strategy (C.7), and $\tilde{g}(\cdot)$ as defined in (3.28) is strictly increasing in the effort incentives. In addition, $\delta_{UE}^{S}\leq 2b^S$ (condition 3) implies that $\vec{\hat{\Gamma}}^{H}\Pi_3\vec{w}\leq\vec{\hat{\Gamma}}^{H}\vec{w}$. These two results then jointly imply that $\vec{\Gamma}^{L}\Pi_3\vec{w}+g\left(\Pi_3,\vec{w}\right)<\vec{\Gamma}^{L}\vec{w}+g\left(I,\vec{w}\right)$ and hence, the contract is guile-free against Π_3.

Finally, the fourth condition of the proposition is ATR at $s=E$. □

As mentioned, condition 1 in Proposition 8 is more likely to hold if $\tilde{g}$ is less convex (i.e. $\tilde{g}''(\cdot) = \Lambda'(\cdot)$ is small). Conditions 2, 3 and 4 require δ^S_{UE} not to be too large while satisfying equation (4.13). This also happens when $\tilde{g}$ is less convex[49], which in turn is implied by the convexity of the cost function V.

C.2. **Details for Section 4.2.** It has been noted in the main text that incentives should only be loaded at states $s = A$ or E. Without loss of generality, we can consider only incentive schemes of the form:

$$p_s = \begin{cases} \bar{w} & , \text{ if } s = U \\ \bar{w} + b_A & , \text{ if } s = A \\ \bar{w} + b_E & , \text{ if } s = E \end{cases}$$

To better illustrate the point that guile can restrict the optimal contract form without affecting its efficiency, let us assume that $b_A = 0$, and then show later that this assumption is without loss of generality.

To deter the Agent from constantly reporting E, there must be some conflict when the Agent reports E while the Principal reports otherwise. In particular, to ensure that the Agent truthfully reports $s = A$ instead of E, the incentive scheme must satisfy:

$$\begin{aligned} & (1-\lambda)\varepsilon(b_E - \delta^S_{UE}) + \eta(b_E - \delta^S_{AE}) + (1-\lambda)\varepsilon b_E \leq 0 \\ \text{(C.12)} \qquad \iff \qquad & \varepsilon(b_E - \delta^S_{UE}) + \tfrac{\eta}{1-\lambda}(b_E - \delta^S_{AE}) + \varepsilon b_E \leq 0 \end{aligned}$$

To ensure that the Agent truthfully report $s = U$ instead of E, the incentive scheme must satisfy:

$$\begin{aligned} & (1-\lambda)\varepsilon(b_E - \delta^S_{UE}) + (1-\lambda)\varepsilon(b_E - \delta^S_{AE}) + (1-\lambda)\varepsilon b_E \leq 0 \\ \text{(C.13)} \qquad \iff \qquad & \varepsilon(b_E - \delta^S_{UE}) + \varepsilon(b_E - \delta^S_{AE}) + \varepsilon b_E \leq 0. \end{aligned}$$

Note that $b_E \leq \delta^S_{AE}$ must hold. To see why, suppose that $b_E - \delta^S_{AE} > 0$. Then it must be true that $\delta^S_{UE} > b_E > 0$ to satisfy both constraints. Since $\frac{\eta}{1-\lambda} > \varepsilon$ by assumption, (C.12) is more stringent than (C.13). As the expected inefficiency of the contract is $(1-\lambda)\varepsilon(\delta^S_{UE} + \delta^S_{AE})$, $\frac{\eta}{1-\lambda} > \varepsilon$ then also implies that it is always more efficient to increase δ^S_{AE} and decrease δ^S_{UE} to satisfy (C.12) which then contradicts $\delta^S_{UE} > 0$. Hence, it must be the case that $b_E - \delta^S_{AE} \leq 0$, which in turn implies that (C.13) is more stringent than (C.12).

The set of $\{\delta^S_{AE}, \delta^S_{UE}\}$ that minimizes the expected inefficiency while satisfying (C.12) and (C.13) is not unique. Any:

$$\text{(C.14)} \qquad \{\delta^S_{AE}, \delta^S_{UE}\}\text{-pair such that } \delta^S_{AE} \geq b_E \text{ and (C.13) binds,}$$

will suffice and thus be a solution to program-SC-R (3.32). This corresponds to the set in (4.14).

