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Contracting, gatekeepers, and unverifiable performance

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A group of diverse principals who represent an institution contract with an agent for the production of a two-dimensional commodity. One dimension of the agent's production is verifiable, while the other is unverifiable. The principals can employ two strategic tools to motivate the agent—a minimum requirement on the verifiable dimension and a tough gatekeeper. A gatekeeper is a principal who is elected and granted authority to determine whether the full group considers the agent's production. A tough gatekeeper can be used to motivate production in the unverifiable dimension. We characterize conditions for which the principals use these two strategic tools, and we examine the economic consequences of partial verifiability.

1. Introduction

■ Institutions often delegate decision-making authority to selected members. For example, universities create tenure committees to evaluate whether to promote assistant professors, honorary societies select electors to screen new members, corporate shareholders choose boards of directors to contract with chief executives, communities elect school boards to evaluate and decide whether to retain school superintendents, and cities elect district attorneys and chiefs of police to enforce their laws. In these examples, the selected members act as a gatekeeper, which either decides the fate of an agent itself or decides whether the agent's performance warrants consideration by the full institution. Which member(s) of an institution are selected as a gatekeeper? Why do some institutions have a strong gatekeeper, while other institutions have either a weak gatekeeper or no gatekeeper at all?

To address these questions we construct a model in which a group of principals, who represent an institution, contract with an agent to produce a product. The agent's production is in two dimensions: one verifiable (i.e., contractible) and the other unverifiable (i.e., noncontractible). Composed of individuals who value these dimensions differently, the principals must agree on how much the agent should produce in each of the dimensions. That is, the principals must agree

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on a contract to offer the agent—a document that states requirements of the agent's production and the process by which the principals evaluate the agent's production.[1]

The principals have a straightforward task of motivating the agent to produce in the verifiable dimension. Put simply, the principals can specify a performance criterion (i.e., a minimum requirement) on the verifiable dimension, and commit to consider the agent's production only if the production of the verifiable characteristic exceeds this minimum requirement.

Motivating the agent to produce in the unverifiable dimension is not straightforward; the principals cannot write unverifiable characteristics in a contract. In a single-principal, single-agent model, Holmström and Milgrom (1991) demonstrate that when the principal provides high-powered incentives (like a minimum requirement) on the verifiable dimension, the agent tends to overproduce in the verifiable dimension. We demonstrate that with multiple principals, rather than with a single principal, the principals have a strategic tool to reduce the overproduction in the verifiable dimension while encouraging production in the unverifiable dimension. The principals can appoint a gatekeeper and commit to consider the agent's production as a full group only if the gatekeeper approves.

In our model, the principals' contracting options are the level of the minimum requirement and the identity of the gatekeeper. Should the contract specify a positive minimum requirement or identify a gatekeeper, the principals commit to evaluate the agent's production as a full group *only* if the minimum requirement is satisfied (if one is specified) and the gatekeeper approves the agent's production (if one is appointed).[2] Knowing the gatekeeper's preferences, and that the gatekeeper will accept the agent's production only if he prefers it to the outside option, the agent has an incentive to satisfy the gatekeeper. As such, while the minimum requirement enforces production in the verifiable dimension, the gatekeeper enforces production in the unverifiable dimension.

We demonstrate that if the principals choose to elect a gatekeeper, they choose a "tough guy." Because the principals have different preferences, they also have different minimum amounts (i.e., reservation values) on the unverifiable dimension that they are willing to accept. Hence, given an agreed-upon level of the minimum requirement on the verifiable dimension, the principals elect a gatekeeper who has a relatively high reservation value on the unverifiable dimension so as to motivate greater production in the unverifiable dimension (i.e., a tough guy).

Schelling (1960, pp. 142–143) recognizes the strategic delegation of decision-making authority to tough guys:

> [A] move that is sometimes available is the delegation of part or all of one's interest, or part or all of one's initiative for decision, to some agent who becomes (or perhaps already is) another player in the game ... The use of a professional collecting agency by a business firm for the collection of debts is a means of achieving unilateral rather than bilateral communication with its debtors and of being therefore unavailable to hear pleas and threats from the debtors... The use of thugs and sadists for the collection of extortion or the guarding of prisoners, or the conspicuous delegation of authority to a military commander of known motivation, exemplifies a common means of making credible a response pattern that the original source of decision might have been thought to shrink from or to find profitless, once the threat had failed.

For the institutions we model, the use of minimum requirements and gatekeepers varies from institution to institution. For example, consider the promotion and tenure processes in academia. At some (but not many) universities, tenured faculty agree on minimum requirements for promotion and state these up front to assistant professors. With regard to gatekeepers, at many universities a tenure committee screens a tenure candidate's performance before the academic department's evaluation of the candidate's record. Many of these tenure committees are powerful and act as gatekeepers. That is, a tenure candidate is considered for promotion only if the tenure committee votes favorably.

Our analysis provides insight as to why the use of gatekeepers and minimum requirements varies from institution to institution. We characterize the equilibrium contracts and the agent's

[1] In our model, the principals vote by majority rule on the contract they offer the agent.

[2] The full-group evaluation process is not a contracting option. The majority-rule evaluation process is specified in the next section.

resulting production for different preferences and production capabilities. For our domain of possible principal and agent utility profiles, we demonstrate in our main theorem that there are four types of equilibrium contracts and agent production. The equilibrium contracts vary by their use of a minimum requirement and a gatekeeper.

To determine the economic effects of partial verifiability (i.e., one dimension is verifiable and the other is unverifiable), we first examine the complete-verifiability case. With complete verifiability, the principals can set minimum requirements on both dimensions to force the agent to produce any allocation she is willing to produce. Then, in our primary analysis, we establish that with partial verifiability, there are allocations the agent is willing to produce, but the principals cannot implement. In this partial-verifiability case, for an established minimum requirement on the verifiable dimension, there may not exist a gatekeeper able to induce the agent to produce the greatest amount of the unverifiable characteristic she is willing to produce. Hence, in comparing the agent's production in the complete- and partial-verifiability cases, with partial verifiability, the agent tends to produce less in the unverifiable dimension and more in the verifiable dimension. In addition, the agent sometimes can use the partial verifiability to her advantage and earn a positive economic surplus.

Economists recognize that in many settings, groups can improve their power by the strategic use of representatives (e.g., gatekeepers) who have different and more demanding preferences. Gatsios and Karp (1991) in their analysis of customs unions suggest that it might be in one union member's best interest to delegate authority to set the external policy to another, more demanding member. In negotiations between two groups, Perry and Samuelson (1994) and Segendorff (1998) demonstrate that a group may strategically delegate authority to a tough bargaining representative.

Aghion and Tirole (1997) and Tirole (1999) provide an alternative explanation of the delegation of decision-making authority. They consider cases in which the individual with formal decision-making authority does not know with certainty the consequences of each decision. This principal may delegate his authority to another party if the other party has a sufficiently lower marginal cost of investigating the decision (e.g., the other party is an expert) and the other party's preferences are sufficiently close to the principal's.

Our article is also related to several other works in the agency literature. In a multiple-principal/single-agent setting, articles including Baron (1985), Bernheim and Whinston (1985, 1986), Spiller (1990), and Dixit, Grossman, and Helpman (1997) examine interactions among multiple principals and a common agent. In these analyses, the principals noncooperatively choose individual incentive schemes for the common agent. Our model differs from these multiple-principal/single-agent models in two important ways. First, our principals must reach a majority agreement on how to contract with the agent. Second, our principals are unable to contract on all dimensions, thus giving rise to the strategic need for a gatekeeper.

Related works outside of the agency literature include the noncooperative analysis of coalitional bargaining (Chatterjee et al., 1993; Perry and Reny, 1994). Focusing on the gains that individual members of a coalition receive, both of these works present noncooperative modelling of endogenous coalition formation. While we also construct a noncooperative model of group interaction, our primary focus is on partial verifiability and the use of gatekeepers and performance standards in contracting.

2. The model

■ **Preferences and information.** The vector $x = (x_1, x_2) \in \mathbb{R}_+^2$ represents an allocation that the agent, A, can produce for the principals, $N = \{1, 2, \ldots, n\}$. The principals are indexed by j, and the number of principals, n, is odd.[3]

[3] We assume n is odd to avoid the analysis of tie-breaking rules. For more on these rules, see Moulin (1980).

The agent's utility from an allocation x is $U^A(x) = -(\beta_1^A x_1 + \beta_2^A x_2)$, where $\beta_1^A, \beta_2^A > 0$.[4] The parameters β_1^A and β_2^A can be interpreted as the agent's marginal costs of producing x_1 and x_2 respectively. (For a diagram of the participants' utility functions, see Figure 3, which apppears later in the article.) The agent's marginal rate of substitution is $MRS_{12}^A \equiv \alpha^A = \beta_1^A/\beta_2^A$. The agent's outside option utility is $-\bar{u} \in \mathbb{R}$. The agent's indifference curve for her outside option utility, $U^A(x) = -\bar{u}$, is her outside option curve, which represents the allocations that are the upper bound of the amount she is willing to produce.

Principal j's utility from an allocation x is $U^j(x) = (\beta_1^j x_1 + \beta_2^j x_2)$, where $\beta_1^j, \beta_2^j > 0$. Principal j's marginal rate of substitution is $MRS_{12}^j \equiv \alpha^j = \beta_1^j/\beta_2^j$. To ease our characterization of the equilibria, we normalize each principal's outside option utility to be equal to $\bar{v} \in \mathbb{R}$. Principal j's indifference curve for his outside option utility, $U^j(x) = \bar{v}$, is his requirement curve, which represents the allocations that are minimally acceptable to him.[5]

We make three technical assumptions concerning the principals' and the agent's utilities that ease our characterization of the equilibrium outcomes and permit a cleaner presentation of the central economic themes of our analysis.

Assumption 1. The principals' preferences satisfy $\beta_1^1 < \beta_1^2 < \cdots < \beta_1^n$ and $\beta_2^1 > \beta_2^2 > \cdots > \beta_2^n$.

Assumption 1 orders not only the principals' utilities for the agent's production in each dimension, but also the principals' marginal rates of substitution, i.e., $\alpha^1 < \alpha^2 < \cdots < \alpha^n$. Accordingly, among all principals, principal 1 places the greatest value on x_2, the smallest value on x_1, and the greatest value on x_2 relative to x_1. Similarly, principal n places the smallest value on x_2, the greatest value on x_1, and the smallest value on x_2 relative to x_1. Note that α^m, where $m = (n+1)/2$, is the median of the marginal rates of substitution. We refer to the principal with the median of the marginal rates of substitution, principal m, as the median principal.

Assumption 1 combined with the normalization of the outside option utilities permits the principals' requirement curves to be ordered by their intersections on the x_1 and x_2 axes. With regard to the x_1 axis, we have that $\bar{v}/\beta_1^1 > \bar{v}/\beta_1^2 > \cdots > \bar{v}/\beta_1^n$. This ordering implies that if the agent produces only x_1, then principal 1—the principal who places the smallest value on the agent's production of x_1—is the least willing of the principals to accept the agent's production, and principal n is the most willing. With regard to the x_2 axis, we have that $\bar{v}/\beta_2^1 < \bar{v}/\beta_2^2 < \cdots < \bar{v}/\beta_2^n$. This implies the opposite. If the agent produces only x_2, then principal 1—the principal who places the greatest value on the agent's production of x_2—is the most willing to accept the agent's production, and principal n is the least willing.

The position of a principal's requirement curve in part determines his ability to motivate the agent to produce x_1. Given x_2, the position of principal j's requirement curve is determined by the minimum amount of x_1 that principal j is willing to accept, i.e., $x_1 = \max\{(\bar{v} - \beta_2^j x_2)/\beta_1^j, 0\}$. Given $x_2 = 0$, as stated above, Assumption 1 and the normalization of the outside option utilities order the principals' requirement curves. However, for any $x_2 > 0$, Assumption 1 and the normalization of the outside option utilities allow any ordering of the principals' requirement curves (i.e., the minimum amounts of x_1 the principals are willing to accept).

Assumption 2. Either $\bar{u}/\beta_1^A > \bar{v}/\beta_1^m$, or $\bar{u}/\beta_2^A > \bar{v}/\beta_2^m$, or both.

Assumption 2 implies that there are allocations that the median principal and the agent both strictly prefer to the outside option.

Our last technical assumption on preferences permits us to avoid the cumbersome case in which the agent and a gatekeeper have identical marginal rates of substitution.

[4] We do not specify wealth in the participants' utility functions because we consider environments in which financial incentives are not used. For example, by institutional rules, the principals may not be permitted to provide financial incentives to the agent.

[5] The normalization of principal j's outside option utility means that we cannot shift his requirement curve by changing his outside option utility. Nevertheless, we can shift this requirement curve in a parallel manner by changing (β_1^j, β_2^j), without changing β_1^j/β_2^j. In Corollary 3 and Example 5, we do precisely this so as to shift a principal's requirement curve and vary the toughness of the principal.

Assumption 3. For any j, $\alpha^A \neq \alpha^j$.

A utility profile is $\beta = (\beta_1^A, \beta_1^1, \ldots, \beta_1^n, \beta_2^A, \beta_2^1, \ldots, \beta_2^n)$. In our model, the domain of utility profiles, B, is all utility profiles, β, that satisfy Assumptions 1, 2, and 3. (To reduce notation, we do not write the outside option utilities in the utility profile.)

Finally, we assume that both the principals and the agent are completely informed about their utilities, the structure of the game, and the allocation produced by the agent. The outside party, who is required to enforce the contract, can observe the contract that the principals offer the agent, the agent's production of x_2, and the actions that the principals take when they evaluate the agent's production. The outside party cannot observe the agent's production of x_1.

□ **The three-stage game.** We model the interactions among the principals and the agent as a three-stage game of complete and perfect information. In stage 1, the principals identify the gatekeeper and set a minimum requirement.[6] In stage 2, the agent either accepts the contract and produces an allocation or the relationship ends. If the agent accepts the contract, in stage 3, the agent's production is evaluated according to the procedures stated in the stage-1 contract.

In stage 1, the principals first elect a gatekeeper and then determine a minimum requirement. The gatekeeper election process is an n-round voting process. In each voting round, the principals vote by roll call (i.e., publicly and sequentially): principal 1 first, then principal 2, on through principal n. The winner of each voting round is determined by simple $(n+1)/2$ majority rule. In the first round, the principals vote on two gatekeeper options: no gatekeeper (denoted as principal $\emptyset$) versus principal 1. In the second round, the principals vote on the round-one winner versus principal 2. This process continues in this same manner, with a given round's winner moving to the next round. The gatekeeper specified in the contract, G, is the winner of the round-n vote. To determine the minimum requirement, each principal first proposes a minimum requirement: principal 1 first, then principal 2, on through principal n. The principals then vote on these proposals using the same n-round voting process they used to elect the gatekeeper. The minimum requirement that the principals as a group impose, r_2, is the winner of this n-round voting process.

At the end of stage 1, the principals offer the agent a contract $C = (G, r_2)$.[7] The contract establishes not only the terms G and r_2, but also specifies the following stage-3 three-step evaluation process that the principals must follow in evaluating the agent's production.

If in stage 2 the agent accepted the contract and produced $x = (x_1, x_2)$, the first step in the stage-3 evaluation process is verification that the agent's production satisfies the minimum requirement, r_2. If $x_2 < r_2$, the relationship ends and the parties receive their outside options. If $x_2 \geq r_2$, the evaluation process proceeds to the second step. In this step, the gatekeeper G decides whether to accept the agent's production. If the gatekeeper does not accept the agent's production, the evaluation process ends and the parties receive their outside options. If the gatekeeper accepts the agent's production, the evaluation process proceeds to the third step. In this step, the principals (including the gatekeeper) vote sequentially in the order 1 through n on whether to accept the agent's production. If at least $(n+1)/2$ of the principals approve the agent's production, the agent's output is accepted by the group. If not, the parties receive their outside options.

We examine subgame-perfect equilibria. We say that a contract $c = (G, r_2)$ implements x if C results in the agent's equilibrium production of x and the principals' equilibrium acceptance of x. An allocation x is *implementable* if there exists a contract C that implements x. We make one last technical assumption that simplifies the analysis of the subgame-perfect equilibria.

Assumption 4. If the agent is indifferent between accepting and rejecting the contract, the agent

6 The principals need at most one gatekeeper. If two dimensions were unverifiable, there would be equilibria in which the principals would elect two gatekeepers—one would place great demands on the production in one dimension, while the other would place great demands on the production in the other dimension. This suggests that with multiple unverifiable dimensions, a committee as opposed to an individual may serve as the gatekeeper.

7 If r_2 is a prohibitively high minimum requirement, the principals implement the outside option. Also, the contract $C = (\emptyset, 0)$ means that the principals commit to a full-group evaluation, independent of the agent's production.

accepts the contract. If a principal is indifferent between accepting and rejecting the agent's production, x, the principal accepts x.[8]

We model the relationship between the principals and agent as a sequential majority-rule voting problem with gatekeeper-and-minimum-requirement contracts for the following four reasons. First, majority rule is the voting rule employed by many of the institutions that we model. In addition, the qualitative features of our results extend to any less-than-unanimity voting rule. Second, we model voting as a sequential process so as to simplify the equilibrium analysis of the voting problem and emphasize the economics of the contracting problem. Third, in settings with complete information, no monetary transactions, and the unverifiability of x_1, we expect that the agent would produce the minimally acceptable amount of x_1—either zero or the amount of x_1 that drives one of the principals to being indifferent to accepting and rejecting the agent's production. Our gatekeeper-and-minimum-requirement contracts implement precisely these allocations. Last, as we noted in the Introduction, these types of contracts are common.

Possible alternative contracts are direct mechanisms. In our model, the principals cannot directly contract on the agent's production of x_1 because the outside party required to enforce the contract cannot observe x_1. In certain cases, principals would prefer to be able to contract on x_1, and in these cases, this inability to contract x_1 creates inefficiency (an inefficiency ignoring the agent's preferences). Recently, economists have investigated direct mechanisms as a possible solution to this type of inefficiency (see Moore, 1992). In the context of our model, however, in any direct mechanism that improves upon our gatekeeper-and-minimum-requirement contract, the principals play weakly dominated strategies.[9]

Before proceeding, we would like to note that the stage-1 contract offered to the agent affects the agent's production only if the principals can credibly commit not to renegotiate either the standards of the contract (i.e., $C = (G, r_2)$) or the stage-3 evaluation procedure. To commit, the principals and agent can use an outside party to enforce these "standards and procedures" and prevent renegotiation.

In the institutions we model, these outside parties often take the form of higher-level decision makers in the institution. In an academic setting, this role may be played by the provost (or board of trustees). Typically, provosts do not have the information or expertise in each academic discipline to set the promotion standards or to evaluate the agent's performance (recall that x_1 is unobservable by outside parties). As such, provosts are not part of the stage-1 contract determination process or the stage-3 evaluation process. Why then, upon faculty approval of a tenure candidate, is it common for the case to go to a provost before the candidate is granted tenure? We claim that one of the roles the provost plays in the approval process is to prevent renegotiation by ensuring that standards are maintained and proper procedures are followed.