The main text has established that the contract in (4.17) is guile-free. To complete the contract specification, b_E will then be determined via the ICE (2.14):

$$\begin{aligned} & 7\varepsilon b_E - \varepsilon(b_E - \delta^S_{AE}) - \varepsilon(b_E - \delta^S_{UE}) = V'(\lambda) \\ \text{(C.15)} \qquad \iff \qquad & b_E = \tfrac{V'(\lambda)}{8\varepsilon}, \end{aligned}$$

[49] To see why a less convex $\tilde{g}$ function implies that δ^S_{UE} does not need to be too large to satisfy (4.13), we start from $\delta^S_{UE} = \frac{V'(\lambda)}{\rho} = b^S$; under this, the left hand side of (4.13) is greater the right hand side, and we need to change δ^S_{UE} to decrease the left hand side. We know from (4.7) that $\delta^S_{UE} > b^S$ and hence, the change in δ^S_{UE} is an increase from the value b^S. When doing so, the marginal increase on $\tilde{g}$ is related to $\tilde{g}'(\cdot)$, while the marginal decrease on $-\Gamma^L_{UU}\delta^S_{UE}$ is always a constant $-\Gamma^L_{UU}$. If $\tilde{g}$ is less convex, then the marginal increase on $\tilde{g}$ is small. Hence, a small increase in δ^S_{UE} can quickly decrease the left hand side of (4.13) so that it equalizes the right hand side.

and $\bar{w}$ is set to satisfy the PC (2.11). Under this contract, the expected inefficiency incurred is $\frac{3}{8}(1-\lambda)V'(\lambda)$.

Next, to illustrate that it is indeed without loss to have set $b_A = 0$, we consider what happens when allowing for $b_A > 0$. Because there are also incentives at signal A, having some conflict there becomes necessary now. In particular, when the underlying true performance is H and the Agent receives signal $s = A$, the Principal must also be receiving $t = A$. Hence conflict should occur at $s = A$ only when the Principal disagrees with the Agent's assessment. Since $\Gamma_{EA}(\lambda) = \Gamma_{UA}(\lambda)$ and $\hat{\Gamma}^H_{EA} = \hat{\Gamma}^H_{UA}$, it is then without loss to have all conflict at δ^S_{UA} and set $\delta^S_{EA} = 0$. The expected inefficiency of this sales contract is then $(1-\lambda)\,\varepsilon\left(\delta^S_{UA} + \delta^S_{UE} + \delta^S_{AE}\right)$ where the values of δ^S_{UA}, δ^S_{UE} and δ^S_{AE} are to be determined.

To ensure that the Agent truthfully reports U instead of E or A, the incentive scheme must satisfy the following two constraints:

$$\begin{aligned} & (1-\lambda)\varepsilon\left(b_E - \delta^S_{UE}\right) + (1-\lambda)\varepsilon\left(b_E - \delta^S_{AE}\right) + (1-\lambda)\varepsilon b_E \leq 0 \\ \iff \quad & \varepsilon\left(b_E - \delta^S_{UE}\right) + \varepsilon\left(b_E - \delta^S_{AE}\right) + \varepsilon b_E \leq 0 \end{aligned} \tag{C.16}$$

and

$$\begin{aligned} & (1-\lambda)\varepsilon\left(b_A - \delta^S_{UA}\right) + (1-\lambda)\varepsilon b_A + (1-\lambda)\varepsilon b_A \leq 0 \\ \iff \quad & \varepsilon\left(b_A - \delta^S_{UA}\right) + \varepsilon b_A + \varepsilon b_A \leq 0. \end{aligned} \tag{C.17}$$

To ensure that the Agent truthfully reports A instead of E, the incentive scheme must also satisfy:

$$\begin{aligned} & (1-\lambda)\varepsilon\left(b_E - b_A - \delta^S_{UE} + \delta^S_{UA}\right) + \eta\left(b_E - b_A - \delta^S_{AE}\right) + (1-\lambda)\varepsilon\left(b_E - b_A\right) \leq 0 \\ \iff \quad & \varepsilon\left(b_E - b_A - \delta^S_{UE} + \delta^S_{UA}\right) + \tfrac{\eta}{1-\lambda}\left(b_E - b_A - \delta^S_{AE}\right) + \varepsilon\left(b_E - b_A\right) \leq 0 \end{aligned} \tag{C.18}$$