Why might a provost be a credible enforcer of standards and procedures and prevent renegotiation following a substandard performance? We propose two motivations here. First, if the provost renegotiates a current contract—which states procedures, requirements, and a possible gatekeeper—then for the consistent application of procedures, he must renegotiate future contracts.[10] In particular, if the provost renegotiates a current contract but fails to renegotiate future contracts, the future agents can file for legal regress for not receiving "equal treatment."[11] Hence,

[8] It is straightforward, but lengthy, to demonstrate that subgame-perfect equilibrium implies that the participants follow the rules in Assumption 4. The proof of this proposition is close to the proof that in any subgame-perfect equilibrium to the ultimatum bargaining game (with a continuous-offer space), the receiver accepts the sender's offer if and only if the receiver *weakly* prefers the offer to the outside option.

[9] See Dearden and Klotz (2001) for an outline of this argument.

[10] Considering the academic example, in many institutions college promotion and tenure committees are elected for terms shorter than the probationary periods of untenured faculty. In these institutions, tenured faculty with preferences for tough gatekeepers have incentives to continually elect tough committees so as to maintain standards. See Sobel (2000) for an analysis of the evolution of standards.

[11] In addition to the threat of legal recourse, institutions may implement consistent procedures because, as Baron and Kreps (1999) contend, people care deeply about being treated fairly, and procedural consistency is one of the ingredients of fairness.

the renegotiation of a current contract carries the cost of future renegotiations. If this cost is sufficiently large, the provost rejects requests to renegotiate.

Now consider a provost who is not convinced that the future cost is sufficiently large. This brings us to a second reason a provost may not permit renegotiation. When the contracting parties approach the provost to request a renegotiation, the provost must discern why the parties would want to renegotiate a substandard performance. One possibility is that the candidate influenced the tenured faculty in some way that benefited the tenured faculty but not the university.[12] If there is sufficient suspicion that this type of influence has taken place, then a provost acting in the interest of the university would not permit renegotiation.

Our contracts and the prevention of renegotiation of the contracts can be enforced not only institutionally, but also by reputations. Consider environments in which reputations affect behavior. One important question is whether it is possible that reputations would keep principals from renegotiating gatekeeper-and-minimum-requirement contracts, but not prevent them from renegotiating contracts that state they will accept only an outstanding, desired performance (e.g., $\bar{x}^1$). The answer is yes if the future agents (who base their behavior on the principals' reputations) can observe whether a gatekeeper-and-minimum-requirement contract is renegotiated, but cannot observe unverifiable variables.

3. Results

■ For comparison purposes, we first analyze the case of complete verifiability. Following this, we analyze our primary case—partial verifiability.

Before we begin our formal analysis, we classify five types of allocations and the notation that we use to represent them. We distinguish these five types of allocations because they correspond to the five types of equilibrium allocations identified in this section. For the first three types of allocations, we use an overbar on an allocation x (i.e., $\bar{x}$) to indicate that the allocation must be on the agent's outside option curve. In the first type of allocation, $\bar{x}^1$, the superscript "1" denotes an x_1-only allocation. In the second type of allocation, $\bar{x}^2$, the superscript "2" denotes an x_2-only allocation. In the third type of allocation, $\bar{x}^{\text{mix}}$, the superscript "mix" indicates positive amounts of both x_1 and x_2. In the fourth type of allocation, x^1, the superscript "1" denotes an x_1-only allocation, and here the absence of an overbar indicates that this allocation may or may not be on the agent's outside option curve. The distinguishing feature of our last allocation type, x^m, is that x^m is on the median principal's requirement curve. The values of these allocations—$\bar{x}^1$, $\bar{x}^2$, x^1, $\bar{x}^{\text{mix}}$, and x^m—are characterized below.

□ **Complete verifiability: x_1 both x_2 and are verifiable.** When both x_1 and x_2 are verifiable, the principals can use a contract that specifies a minimum requirement on either x_1, x_2, or both x_1 and x_2. As a result, when both x_1 and x_2 are verifiable, the principals can implement any allocation, x, that (i) the agent is willing to produce (i.e., $U^A(x) \geq -\bar{u}$) and (ii) a majority of principals weakly prefer to the outside option (i.e., $\#\{j : U^j(x) \geq \bar{v}\} \geq (n+1)/2$).

Among the set of implementable allocations, for some utility profiles, a majority of principals strictly prefer the greatest amount of x_1 the agent is willing to produce. This x_1-only allocation is[13]

$$\bar{x}^1 \equiv \arg\max_x x_1$$

subject to

(i) $U^A(x) = -\bar{u}$ and
(ii) $U^m(x) > \bar{v}$.

[12] See Milgrom and Roberts (1988) for more on the economic rationale of influence activities.

[13] Note that $U^m(x) > \bar{v}$ and not $U^m(x) \geq \bar{v}$ is a constraint in the definitions of $\bar{x}^1$ and $\bar{x}^2$. We require $U^m(x) > \bar{v}$ in these definitions so that we can distinguish x^m—an allocation on principal m's requirement curve—from $\bar{x}^2$—an allocation that is not on principal m's requirement curve. Also, by Assumptions 1 and 2, the constraint $U^m(x) > \bar{v}$ implies $\#\{j : U^j(x) \geq \bar{v}\} \geq (n+1)/2$.

That is, if $\bar{x}^1$ exists, then $\bar{x}^1 = (\bar{u}/\beta_1^A, 0)$. For other utility profiles, a majority of principals strictly prefer the greatest amount of x_2 the agent is willing to produce. This x_2-only allocation is

$$\bar{x}^2 \equiv \arg\max_x x_2$$

subject to
(i) $U^A(x) = -\bar{u}$ and
(ii) $U^m(x) > \bar{v}$.

That is, if $\bar{x}^2$ exists, then $\bar{x}^2 = (0, \bar{u}/\beta_2^A)$. Theorem 1 demonstrates that one and only one of these allocations, $\bar{x}^1$ or $\bar{x}^2$, is the equilibrium allocation. The allocation that prevails solely depends on α^A compared to α^m.

Theorem 1. Suppose x_1 and x_2 are verifiable. For any $\beta \in B$, $\bar{x}^1$ is the subgame-perfect equilibrium allocation if and only if $\alpha^A < \alpha^m$, and $\bar{x}^2$ is the subgame-perfect equilibrium allocation if and only if $\alpha^A > \alpha^m$.

Proof. All proofs are in the Appendix.

❑ **Partial verifiability: only x_2 is verifiable.** Unlike the case where both x_1 and x_2 are verifiable, when only x_2 is verifiable, there are allocations that a majority of principals and the agent prefer to the outside option, but the principals cannot implement. When x_1 is unverifiable, the reason the principals cannot implement these allocations stems from the fact that the principals can contract on x_1 only indirectly through the use of a gatekeeper. Since there is a finite number of possible gatekeepers, the set of allocations that can be enforced by the use of a gatekeeper is limited.

For $\beta \in B$, we denote the set of implementable allocations when only x_2 is verifiable by $IA(\beta)$. In Lemma 1, for each $\beta \in B$, we characterize $IA(\beta)$.

Lemma 1. Suppose x_2 is verifiable and x_1 is unverifiable. For any $\beta \in B$, $x \in IA(\beta)$ if and only if the following two participation conditions are satisfied

$$\#\{j : U^j(x) \geq \bar{v}\} \geq (n+1)/2, \tag{1}$$

$$U^A(x) \geq -\bar{u}, \tag{2}$$

and one of the following conditions—which constitute the agent's incentive compatibility constraint—is satisfied

$$x = (0, x_2) \tag{3a}$$

or

$$x = (x_1, x_2),\ \text{where } x_1 > 0,\ \text{and } U^j(x) = \bar{v} \text{ and } \alpha^A < \alpha^j \text{ for at least one } j \in N. \tag{3b}$$

Moreover, $IA(\beta) \neq \emptyset$.

To characterize the equilibrium allocations, we introduce the win set—the set of implementable allocations that a majority of the principles weakly prefer to all other implementable allocations. For utility profile β and for the set of implementable allocations $IA(\beta)$, the *Win Set* is

$$W(\beta) = \{x \in IA(\beta) : \#\{j : U^j(x) \geq U^j(x')\} \geq (n+1)/2 \text{ for each } x' \in IA(\beta)\}.$$

Lemma 2 establishes that $W(\beta)$ can be characterized by the median principal's ideal allocations among $IA(\beta)$.

Lemma 2. Consider $\beta \in B$. An allocation $x \in IA(\beta)$ is in $W(\beta)$ if and only if for each $x' \in IA(\beta)$, $U^m(x) \geq U^m(x')$.

Lemma 3 establishes that if $x \in W(\beta)$, then x must be one of the following four allocations:

$\bar{x}^2$;

$\bar{x}^{\text{mix}} \equiv \arg\max_x x_1$ subject to

(i) $U^A(x) = -\bar{u}$,
(ii) $U^m(x) > \bar{v}$, and
(iii) for some $G \in \{m+1, \ldots, n\}$, $U^G(x) = \bar{v}$ and $\alpha^A < \alpha^G$;

$\bar{x}^1 \equiv \arg\max_x x_1$ subject to

(i) $U^A(x) \geq -\bar{u}$,
(ii) $U^m(x) > \bar{v}$, and
(iii) for some $G \in \{1, \ldots, m-1\}$, $U^G(x) = \bar{v}$ and $\alpha^A < \alpha^G$; or

x^m, where x^m is any allocation in

$$X^m \equiv \left\{x : U^A(x) \geq -\bar{u},\ U^m(x) = \bar{v},\ \text{and}\ \alpha^A < \alpha^m\right\}.$$

Moreover, Lemma 3 completely characterizes $W(\beta)$.