Next, we consider the Agent's effort incentives for task H when the Agent plays a non-truthful reporting strategy. The change in effort incentives when the Agent reports E when she actually sees $s = U$ is:

$$-\,\varepsilon\left(b_E - \delta^S_{UE}\right) - \varepsilon\left(b_E - \delta^S_{AE}\right) - \varepsilon b_E, \tag{C.19}$$

the change in effort incentives when the Agent reports A when she actually sees U is:

$$-\,\varepsilon\left(b_A - \delta^S_{UA}\right) - \varepsilon b_A - \varepsilon b_A, \tag{C.20}$$

and the change in effort incentives when the Agent reports E when she actually sees $s = A$ is:

$$-\,\varepsilon\left(b_E - b_A - \delta^S_{UE} + \delta^S_{UA}\right) - \varepsilon\left(b_E - b_A\right). \tag{C.21}$$

By a similar argument as for (4.17), setting:

$$\begin{aligned} \delta^S_{AE} &= b_E - b_A \\ \delta^S_{UE} &= 2b_E + b_A \\ \delta^S_{UA} &= 3b_A, \end{aligned} \tag{C.22}$$

can ensure that the truthful-reporting constraints (C.16) to (C.18) are satisfied while minimizing the total expected inefficiency, and the change in effort incentive in (C.19) to (C.21) are all zero at the same time. Hence this contract is definitely guile-free.

The expected inefficiency associated with the contract is then:

$$(1-\lambda)\left[\varepsilon\left(b_E - b_A\right) + \varepsilon\left(2b_E + b_A\right) + \varepsilon\left(3b_A\right)\right] = 3(1-\lambda)\varepsilon\left[b_E + b_A\right]. \tag{C.23}$$

The contract is required to provide effort incentive which is characterized by:

$$\begin{aligned} V'(\lambda) &= -\varepsilon\left(b_A-\delta^S_{UA}\right)-\varepsilon b_A-\varepsilon\left(b_E-\delta^S_{UE}\right)-\varepsilon\left(b_E-\delta^S_{AE}\right)+7\varepsilon b_E \\ &= -\varepsilon\left(b_A-3b_A\right)-\varepsilon b_A-\varepsilon\left(b_E-2b_E-b_A\right)-\varepsilon\left(b_E-b_E+b_A\right)+7\varepsilon b_E \\ &= \varepsilon b_A+8\varepsilon b_E \end{aligned} \tag{C.24}$$

It is then immediate from (C.23) and (C.24) that the inefficiency is minimized by setting $b_A = 0$ and $b_E = \frac{V'(\lambda)}{8\varepsilon}$ as above. Hence there can be no gain from allowing for $b_A > 0$.

Malfeasance. However, the presence of malfeasance task m prohibits b_A from being 0. To see why, first let the wage vector of the contract be denoted by $\vec{w}$ where the conflicts are set as in (C.22) to deter pure guile. The marginal probabilities from effort on task m is:

$$\hat{\Gamma}^m = \begin{bmatrix} -\varepsilon & -\varepsilon & -\varepsilon \\ -\varepsilon & -\eta & -\varepsilon \\ 1-\varepsilon & -\varepsilon & 0 \end{bmatrix}$$

Consider the Agent exerting effort $\lambda_m > 0$ (to be determined) on task m and zero effort on task H, and then playing a reporting strategy Π of reporting E when she sees $s = U$, reporting truthfully when she sees $s = A$, and reporting U when she sees $s = E$.

The Agent's gain in expected payoff from doing so as opposed to adhering to the contract obligation can be expressed as:

$$\left[\vec{\Gamma}^L(\Pi - I)\vec{w}\right] + \left[\Big(\lambda_m V'(\lambda_m) - V(\lambda_m)\Big) - \Big(\lambda V'(\lambda) - V(\lambda)\Big)\right] \tag{C.25}$$

where λ_m is characterized by $V'(\lambda_m) = \vec{\hat{\Gamma}}^m \Pi\vec{w}$, the Agent's effort incentives on task m from her reporting strategy Π. For there to be no incentives for the Agent to engage in malfeasance with guile this way, (C.25) must be non-positive. The term in the first square bracket of (C.25) is:

$$\vec{\Gamma}^L(\Pi - I)\vec{w} = \varepsilon b_E,$$

which is strictly positive. Hence the term in the second square bracket of (C.25) must be strictly negative which then implies that λ_m must be strictly less than λ. Notice that:

$$\begin{aligned} V'(\lambda_m) &= \vec{\hat{\Gamma}}^m \Pi\vec{w} \\ &= -\varepsilon\left(b_E-\delta^S_{UE}\right)-\varepsilon\left(b_E-\delta^S_{AE}\right)+(1-\varepsilon)b_E-\varepsilon\left(b_A-\delta^S_{UA}\right)-\eta b_A-\varepsilon b_A \\ &= b_E+(\varepsilon-\eta)\,b_A, \end{aligned}$$

and $V'(\lambda)$ has been derived in (C.24). Hence

$$\begin{aligned} V'(\lambda_m)-V'(\lambda) &= \left(b_E+(\varepsilon-\eta)\,b_A\right)-\left(\varepsilon b_A+8\varepsilon b_E\right) \\ &= (1-8\varepsilon)\,b_E-\eta b_A \\ &= (\eta-\varepsilon)\,b_E-\eta b_A \end{aligned}$$

where the last equality follows from $1 = \eta + 7\varepsilon$. With $\eta - \varepsilon > 0$, for λ_m to be strictly less than λ, it must then be the case that $b_A > 0$; incentives must thus be given at signal A as well.

Appendix D. Linear Programming and the Optimal Contract (For Online Publication Only)

Program-AC (3.3) and program-SC-R (3.32) are linear programs and hence, we can characterize their solutions using linear-programming techniques. This appendix states the well-known duality theorem and describe how to convert program-AC and program-SC-R into standard-form linear programs.

D.1. **Preliminaries.** Consider a primal standard-form linear program given by:

$\mathcal{P}$

$$min_{\vec{x}\in\Re^J}\ \vec{v}^T\vec{x},$$

subject to:

$$\begin{aligned} A\vec{x} &= \vec{b} \\ x &\geq \vec{0} \end{aligned}$$

where $\vec{b}\in\Re^I$, $b_i\geq 0\ \forall i\in\{1,\ldots,I\}$, $\vec{v}\in\Re^J$ and A is a $I\times J$ matrix with $I\leq J$. The dual to this problem is then given by:

$\mathcal{D}$

$$max_{\vec{\mu}\in\Re^I}\ \vec{\mu}^T\vec{b},$$

subject to:

$$\begin{aligned} \vec{\mu}^T A &\leq \vec{v}^T \\ \vec{\mu} &\geq \vec{0} \end{aligned}$$

μ_i is the Lagrangian multiplier of the constraint corresponding to the i-th row of $A\vec{x}=\vec{b}$.

Theorem 1. *(Complementary slackness) Let $\vec{x}$ and $\vec{\mu}$ be feasible solutions to the primal problem $\mathcal{P}$ and dual problem $\mathcal{D}$ respectively. $\vec{x}$ and $\vec{\mu}$ are also optimal solutions to their respective programs if and only if:*

$$(v_j-\vec{\mu}^T A_j)x_j=0\ \ \forall j, \tag{D.1}$$

where A_j is the j-th column of matrix A.