Lemma 3. Consider $\beta \in B$. If $\alpha^A > \alpha^m$, then $W(\beta) = \bar{x}^2$. If $\alpha^A < \alpha^m$, then

$$W(\beta) = \Big\{x \in \{\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\} \setminus \emptyset\} : U^m(x) \geq U^m(x') \text{ for each } x' \in \{\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\} \setminus \emptyset\}\Big\}.$$

Specifically, for each $\beta \in B$ that satisfies $\alpha^A < \alpha^m$, Figures 1 and 2 characterize $W(\beta)$.

Theorem 2 demonstrates that x is a subgame-perfect equilibrium allocation if and only if $x \in W(\beta)$. Theorem 2 also characterizes equilibrium contracts. At this point, we want to emphasize the types of environments—represented in Lemma 3—that result in each of the four types of equilibrium allocations.

FIGURE 1

THE WIN SET AND EQUILIBRIUM ALLOCATIONS IF $\alpha^A < \alpha^{m-1}$

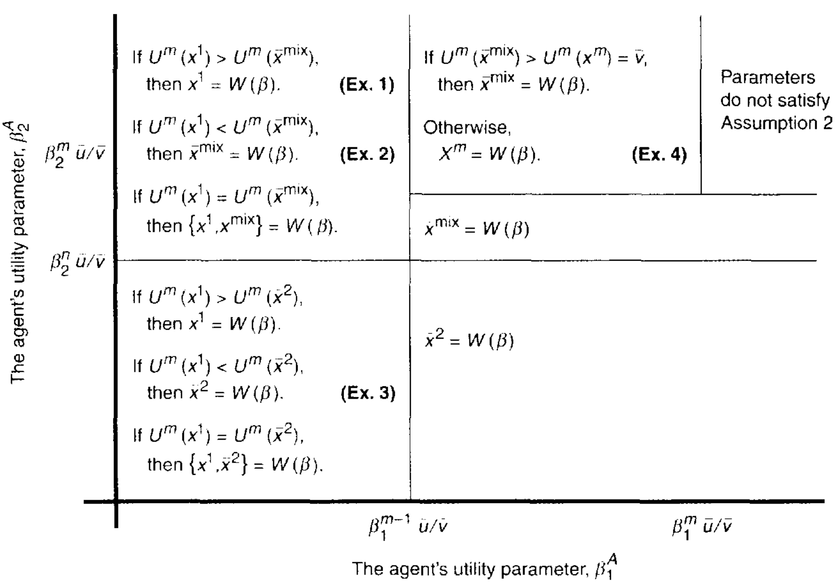
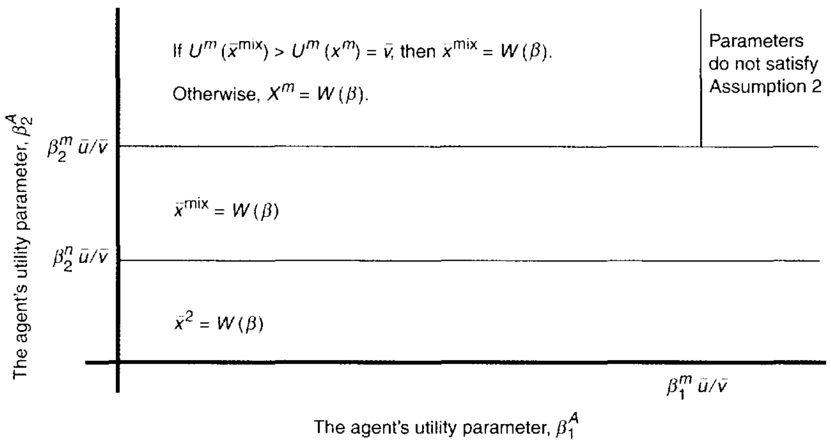


FIGURE 2

THE WIN SET AND EQUILIBRIUM ALLOCATIONS IF $\alpha^{m-1} < \alpha^A < \alpha^m$



If $\alpha^A > \alpha^m$, then as in the case of complete verifiability, the agent is sufficiently good at producing x_2 that (at least) principals 1 through m strictly prefer $\bar{x}^2 = (0, \bar{u}/\beta_2^A)$ to any other allocation the agent is willing to produce. Hence, $W(\beta) = \bar{x}^2$.

If $\alpha^A < \alpha^m$, the characterization of $W(\beta)$ depends on (i) principal m's utility function and (ii) which of the allocations in the set $\{\bar{x}^2, \bar{x}^{mix}, x^1, X^m\}$ exist. To illustrate how principal m's utility function and the existence conditions determine $W(\beta)$, Figures 1 and 2 characterize $W(\beta)$ in terms of the marginal valuations, β, the marginal rates of substitution, $\alpha = (\alpha^A = \beta_1^A/\beta_2^A, \alpha^1 = \beta_1^1/\beta_2^1, \ldots, \alpha^n = \beta_1^n/\beta_2^n)$, principal m's utility function, $U^m(x) = \beta_1^m x_1 + \beta_2^m x_2$, and the outside option utilities.

For example, consider the regions displayed in Figures 1 and 2 for which x^1 is in $W(\beta)$. Assumptions 1 and 2 imply that this allocation exists if and only if $\alpha^A < \alpha^{m-1}$ and $\bar{u}/\beta_1^A \geq \bar{v}/\beta_1^{m-1}$. Hence, as displayed in the figures, x^1 is in $W(\beta)$ only if $\alpha^A < \alpha^{m-1}$ and $\bar{u}/\beta_1^A \geq \bar{v}/\beta_1^{m-1}$. In addition, we can see in Figures 1 and 2 that when x^1 exists, whether x^1 is in $W(\beta)$ depends on U^m.

The existence condition for x^1 and principal m's utility function provide us with intuition about the types of environments for which x^1 is in $W(\beta)$. Specifically, the existence condition, $\alpha^A < \alpha^{m-1}$ and $\bar{u}/\beta_1^A \geq \bar{v}/\beta_1^{m-1}$, means that there is a gatekeeper who can enforce the agent's production of x^1. Note from the definition of x^1 that this gatekeeper must be one of the principals who are more demanding of the agent's production of x_1 (i.e., one of the principals from 1 through $m-1$). The existence condition also means that the agent is both good at producing x_1 (i.e., $\bar{u}/\beta_1^A \geq \bar{v}/\beta_1^{m-1}$) and relatively good at producing x_1 (i.e., $\alpha^A < \alpha^{m-1}$).

With regard to principal m's utility for x^1, $U^m(x^1) = \beta_1^m x_1^1 + \beta_2^m x_2^1$ of course depends on β_1^m and β_2^m as well as the position of x^1. The position of x^1 depends in turn on the strength of the gatekeeper and the agent's production capabilities. Hence, principal m prefers x^1 to the other implementable allocations when he has a sufficiently strong preference for x_1 (i.e., $\alpha^m = \beta_1^m/\beta_2^m$ is sufficiently large), and when the agent is sufficiently good at producing x_1 and the gatekeeper who can enforce x^1 is sufficiently tough (i.e., x^1 is sufficiently large). We emphasize a typical case for which x^1 is in $W(\beta)$, as well as the typical cases for which the other three types of allocations—$\bar{x}^2$, $\bar{x}^{mix}$, and X^m—are in $W(\beta)$, in the examples following Theorem 2. Also, note that the existence conditions for the four types of allocations as well as important properties about principal m's utility function are in the proof of Lemma 3.

Before proceeding to Theorem 2, we characterize the equilibrium gatekeeper. Specifically, if the principals elect a gatekeeper, then they elect a tough guy. That is, they elect as gatekeeper the principal who, given the minimum requirement r_2, enforces the greatest production of x_1. Formally, given r_2, the equilibrium gatekeeper is

$$G^* \equiv \arg\max_{j \in N} x_1 \text{ subject to } U^A(x_1, r_2) \geq -\bar{u},\ U^j(x_1, r_2) = \bar{v} \text{ and } \alpha^A < \alpha^j.$$

Theorem 2. Suppose that x_2 is verifiable and x_1 is unverifiable. For any $\beta \in B$ for which $\alpha^A > \alpha^m$, x is a subgame-perfect equilibrium allocation if and only if $x = W(\beta) = \bar{x}^2$. For any $\beta \in B$ for which $\alpha^A < \alpha^m$, x is a subgame-perfect equilibrium allocation if and only if

$$x \in W(\beta) = \Big\{x \in \{\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\} \setminus \emptyset\} : U^m(x) \geq U^m(x') \text{ for each } x' \in \{\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\} \setminus \emptyset\}\Big\}.$$

Specifically, for each $\beta \in B$ for which $\alpha^A < \alpha^m$, the subgame-perfect equilibrium allocations are those identified in Figures 1 and 2. Moreover, if $\bar{x}^2$ is an equilibrium allocation, then $C = (\emptyset, \bar{x}_2^2)$ is an equilibrium contract. If $\bar{x}^{\text{mix}}$ is an equilibrium allocation, then $C = (G^*, \bar{x}_2^{\text{mix}})$ is an equilibrium contract. If x^1 is an equilibrium allocation, then $C = (G^*, 0)$ is an equilibrium contract. For any $x^m \in X^m$, if x^m is an equilibrium allocation, then $C = (m, x_2^m)$ is an equilibrium contract.[14]

Considering the types of contracts that the principles offer to the agent (and the resultant equilibrium production) Theorem 2 demonstrates that the use of a tough gatekeeper, and also of a minimum requirement on the verifiable dimension, depends on the agent's production capability, the toughness of the possible gatekeepers, and the median principal's utility of the verifiable and unverifiable dimensions. Figures 1 and 2 show that the principals tend to use a gatekeeper when the agent is relatively good at producing the unverifiable characteristic and there is a gatekeeper who can enforce a sufficiently large production of the unverifiable characteristic; the principals tend to use a minimum requirement when the agent is relatively good at producing the verifiable characteristic or there is no gatekeeper who can enforce a sufficiently large production of only the unverifiable characteristic.