Theorem 2. *(Duality theory) If $\vec{x}^*$ and $\vec{\mu}^*$ are optimal solutions to the primal problem $\mathcal{P}$ and dual problem $\mathcal{D}$ respectively, then*

$$\vec{v}^T\vec{x}^*=\vec{\mu}^{*T}\vec{b}. \tag{D.2}$$

D.2. **Converting the Optimal Contracting Problem into Standard-form Linear Programs.** To transform each program into standard form linear programming problems, we need to define $\vec{x},\vec{c},\vec{b}$ and matrix A appropriately. Standard-form linear program requires that all constraints be equality constraints. To convert an inequality constraint of the form:

$$a_{i1}x_1+a_{i2}x_2+\cdots+a_{iJ}x_J\leq b_i,$$

into an equality constraint, we will introduce a *slack variable* η_i and rewrite the inequality constraint as:

$$a_{i1}x_1+a_{i2}x_2+\cdots+a_{iJ}x_J+\eta_i=b_i.$$

The slack variable $\eta_i \geq 0$ will then be one of the choice variables. We will describe only the program without malfeasance ($\mathbb{M} = \emptyset$) to simplify the presentation. The addition of malfeasance is a straightforward extension of adding constraints ICM (2.15) with an associated slack variable accordingly.

D.2.1. *Program-AC.* The $\vec{x}$ vector includes price-wage vector $\vec{p}^A$, the conflict vector $\vec{\delta}^A$ and the necessary slack variable vector $\vec{\eta}$ (to be described). The standard-form linear program restricts that $x_i \geq 0\ \forall i$. As stated in the main text, it is without loss to consider only non-negative price-wage vector $\vec{p}^A$.

We can thus define the choice variable $\vec{x}$ for the problem as the contract terms and the slack variables:

$$\vec{x} = \begin{bmatrix} \left[\vec{p}^A\right] \\ \left[\vec{\delta}^A\right] \\ [\vec{\eta}] \end{bmatrix} \in \Re^J$$

where $J = n + n^2 + n(n-1)$. The dimension of $\vec{\eta}$ is $n(n-1)$ because there are $n(n-1)$ inequality constraints which are the PTR (3.2). Define the index function $\tilde{\mathcal{I}}$ as $\tilde{\mathcal{I}}(tt') = (n-1)t + t'$. Each PTR constraint can then be written as:

$$\gamma_t(\lambda)(p_t^A - p_{t'}^A) + \sum_{s \in S} \Gamma_{ts}(\lambda)(\delta_{ts}^A - \delta_{t's}^A) + \eta_{tt'} = 0,$$

where $\eta_{tt'}$ is the $\tilde{\mathcal{I}}(tt')$-th entry of $\vec{\eta}$. Including the PC (2.11) and ICE (2.14) constraints, there are a total of $I = 2 + n(n-1)$ constraints. We describe the corresponding vectors $\vec{v}$ and $\vec{b}$, and matrix A now. The $\vec{v}$ vector is simply:

$$\vec{v} = \left[\underbrace{\gamma_0(\lambda), .., \gamma_t(\lambda), \dots \gamma_{n-1}(\lambda)}_{\text{first } n \text{terms}}, \underbrace{\vec{0}}_{n^2 + n(n-1) \text{ terms}} \right]^T$$

such that:

$$\vec{v}^T \vec{x} = \sum_{t \in S} \gamma_t(\lambda) p_t^A.$$

Let $A[i] \in \Re^J$ be the i-th row of A with $i = 0, 1, \dots, I-1$. $A[0]$ is the PC constraint row; hence $A[0] = \vec{v}^T$ and b_0 is $V(\lambda) + U^0$.

Next, $A[1]$ is the ICE constraint row, where:

$$A[1] = \left[\underbrace{\hat{\gamma}_0, .., \hat{\gamma}_t, \dots \hat{\gamma}_{n-1}}_{\text{first } n \text{terms}}, \underbrace{\vec{0}}_{n^2 + n(n-1) \text{ terms}} \right]$$

such that:

$$A[1]\vec{x} = \sum_{t \in S} \hat{\gamma}_t p_t^A.$$

b_1 is then $V'(\lambda)$.

All subsequent rows will be PTR constraints. For a constraint ensuring that the Principal reports the true signal t instead of some other $t' \neq t$, the corresponding row in matrix A is

$$A\left[2 + \tilde{\mathcal{I}}(tt')\right] = \left[\underbrace{0, .., \gamma_t(\lambda), 0.., -\gamma_t(\lambda), 0, \dots}_{n \text{ terms}}, \underbrace{0, .., \vec{\Gamma}_t(\lambda), 0, ..., -\vec{\Gamma}_t(\lambda), 0, \dots}_{n^2 \text{ terms}}, \underbrace{0, \dots, 1, 0, ..., 0}_{n(n-1) \text{ terms}} \right]$$

where $\vec{\Gamma}_t(\lambda) = [\Gamma_{t0}(\lambda), \dots, \Gamma_{t(n-1)}(\lambda)]$. $\gamma_t(\lambda)$ is the t-th entry, $-\gamma_t(\lambda)$ is the t'-th entry, $\vec{\Gamma}_t(\lambda)$ forms the $(n + nt)$-th to $(n + nt + n - 1)$-th entries, $-\vec{\Gamma}_t(\lambda)$ forms the $(n + nt')$-th to $(n + nt' + n - 1)$-th entries, and the 1 is at the $\left(n+n^2+\tilde{\mathcal{I}}(tt')\right)$-th entry. The entries are inserted so that:

$$A\left[2+\tilde{\mathcal{I}}(tt')\right]\vec{x}=\gamma_t(\lambda)\left(p_t-p_{t'}\right)+\sum_{s\in S}\Gamma_{ts}(\lambda)\left(\delta^A_{ts}-\delta^A_{t's}\right)+\eta_{tt'}.$$

$b_{2+\tilde{\mathcal{I}}(tt')}$ will 0 for all t,t'.

D.2.2. *Program-SC-R.* The $\vec{x}$ vector now includes price-cost vector $\vec{p}^S$, the conflict vector $\vec{\delta}^S$ and the necessary slack variable vector $\vec{\eta}$:

$$\vec{x}=\begin{bmatrix}\left[\vec{p}^S\right]\\ \left[\vec{\delta}^S\right]\\ \left[\vec{\eta}\right]\end{bmatrix}\in\Re^J$$

where $J=n+n^2+n(n-1)$. The dimension of $\vec{\eta}$ is $n(n-1)$ because there are $n(n-1)$ inequality constraints which are the ATR (3.22).

It is more convenient to now index the states along s first before t. Hence, we abuse notation and now let:

$$\vec{\Gamma}^o=\left[\vec{\Gamma}^o_{00},\ldots,\vec{\Gamma}^o_{(n-1)0},\vec{\Gamma}^o_{01},\ldots,\vec{\Gamma}^o_{(n-1)0},\ldots,\vec{\Gamma}^o_{0(n-1)},\ldots\vec{\Gamma}^o_{(n-1)(n-1)}\right]^T$$

and do the same thing for $\vec{\delta}^S$:

$$\vec{\delta}^S=\left[\delta^S_{00},\ldots,\delta^S_{(n-1)0},\delta^S_{01},\ldots,\delta^S_{(n-1)1},\ldots,\delta^S_{0(n-1)},\ldots\delta^S_{(n-1)(n-1)}\right]^T$$

The setup is then similar to program-AC. The $\vec{v}$ vector is:

$$\vec{v}=\left[\underbrace{\beta_0(\lambda),..,\beta_s(\lambda),\ldots\beta_{n-1}(\lambda),}_{\text{first } n\text{terms}}\underbrace{-\vec{\Gamma}(\lambda)}_{\text{next } n^2\text{terms}},\underbrace{\vec{0}}_{n(n-1)\text{ terms}}\right]^T$$

such that:

$$\vec{v}^T\vec{x}=\sum_{s\in S}\beta_s(\lambda)p^S_s-\sum_{ts\in S^2}\Gamma_{ts}(\lambda)\delta^S_{ts}.$$

$A[0]$ is the PC constraint row with $A[0]=\vec{v}^T$ and b_0 is $V(\lambda)+U^0$. $A[1]$ is the ICE constraint row with $b_1=V'(\lambda)$, where:

$$A[1]=\left[\underbrace{\hat{\beta}_0,..,\hat{\beta}_s,\ldots\hat{\beta}_{n-1},}_{\text{first } n\text{terms}}\underbrace{-\vec{\hat{\Gamma}}^H}_{\text{next } n^2\text{terms}},\underbrace{\vec{0}}_{n(n-1)\text{ terms}}\right]$$

such that

$$A[1]\vec{x}=\sum_{s\in S}\hat{\beta}_sp^S_s-\sum_{ts\in S^2}\hat{\Gamma}^H_{ts}\delta^S_{ts}.$$