In Corollaries 1 through 3 we examine three economic features of the equilibria: the agent's economic surplus, the agent's production, and the toughness of the gatekeeper. Corollary 1 establishes the conditions for which the agent earns a positive economic surplus. Roughly, the agent earns a positive economic surplus if and only if she is relatively good at producing the unverifiable characteristic and an appropriate gatekeeper who can extract the entire surplus from the agent does not exist.

Corollary 1. Suppose that x_2 is verifiable and x_1 is unverifiable. The agent earns a positive surplus if and only if she produces either x^1 (where $x^1 < \bar{x}^1$ so that $U^A(x^1) > -\bar{u}$) or x^m (where $U^A(x^m) > -\bar{u}$).

Corollary 2 compares the agent's equilibrium production of the complete- and partial-verifiability cases. To ease this comparison, we let x^{cv} denote the equilibrium allocation with complete verifiability and x^{pv} denote the equilibrium allocation with partial verifiability. In the partial-verifiability environment, we say that the agent underproduces x_1 if $x_1^{\text{cv}} > x_1^{\text{pv}}$ and overproduces x_2 if $x_2^{\text{cv}} < x_2^{\text{pv}}$.

Corollary 2. Consider $\beta \in B$. If $\alpha^A > \alpha^m$, then $x_1^{\text{cv}} = x_1^{\text{pv}}$ and $x_2^{\text{cv}} = x_2^{\text{pv}}$. If $\alpha^A < \alpha^m$ and $x^1 = \bar{x}^1$, then $x_1^{\text{cv}} = x_1^{\text{pv}}$ and $x_2^{\text{cv}} = x_2^{\text{pv}}$. If $\alpha^A < \alpha^m$ and $x^1 < \bar{x}^1$, then $x_1^{\text{cv}} > x_1^{\text{pv}}$ and $x_2^{\text{cv}} \leq x_2^{\text{pv}}$.

[14] The equilibrium allocation is one and only one type of allocation—either $\bar{x}^2$, $\bar{x}^{\text{mix}}$, x^1, or X^m—with measure one over the domain of utility profiles, B. However, this does not imply that the equilibrium allocation is unique because if X^m is the equilibrium type, then any allocation $x^m \in X^m$ is an equilibrium allocation. Also, note that if principal m is the equilibrium gatekeeper, then $G^* = m$.

Corollary 2 states that if $\alpha^A > \alpha^m$, then with partial verifiability, the principals can implement the complete-verifiability outcome, $\bar{x}^2$. If $\alpha^A < \alpha^m$, however, then partial verifiability may result in the underproduction of x_1 and overproduction of x_2 compared to the complete-verifiability case. To understand the economics behind the underproduction of x_1 and the overproduction of x_2, suppose that an ideal gatekeeper is present, i.e., one that has $\beta_1^j \bar{x}^1 = \bar{v}$. In this case, the verifiable outcome is implementable by the use of this ideal gatekeeper. Without this ideal gatekeeper, however, the underproduction of the x_1 result emerges because the principals cannot commit to accepting only $\bar{x}^1$; i.e., the agent knows that she can supply less x_1 and still satisfy a gatekeeper. As a way to reduce the agent's surplus, the principals sometimes raise the requirement of x_2—hence, the overproduction of x_2. The unverifiable outcome therefore departs from the verifiable outcome because an ideal gatekeeper does not exist and the agent would otherwise earn a greater surplus. In this sense, the production distortions arise because of slackness in the participation constraints. This result is unlike the Holmström and Milgrom (1991) result, where the shift toward the verifiable variable arises because of the substitutability of the verifiable and unverifiable variables in the agent's production and distorted incentives.

Corollary 3 examines the relationship between the ability of a principal to enforce the agent's production of x_1 and whether the principal serves as gatekeeper. To do so, we make a single principal more demanding (without affecting his marginal rate of substitution) by shifting his requirement curve in a parallel manner (i.e., decreasing β_1^j and β_2^j without affecting β_1^j/β_2^j). Corollary 3 shows that if a principal becomes more demanding, but not so demanding that the agent is unwilling to satisfy his requirements, then the principal will be more likely to be the gatekeeper. To compare the equilibria of different utility profiles, we let $G^*(\beta)$ denote the equilibrium gatekeeper and $x^*(\beta)$ denote the equilibrium allocation for profile β. In Corollary 3, we consider only the case in which the principals possibly use a gatekeeper (i.e., $\alpha^A < \alpha^m$).

Corollary 3. Consider β and $\tilde{\beta}$ for which $\alpha^A = \tilde{\alpha}^A < \tilde{\alpha}^m = \alpha^m$; $\beta_1^j = t\tilde{\beta}_1^j$ and $\beta_2^j = t\tilde{\beta}_2^j$ for some $j \in N$ and $t > 1$; and $\beta^{-j} = \tilde{\beta}^{-j}$. If $G^*(\beta) = j'$ and either $\bar{u}/\tilde{\beta}_1^A \geq \bar{v}/\tilde{\beta}_1^j$, or $\bar{u}/\tilde{\beta}_2^A \geq \bar{v}/\tilde{\beta}_2^j$, or both, then $G^*(\tilde{\beta}) \in \{j, j'\}$. If $G^*(\beta) = j$ and either $\bar{u}/\tilde{\beta}_1^A \geq \bar{v}/\tilde{\beta}_1^j$, or $\bar{u}/\tilde{\beta}_2^A \geq \bar{v}/\tilde{\beta}_2^j$, or both, then $G^*(\tilde{\beta}) = j$. If $\bar{u}/\tilde{\beta}_1^A < \bar{v}/\tilde{\beta}_1^j$ and $\bar{u}/\tilde{\beta}_2^A < \bar{v}/\tilde{\beta}_2^j$, then $G^*(\tilde{\beta}) \neq j$.

We now move on to investigate cases for which each of the four types of equilibrium allocations and contracts identified in Theorem 2 are likely to arise, and highlight the properties of these equilibria.

Case 1. $\alpha^A > \alpha^m$. In both the complete- and partial-verifiability cases, the principals implement the same allocation—$\bar{x}^2$.

Case 2. $\alpha^A < \alpha^m$. The agent is relatively good at producing x_1, and (at least) principals m through n strictly prefer $\bar{x}^1 = (\bar{u}/\beta_1^A, 0)$ to any other allocation the agent is willing to produce. But when x_1 is unverifiable, Theorem 2 demonstrates that the equilibrium allocation must be in $W(\beta) \subset \{\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\} \backslash \emptyset\}$. Which of these four types of allocations prevails in equilibrium depends on the ones that exist as well as the median principal's ideal allocation among those that exist, which in turn depend on the agent's production capabilities and the preferences of the principals (who can serve as the gatekeeper).

To investigate this case in which $\alpha^A < \alpha^m$, we construct four three-principal examples—one example for each type of equilibrium. In each of these four examples, we set $U^1(x) = x_1/2 + 2x_2$, $U^m(x) = x_1 + x_2$, $U^3(x) = 2x_1 + x_2/3$, and $\bar{u} = \bar{v} = 1$. We vary the agent's production capabilities. Specifically, in Examples 1 through 3, we fix the agent's ability to produce x_1 at $\beta_1^A = 1/5$ and increase her ability to produce x_2 (i.e., decrease β_2^A). By means of these first three examples, we emphasize how the agent's production capabilities, relative to the principals' preferences, affect both the type of equilibrium contract that the principals offer the agent—whether the principals use a gatekeeper or minimum requirement—and the agent's equilibrium production. Specifically, as the agent in these examples moves from being poor to being exceptionally good at producing x_2, the equilibrium contract shifts from a gatekeeper-only contract to a gatekeeper-and-minimum-requirement contract to a minimum-requirement-only contract, and the equilibrium allocation shifts from x^1 to $\bar{x}^{\text{mix}}$ to $\bar{x}^2$. In Example 4, the agent produces $x^m \in X^m$. We note the four examples in Figure 1.

Example 1. $U^A(x) = -(x_1/5 + 10x_2)$. Relative to the principals' preferences, the agent is exceptionally good at producing x_1 but is poor at producing x_2. In fact, the agent is so poor at producing x_2 that $\bar{x}^2$ and $\bar{x}^{\text{mix}}$ do not exist. However, the allocations $x^1 = (\bar{v}/\beta_1^{G^*}, 0) = (2, 0)$ and X^m do exist, and the principals can implement either x^1 or any one allocation x^m in X^m. All three principals strictly prefer x^1 to any $x^m \in X^m$. Hence, $W(\beta) = x^1$. To implement x^1, the principals state no minimum requirement and specify that principal 1—the tough guy who is most demanding of the agent's production of x_1—is the gatekeeper (i.e., $C^* = (1, 0)$).

The agent is willing to produce $\bar{x}^1 = (\bar{u}/\beta_1^A, 0) = (5, 0)$, but there is no gatekeeper who can enforce an x_1-only allocation greater than $x^1 = (\bar{v}/\beta_1^{G^*}, 0) = (2, 0)$. Hence, as indicated in Corollary 2, the agent underproduces x_1. In the remaining three examples, the agent not only underproduces x_1, but also overproduces x_2.

The agent earns a positive economic surplus. (See Corollary 1.) Although the principals could impose a minimum requirement and squeeze the entire surplus from the agent, the opportunity cost in terms of x_1 of doing so, $dx_1/dx_2|_{dU^1=0} = 1/\alpha^1 = 4$, is too large for principals m and 3.[15] Hence, the agent earns this surplus because the principals are unwilling to impose a minimum requirement on x_2 and sacrifice production of x_1.

Example 2. $U^A(x) = -(x_1/5 + 11x_2/30)$. (See Figure 3.) Relative to the principals' preferences, the agent is good at producing x_1 and moderately talented at producing x_2. The allocations

$$x^1 = \left(\bar{v}/\beta_1^{G^*}, 0\right) = (2, 0),$$
$$\bar{x}^2 = \left(0, \bar{u}/\beta_2^A\right) = (0, 30/11),$$

and

$$\bar{x}^{\text{mix}} = \left(\frac{\beta_2^A - \beta_2^G}{\beta_2^A\beta_1^G - \beta_1^A\beta_2^G}, \frac{\beta_1^G - \beta_1^A}{\beta_2^A\beta_1^G - \beta_1^A\beta_2^G}\right) = \left(\frac{1}{20}, \frac{54}{20}\right)$$

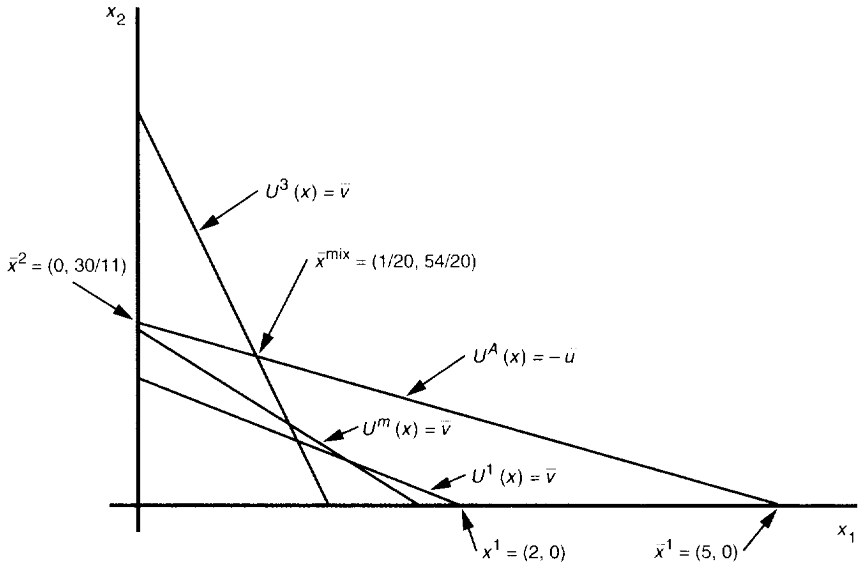
exist, and thus the principals can implement one of these three allocations. The set X^m does not exist because the agent's outside option curve lies outside principal m's requirement curve. Since principals m and 3 strictly prefer $\bar{x}^{\text{mix}}$ to x^1 and $\bar{x}^2$, we have that $W(\beta) = \bar{x}^{\text{mix}}$. To implement $\bar{x}^{\text{mix}}$ and thus have the agent produce both x_1 and x_2, principal 3—the tough guy in this example—serves as the gatekeeper and the principals set the minimum requirement on x_2 at $\bar{x}_2^{\text{mix}}$ (i.e., $C = (3, 54/20)$). Note that the principals do not elect principal 1 as the gatekeeper, and therefore do not implement x^1, because principal 1 is too weak and cannot enforce a sufficiently large x_1-only allocation. Also, the minimum requirement, $r_2 = \bar{x}_2^{\text{mix}}$, is set to extract the entire surplus from the agent.

Example 3. $U^A(x) = -(x_1/5 + x_2/4)$. The agent is so good at producing both x_1 and x_2 that the agent's outside option curve lies outside of all of the principals' requirement curves. Hence, $\bar{x}^{\text{mix}}$ and X^m do not exist. However, $x^1 = (\bar{v}/\beta_1^{G^*}, 0) = (2, 0)$ and $\bar{x}^2 = (0, 4)$ do exist, and the principals can implement either one of these allocations. Since principals 1 and m strictly prefer $\bar{x}^2$ to x^1, we have that $W(\beta) = \bar{x}^2$. To implement $\bar{x}^2 = (0, 4)$ and thus have the agent produce only x_2, the principals use the contract $C^* = (\emptyset, 4)$. As in Example 2, the principals set the minimum requirement to extract the entire surplus from the agent.

Example 4. $U^A(x) = -(9x_1/10 + 11x_2/10)$. The agent is moderately talented at producing x_1 (i.e., only principals m and 3 weakly prefer $\bar{x}^1$ to the outside option) and poor at producing x_2. The allocations x^1, $\bar{x}^{\text{mix}}$, and $\bar{x}^2$ do not exist. However, X^m exists, and $X^m = W(\beta)$. The principals

[15] Even with a minimum requirement, the principals would elect principal 1 as gatekeeper, and the agent would produce an allocation on this principal's requirement curve. Hence, the inverse of the slope of principal 1's requirement curve determines this opportunity cost.

FIGURE 3



will implement any one allocation $x^m \in X^m$. Unlike the other examples, in this example, there is a continuum of equilibrium allocations—any allocation on principal m's requirement curve that the agent is willing to produce. The continuum of equilibria stems from principal m's indifference among these allocations. To implement $x^m \in X^m$, the principals offer the contract $C^* = (m, x_2^m)$. The agent earns a surplus if and only if $U^A(x^m) > -\bar{u}$.

We construct one last example that highlights the Corollary 3 result on the toughness of a principal and whether he serves as the gatekeeper. Note that we relax Assumption 1 in this example.

Example 5. The gatekeeper is demanding, but not too demanding. We move principal 1 from being weaker than the other principals (i.e., principal 1's requirement curve is inside the requirement curves of the other two principals) to being stronger than the other principals. In doing so, principal 1 moves into the gatekeeper role because he becomes sufficiently demanding of the agent's performance and then out of the gatekeeper role because he becomes too demanding.

Let $U^1(x) = \beta_1^1 x_1 + (3\beta_1^1)x_2$. This specification means that we manipulate principal 1's preferences, holding $\beta_1^1/\beta_2^1 = 1/3$ constant. For the remaining participants, let $U^A(x) = x_1/4 + x_2/2$, $U^m(x) = x_1/2 + x_2/2$, and $U^3(x) = x_1 + x_2/4$.[16] Let $\bar{u} = \bar{v} = 1$.

For these preferences, depending on the value of β_1^1, the equilibrium allocation is either $\bar{x}^{mix} = (4/7, 12/7)$ or $x^1 = (1/\beta_1^1, 0)$. If $\beta_1^1 > 7/16$, then a majority of principals strictly prefer $\bar{x}^{mix}$ to x^1. In this case principal 3 is the gatekeeper because principal 1 is too weak on the agent's performance. If, however, $1/4 < \beta_1^1 < 7/16$, then a majority of principals strictly prefer x^1 to $\bar{x}^{mix}$, and principal 1 is the gatekeeper. Lastly, if $\beta_1^1 < 1/4$, then the agent is not willing to produce $(1/\beta_1^1, 0)$. In this case, principal 1 is not the gatekeeper because he is too demanding.

4. Conclusion

■ We offered an explanation as to why cities elect chiefs of police and district attorneys who are "tough on crime," why military chiefs select commanders who are of "known motivation," and why universities sometimes choose tough tenure committees. Given some desired level of production of a verifiable characteristic, the tough-guy gatekeepers enforce production in the unverifiable dimensions. We demonstrated that the use of gatekeepers and minimum requirements depends

[16] With these preferences, Assumption 1 is satisfied if and only if $1/6 < \beta_1^1 < 1/2$.

on the agent's production capability, the possible toughness of the potential gatekeepers, and the principals' preferences for the verifiable and unverifiable dimensions. Moreover, even with the use of a gatekeeper to encourage production in the unverifiable dimension, we established that the agent underproduces the unverifiable characteristic and possibly overproduces the verifiable characteristic. Finally, the agent benefits from the partial verifiability (i.e., earns a positive economic surplus) if and only if she is relatively good at producing the unverifiable characteristic and an appropriate gatekeeper who can extract the entire surplus from the agent does not exist.

Appendix

■ Proofs of the lemmas, theorems, and corollaries follow. Note that the proof of Theorem 1 follows the proof of Theorem 2. Lemmas 1 through 3 and Lemma A1 will be used to prove Theorems 1 and 2.

Proof of Lemma 1. We prove the second sentence of Lemma 1.

Only if. Assumption 4 and the subgame-perfect equilibrium imply that the principals accept the agent's production only if condition (1) is satisfied. (For a detailed proof of this statement, see Lemma A1 below.) Assumption 4 and subgame-perfect equilibrium imply that the agent's equilibrium production satisfies condition (2). Assuming conditions (1) and (2) are satisfied, for any contract $C = (j, r_2)$, the agent's utility-maximizing production, x, satisfies either condition (3a) or (3b).

If. If x satisfies conditions (1), (2), and (3a), then the contract $C = (\emptyset, x_2)$ implements x; and if x satisfies (1), (2), and (3b), then the contract $C = (j, x_2)$ implements x.

We now prove the last sentence of Lemma 1. Assumptions 1 and 2 imply that there exist allocations that satisfy conditions (1) and (2). Hence, $IA(\beta) \neq \emptyset$. *Q.E.D.*

Proof of Lemma 2. We define the following two sets: $B^1(x) = \{x' \in \mathrm{IA}(\beta) : x_1' \geq x_1 \text{ and } x' \neq x\}$; and $B^2(x) = \{x' \in \mathrm{IA}(\beta) : x_2' \geq x_2 \text{ and } x' \neq x\}$.