All subsequent rows will be ATR constraints. Analogously, let $\vec{\Gamma}_s(\lambda)=[\Gamma_{0s}(\lambda),\ldots,\Gamma_{(n-1)s}(\lambda)]$. For a constraint ensuring that the Agent reports the true signal s instead of some other $s'\neq s$, the corresponding row in matrix A is

$$A\left[2+\tilde{\mathcal{I}}(ss')\right]=\left[\underbrace{0,..,\beta_s(\lambda),0..,-\beta_s(\lambda),0,\ldots,}_{n\text{ terms}}\underbrace{0,..,-\vec{\Gamma}_s(\lambda),0,...,\vec{\Gamma}_s(\lambda),0,\ldots,}_{n^2\text{ terms}}\underbrace{0,\ldots,-1,0,...,0}_{n(n-1)\text{ terms}}\right]$$

$\beta_s(\lambda)$ is the s-th entry, $-\beta_s(\lambda)$ is the s'-th entry, $\vec{\Gamma}_s(\lambda)$ forms the $(n+ns)$-th to $(n+ns+n-1)$-th entries, $-\vec{\Gamma}_s(\lambda)$ forms the $(n+ns')$-th to $(n+ns'+n-1)$-th entries, and the -1 is at the $\left(n+n^2+\tilde{\mathcal{I}}(ss')\right)$-th entry.

The entries are inserted so that:

$$A\left[2+\tilde{\mathcal{I}}(ss')\right]\vec{x} = \beta_s(\lambda)\left(p_s^S - p_{s'}^S\right) - \sum_{t\in S}\Gamma_{ts}(\lambda)\left(\delta_{ts}^S - \delta_{ts'}^S\right) - \eta_{ss'}.$$

$b_{2+\tilde{\mathcal{I}}(ss')}$ will 0 for all s, s'.

D.3. **Properties of the Solutions.** An important feature of the optimal solution is that it can be characterized in terms of the basic feasible solution. Let x^* be a solution to the primal problem. Then the *optimal basis* is a set of indexes $B \subset \{0, ..., J\}$ such that $x_j^* = 0$ for $j \notin B$ and the matrix:

$$A_B = [A_j]_{j\in B} \in \Re^{I\times I}$$

is invertible. Then $\vec{x}_B^* = \left[x_j^*\right]_{j\in B}$ is called the optimal basic solution and since $A\vec{x} = \vec{b}$, we know that:

$$\vec{x}_B^* = A_B^{-1}\vec{b}.$$

Hence, once we have identified the optimal basis B, we can compute the optimal solution. Let

$$v_B = [v_j]_{j\in B} \in \Re^I$$

The complementary slackness condition (Theorem 1) implies that:

$$\vec{v}_B^T = \vec{\mu}^{*T} A_B,$$

from which we conclude that:

$$\mu^{*T} = A_B^{-1}\vec{v}_B^T.$$

If $x_j^* = 0$ for some $j \in B$, then μ^*, the solution to the dual, will not be unique in general.

Recall that μ_0 and μ_1 are the Lagrangian multipliers of the PC and ICE respectively.

Lemma 4. *Let μ^{A*} and μ^{S*} be the solutions to the dual program of program-AC and program-SC-R respectively. Then $\mu_0^{A*} = \mu_0^{S*} = 1$, and the expected costs of the contract for program-AC and program-SC-R are respectively $U^0 + V(\lambda) + \mu_1^{A*}V'(\lambda)$ and $U^0 + V(\lambda) + \mu_1^{S*}V'(\lambda)$.*

Proof. From Theorem 2, $v^T x^* = \mu^* b$. Observe that for any constant α, $\vec{p}^* + \alpha \cdot \vec{1}$ also satisfies all the constraints with the PC constraint modified to $U^0 + V(\lambda) + \alpha$. Hence, $\vec{\delta}$ remains unchanged, and this does not change the solution for the dual problem. Thus we have:

$$v^T x^* + \alpha = \mu_0\left(U^0 + V(\lambda) + \alpha\right) + \mu_1 V'(\lambda),$$

for all α from which we conclude that $\mu_0 = 1$. The expected cost of the contract $v^T x^*$ then follows directly. □

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