Only if. Suppose to the contrary that $x \in W(\beta)$, but there exists $x' \in \mathrm{IA}(\beta)$ such that $U^m(x) < U^m(x')$. If $x' \in B^1(x)$, then for each j, $j \geq m$, $U^j(x) < U^j(x')$; and if $x' \in B^2(x)$, then for each j, $j \leq m$, $U^j(x) < U^j(x')$. Hence, $x \notin W(\beta)$. A contradiction.

If. Suppose $U^m(x) \geq U^m(x')$ for each $x' \in \mathrm{IA}(\beta)$. For each j, $j \geq m$, and for each $x' \in B^1(x)$, we have $U^j(x) > U^j(x')$; and for each j, $j \geq m$, and for each $x' \in B^2(x)$, we have that $U^j(x) > U^j(x')$. Moreover, by Assumption 2, $U^m(x) \geq \bar{v}$. Hence, $x \in W(\beta)$. *Q.E.D.*

Proof of Lemma 3. We first demonstrate that $W(\beta) \neq \emptyset$. To do so, we establish that for any $\beta \in B$, at least one of the allocations—$\bar{x}^2$, $\bar{x}^{\text{mix}}$, x^1, and $x^m \in X^m$—exists. The definitions of these allocations and Assumptions 1 and 2 imply the following existence conditions of each of these allocations. The allocation $\bar{x}^2$ exists if and only if β satisfies $\bar{u}/\beta_1^A > \bar{v}/\beta^m$. The allocation x^1 exists if and only if β satisfies $\alpha^A < \alpha^{m-1}$ and $\bar{u}/\beta_1^A \geq \bar{v}/\beta_1^{m-1}$. The allocation $\bar{x}^{\text{mix}}$ exists if and only if β satisfies $\bar{u}/\beta_1^A < \bar{v}/\beta_1^n$, $\alpha^A < \alpha^n$, and $U^m(\bar{x}^{\text{mix}}) > \bar{v}$. Lastly, the set X^m exists if and only if β satisfies $\alpha^A < \alpha^m$, $\bar{u}/\beta_1^A \geq \bar{v}/\beta_1^m$, and $\bar{u}/\beta_2^A \leq \bar{v}/\beta_2^m$. Since these existence conditions span B, at least one of these allocations exists. Hence, $W(\beta) \neq \emptyset$.

We now demonstrate that for any $\beta \in B$, if $x \in W(\beta)$, then x must be one the allocations—$\bar{x}^2$, $\bar{x}^{\text{mix}}$, x^1, and $x^m \in X^m$. To do so, we partition $IA(\beta)$ into five subsets. For each subset, we characterize the allocations that are candidates for $W(\beta)$, and Lemma 2 permits us to characterize these candidates in terms of U^m. The first subset consists of x_2-only allocations in $IA(\beta)$. By strict monotonicity of U^m, if $(0, x_2) \in W(\beta)$, then $(0, x_2) = \bar{x}^2$. Second, consider x_1-only allocations in $IA(\beta)$. Principal m strictly prefers x^1 (if it exists) or $(x_1^m, 0) \in X^m$ (if x^1 does not exist) to any other x_1-only allocation in $IA(\beta)$. Hence, if $(x_1, 0) \in W(\beta)$, then $(x_1, 0)$ is either x^1 or $(x_1^m, 0) \in X^m$. Third, consider the allocations in $IA(\beta)$ that are on principal j's, $j \in \{m+1, \dots, n\}$, requirement curve. Principal m strictly prefers $\bar{x}^j$ (which we define as the allocation on j's requirement curve with the greatest amount of x_2 that the agent is willing to produce) to any other allocation on j's requirement curve. Now, if $\bar{x}^j \neq \bar{x}^{\text{mix}}$ and $\alpha^A < \alpha^m$, then $U^m(\bar{x}^{\text{mix}}) > U^m(\bar{x}^j)$. Moreover, if $\bar{x}^j \neq \bar{x}^2$ and $\alpha^A > \alpha^m$, then $U^m(\bar{x}^2) > U^m(\bar{x}^j)$. Hence, if an allocation in this third subset is in $W(\beta)$, then it must be either $\bar{x}^{\text{mix}}$ or $\bar{x}^2$. Fourth, consider allocations in $IA(\beta)$ that are on principal j's, $j \in \{1, \dots, m-1\}$, requirement curve. Principal m strictly prefers $\tilde{x}^j$ (which we define as the x_1-only allocation on j's requirement curve) to any other allocation on j's requirement curve. Now, if $\tilde{x}^j \neq x^1$, then principal m strictly prefers x^1 to $\tilde{x}^j$. Thus, if an allocation in this fourth subset is in $W(\beta)$, then it must be x^1. Fifth, any allocation in $IA(\beta)$ that is on principal m's requirement curve (i.e., $x^m \in X^m$) is a candidate for $W(\beta)$.

We now have that $W(\beta) \neq \emptyset$ and any $x \in W(\beta)$ is either $\bar{x}^2$, $\bar{x}^{\text{mix}}$, x^1, or $x^m \in X^m$. Since Lemma 2 implies that $x \in W(\beta) \subset \{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\} \setminus \emptyset$ if and only if $U^m(x) \geq \max\{U^m(x') : x' \in \{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\} \setminus \emptyset\}$, we can use the existence conditions stated earlier in this proof for the allocations in $\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\}$ and U^m to characterize the set $W(\beta)$. (See Figures 1 and 2.)

To complete the proof, we need to prove three points about the relationship between U^m and the characterization of $W(\beta)$. First, if $\alpha^A > \alpha^m$, then $U^m(\bar{x}^2) > \max\{U^m(x') : x' \in \{\bar{x}^{\text{mix}}, x^1, X^m\} \setminus \emptyset\}$, and $\bar{x}^2 = W(\beta)$. Second, for any $x^m \in X^m$, $U^m(x^m) = \bar{v}$. Hence, principal m weakly prefers any allocation that exists from $\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, \}$ to $x^m \in X^m$. Third, if $\alpha^A < \alpha^m$ and $\bar{x}^{\text{mix}}$ and $\bar{x}^2$ exist, then $U^m(\bar{x}^{\text{mix}}) > U^m(\bar{x}^2)$. *Q.E.D.*

Lemma A1, stated below, is needed to prove Theorems 1 and 2. Lemma A1 analyzes the sequential voting process that is used to determine the gatekeeper and minimum requirement. In the gatekeeper election process, let a^k represent an equilibrium outcome to the continuation game that follows the election of principal k as gatekeeper. In the minimum requirement election process, after the minimum requirement proposals have been made, let a^k represent an equilibrium outcome to the continuation game that follows the election of principal k's minimum requirement proposal. In both of these elections—the gatekeeper and minimum requirement election process—the principals are effectively voting over the set of allocations $A = \{a^{\emptyset}, a^1, \ldots, a^n\} \subset \text{IA}(\beta)$.

One important note is that to simplify our description of the voting process, we specify one specific order of voting in our sequential voting process. It is straightforward to demonstrate that Lemma A1 is invariant to any order in which the principals vote on the alternatives and any order by which the principals state their votes. Moreover, the results in our main propositions are invariant to the ordering of the principals in their vote on whether to accept the agent's production as well as the ordering of the principals in their statements of their candidates as minimum requirements.

Lemma A1. Consider the sequential voting process over $A = \{a^{\emptyset}, a^1, \ldots, a^n\} \subset \text{IA}(\beta)$. Suppose $\{A \cap W(\beta)\} \neq \emptyset$. The allocation $a^k \in A$ is the outcome of a subgame-perfect equilibrium if and only if $a^k \in W(\beta)$.

Proof. Consider the last round of voting, and suppose that the principals vote on a^k versus $a^{k'}$. We evaluate two cases.

Case 1. $a^k \in W(\beta)$ and $a^{k'} \notin W(\beta)$. Let $N_{a^k} \equiv \{j \in N : U^j(a^k) > U^j(a^{k'})\}$. The assumption $a^k \in W(\beta)$ implies $\#|N_{a^k}| \geq (n+1)/2$. We proceed with the following steps.

Step 1. Consider any node for which (i) the last principal, denoted as j', from N_{a^k} votes and (ii) $(n+1)/2 - 1$ of the principals have voted for a^k. If j' votes for a^k, then his preferred allocation, a^k, wins. Hence, subgame-perfect equilibrium requires that if $(n+1)/2 - 1$ of the principals have voted for a^k, then j' must vote so that a^k wins.

Step 2. Consider any node for which (i) the next-to-last principal, denoted j'', from N_{a^k} votes and (ii) $(n+1)/2 - 2$ of the principals have voted for a^k. If principal j'' votes for a^k, then Step 1 implies that at least one of the principals who vote after him also votes for a^k. Hence, if j'' votes for a^k, then a^k wins. Therefore, subgame-perfect equilibrium requires that if $(n+1)/2 - 2$ of the principals have voted for a^k, then j'' must also vote so that a^k wins.

We continue with this process to Step $(n+1)/2$.

Step $(n+1)/2$. Consider any node for which (i) the $(n+1)/2$th-to-last principal from N_{a^k} votes and (ii) none of the principals have voted for a^k. By the same analysis as in Step 2, we can establish that if zero of the principals who state their votes prior to this principal have voted for a^k, then subgame-perfect equilibrium requires that this principal vote so that a^k wins.

The result $\#|N_{a^k}| \geq (n+1)/2$ implies that the path of any strategy profile to this last round of voting that results in the election of $a^{k'}$ must include at least one of the nodes specified in Steps 1 through $(n+1)/2$. Moreover, if any of these nodes is reached, we demonstrated that a^k wins. Hence, if a^k is considered in the last round of voting, then in any subgame-perfect equilibrium to this last round of voting, a^k wins.

Case 2. $a^k, a^{k'} \in W(\beta)$. We can repeat the proof of Case 1 with the exception of the principal who is indifferent between a^k and $a^{k'}$. (Note that for any $\beta \in B$, only one principal can be indifferent between a^k and $a^{k'}$.) When this indifferent principal can affect the outcome, in some equilibria he votes so that a^k wins and in the remaining equilibria votes so that $a^{k'}$ wins. By repeating the proof of Case 1 we can demonstrate that both a^k and $a^{k'}$ are equilibrium outcomes to the last round of voting in which these two allocations are considered.

Consider any voting round in which the principals vote on $a^{k''}$ versus some other allocation. Suppose that $a^{k'''}$ is the outcome of the equilibrium to the continuation game that follows $a^{k''}$ winning in the round under consideration. Working backward from the last round, it follows from our analysis of the last round that $a^{k''}$ is the outcome of a subgame-perfect equilibrium to the round under consideration if and only if $a^{k'''}$ is in $W(\beta)$. *Q.E.D.*

Proof of Theorem 2. Lemma 1 characterized $IA(\beta)$. That is, for each possible stage-1 contract, Lemma 1 characterized the outcome of the equilibrium play in stages 2 and 3 of the game. Hence, to complete the proof of Theorem 2, we need only determine the stage-1 equilibrium contract. To do so, we partition B into five subsets and characterize the equilibrium contract(s) and allocation(s) for each one. We use $W(\beta)$, which we characterized in Lemma 3, to partition B. Note that because these five subsets partition B, we characterize the equilibrium contract(s) and allocations(s) for each $\beta \in B$.

Subset 1. All $\beta \in B$ for which $\bar{x}^2 = W(\beta)$. We first characterize the equilibrium minimum requirement. Suppose the principals elect no gatekeeper. Subgame-perfect equilibrium requires that at least one principal (notably the median principal if no other principal) nominate $r_2 = \bar{x}_2^2$ as the minimum requirement. Next, if no gatekeeper has been elected and $r_2 = \bar{x}_2^2$ has been nominated, then Lemma A1 and the assumption $\bar{x}^2 = W(\beta)$ imply that the outcome of any equilibrium to the minimum requirement voting process is $r_2 = \bar{x}_2^2$.

We now have that if the principals elect no gatekeeper, then they impose $r_2 = \bar{x}_2^2$ and implement $\bar{x}^2$. Moreover, any principal, j, for whom $U^j(\bar{x}^2) \geq \bar{v}$ could be (an ineffective) gatekeeper and the principals would implement $\bar{x}^2$. In the gatekeeper election, Lemma A1 and the assumption $\bar{x}^2 = W(\beta)$ therefore imply that the principals elect either no principal or one of these ineffective gatekeepers. An ineffective gatekeeper is equivalent to no gatekeeper.

Subset 2. All $\beta \in B$ for which $x^1 = W(\beta)$. By the same type of analysis as for subset 1, the principals set $r_2 = 0$ and elect principal G^* as gatekeeper.

Subset 3. All $\beta \in B$ for which $x^{\text{mix}} = W(\beta)$. By the same type of analysis as for subset 1, the principals set $r_2 = \bar{x}_2^{\text{mix}}$ and elect principal G^* as gatekeeper.

Subset 4. All $\beta \in B$ for which $X^m = W(\beta)$. In nominating candidates as minimum requirement, principal m is indifferent between any $r_2 \in [0, \bar{x}_2^m]$, where $\bar{x}^m$ denotes the allocation on principal m's requirement curve for which the agent earns zero economic surplus. Hence, by subgame perfection, principal m can nominate any $r_2 \in [0, \bar{x}_2^m]$. By Lemma A1, any minimum requirement $r_2 \in [0, \bar{x}_2^m]$ that has been nominated is the outcome of a subgame-perfect equilibrium. In the gatekeeper election, Lemma A1 and the assumption $X^m = W(\beta)$ imply that the principals elect principal m.

Subset 5. All $\beta \in B$ for which $W(\beta)$ contains multiple allocations from $\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\}$. For example, suppose $\alpha^A < \alpha^m, \bar{u}/\beta_1^A \geq \bar{v}/\beta_1^{m-1}, \bar{u}/\beta_2^A < \bar{v}/\beta_2^m$, and $U^m(x^1) = U^m(\bar{x}^{\text{mix}})$. In this example, principal m is indifferent between x^1 and $\bar{x}^{\text{mix}}$, and $W(\beta) = \{x^1, \bar{x}^{\text{mix}}\}$. Then, by the same type of analyses as for the previous subsets, the principals set the minimum requirement and elect the gatekeeper who implements either x^1 or $\bar{x}^{\text{mix}}$. *Q.E.D.*

Proof of Theorem 1. By the proof of Theorem 2, subset 1, if $\alpha^A > \alpha^m$, then $\bar{x}^2$ is the outcome of any equilibrium. If $\alpha^A < \alpha^m$, the proof that $\bar{x}^1$ is the outcome of any equilibrium is analogous to the proof of Theorem 2, subset 1. *Q.E.D.*

Proof of Corollary 1. The proof follows directly from Theorem 2. *Q.E.D.*

Proof of Corollary 2. The proof follows directly from Theorems 1 and 2. *Q.E.D.*

Proof of Corollary 3. If either $\bar{u}/\tilde{\beta}_1^A \geq \bar{v}/\tilde{\beta}_1^j$, or $\bar{u}/\tilde{\beta}_2^A \geq \bar{v}/\tilde{\beta}_2^j$, or both, then for $\tilde{\beta}$, there exists $x \in \mathbb{R}_+^2$ that the agent is willing to produce and principal j is willing to accept. Hence, for $\tilde{\beta}$, principal j can serve as gatekeeper. With the movement from β to $\tilde{\beta}$, of the allocations in $\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m\}$, either $\bar{x}^2, \bar{x}^{\text{mix}}, x^1, X^m$, or none of these allocations changes. Recall from Theorem 2 that the equilibrium allocation is determined by U^m. Suppose $j \neq m$. If $j \neq m$, with the movement from β to $\tilde{\beta}$, only $\bar{x}^{\text{mix}}$ or x^1 possibly changes. If $\bar{x}^{\text{mix}}(\beta) \neq \bar{x}^{\text{mix}}(\tilde{\beta})$, then by the definition of $\bar{x}^{\text{mix}}$, we have that $U^m(\bar{x}^{\text{mix}}(\beta)) < U^m(\bar{x}^{\text{mix}}(\tilde{\beta}))$. By a revealed preference argument, $x^*(\tilde{\beta}) \in \{x^*(\beta), \bar{x}^{\text{mix}}(\tilde{\beta})\}$. Similarly, if $x^1(\beta) \neq x^1(\tilde{\beta})$, then $x^*(\tilde{\beta}) \in \{x^*(\beta), x^1(\tilde{\beta})\}$. If $\bar{x}^{\text{mix}}(\beta) = \bar{x}^{\text{mix}}(\tilde{\beta})$ and $x^1(\beta) = x^1(\tilde{\beta})$, then $x^*(\tilde{\beta}) = x^*(\beta)$. Suppose $j = m$. If $j = m$, with the movement from β to $\tilde{\beta}$, only X^m can possibly change. Also, with the movement from β to $\tilde{\beta}$, because $\beta_1^m/\beta_2^m = \tilde{\beta}_1^m/\tilde{\beta}_2^m$, principal m's ranking of the allocations in $\{\bar{x}^2, \bar{x}^{\text{mix}}, x^1, \}$ is unaffected. Hence, $x^*(\tilde{\beta}) \in \{x^*(\beta), \{X^m(\tilde{\beta})\}\}$.

If $\bar{u}/\tilde{\beta}_1^A < \bar{v}/\tilde{\beta}_1^j$ and $\bar{u}/\tilde{\beta}_2^A < \bar{v}/\tilde{\beta}_2^j$, then principal j cannot serve as gatekeeper because he would reject any x the agent is willing to produce. *Q.E.D.*

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RAND Journal of Economics Turnaround Times

Month Submitted	First Decision (%) 0–3 Months	4–6 Months	7–9 Months	10+ Months	No Decision (%)	Total (%)
Jan. 2000	50	35	15	—	—	100
Feb.	74	22	4	—	—	100
Mar.	37	52	4	7	—	100
Jan.-Mar. '00	53	37	8	2	—	100
April 2000	58	24	14	4	—	100
May	50	34	11	5	—	100
June	31	35	23	11	—	100
April-June '00	46	32	15	7	—	100
July 2000	50	24	26	—	—	100
Aug.	29	46	18	7	—	100
Sept.	39	42	3	16	—	100
July-Sept. '00	38	38	15	9	—	100
Oct. 2000	36	39	6	19	—	100
Nov.	48	26	4	22	—	100
Dec.	25	43	18	14	—	100
Oct.-Dec. '00	36	37	9	18	—	100
Jan. 2001	58	24	3	15	—	100
Feb.	50	19	8	23	—	100
Mar.	22	30	22	26	—	100
Jan.-Mar. '01	45	23	10	22	—	100
April 2001	48	30	11	11	—	100
May	45	37	7	11	—	100
June	28	33	10	29	—	100
April-June '01	37	33	10	20	—	100
July 2001	31	39	17	13	—	100
Aug.	48	33	—	15	4	100
Sept.	33	38	—	25	4	100
July-Sept. '01	37	37	6	17	3	100
Oct 2001	—	46	18	9	27	100
Nov.	7	40	20	6	27	100
Dec.	11	34	22	11	22	100
Oct.-Dec. '01	6	40	20	13	21	100
Jan. 2002	22	48	4	—	26	100
Feb.	19	46	4	—	31	100
Mar.	37	33	4	—	26	100
Jan.-Mar. '02	26	42	4	—	28	100

Note: Figures as of November 14, 2002.