SUBMITTING TO AUTHORITY:

AGREEING TO FOLLOW EX ANTE UNKNOWN ORDERS

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Abstract

Though contracts under which workers agree to follow ex ante unknown orders in return for constant hourly wages are very common, we do not have a satisfactory rationale for their use. We here show that such contracts can be asymptotically efficient. Players do not need to know the set of possible orders nor ever observe each other's payoffs; they just need to know the distributions of costs and values. This allows them to sustain a relational contract in the form of a quota mechanism even if costs have infinite support. The mechanism lets the players identify inefficient orders such that they can avoid implementing them. (*JEL* D01, D02, D86, J41, L14) (*Key Words:* Authority, Incomplete contracts, Employment, Quota mechanisms.)

I. INTRODUCTION

In a recent job posting MIT was looking for a salaried academic secretary to

- perform a variety of administrative tasks for MIT.nano,

- assist with conference and event planning and coordinating,

- provide complex administrative office support,

- coordinate conference rooms bookings,

- maintain and update portions of facility website content,

- act as the primary point of contact and customer success representative, and

- support existing users with administrative inquiries, registration, and onboarding activities.

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The job offered has a lot of richness combined with extreme simplicity. By taking it, you agree to follow orders without knowing what they will be and yet the hourly pay is the same no matter how onerous individual tasks are. Think about the second item: “Assist with conference and event planning and coordinating,” This can be something as simple as booking hotel rooms but may also be much, much more perhaps involving travel. Beyond not knowing what the tasks will be, you also will not know how highly the boss values specific tasks just as she will not know how burdensome you find them. There is no possibility of contracting based on tasks or their values and costs. An additional complication is that some of the tasks may be so costly that they really should not be done: If you have an injury that makes it painful to carry heavy things, if your child has a doctor’s appointment, if you feel unsecure about how to do something, etc.. In such cases you might ask the boss to be relieved and she may or may not grant that. In the vast majority of cases you will, however, simply follow whatever order you are given and receive the same hourly pay no matter what. One might wonder why anybody would take such a job, but we know that these contracts are extremely common.

The purpose of this paper is to explain why they are used. In the environment described above we show the existence and asymptotical efficiency of a perfect Bayesian equilibrium in which orders are given and most often followed in return for a fixed per-period wage. The efficiency result does not depend on players having any ex ante knowledge of the set of possible tasks, only that they know the probability distributions of their costs and values. The other critical assumption is that orders are issued frequently such that the inter-task discount rate is small. There is very little systematic evidence about the frequency with which orders are given, but the data we do have is quite compelling. In particular, Guest (1968) followed 56 foremen in an auto plant and found that they attended to a new issue every 48 seconds and spent an average of 26.4% of their time face to face with direct reports. This suggests that the average foreman gave a new order every three minutes and, if they had ten direct reports, that the average worker received a new order every half hour.

Model and main result

In each period one of infinitely many tasks can create value for the boss and she learns its identity at the start of that period. The other player, the worker, can perform the task though he incurs a cost in the process. Costs and values are private information of the worker and the boss respectively and ex post unobservable. To implement all efficient tasks and eliminate those for which cost exceeds value, the players use a quota mechanism. The mechanism divides time into blocks with equal numbers of periods/tasks and a per-block quota for each player. Specifically, the worker may, in each block, make a maximum number of unverifiable claims to the effect that the current task has high costs. If such a claim is made, the boss may accept it and withdraw the order but could also make an unverifiable counterclaim to the effect that the task has high value, implying that it should be performed in spite it's the high cost.[1] Counterclaims about a task can only be made after the worker has made a claim about that same task and the number made per block is also subject to a quota. Using their knowledge of the cost and value distributions, players can rely on the law of large numbers to assess the veracity of the claims by comparing the actual frequency of high cost (value) claims with theoretical frequencies over the number of tasks in the block.[2] Claims and counterclaims are restricted to "high" or "low" and values are either high or low, but costs are drawn from a distribution with infinite support.

The proof is complicated because the actual and theoretical frequencies differ, because discounting means that the players will be tempted to make false claims in the early part of a block, and because of the infinite number of possible costs. The first two complications vanish as blocks become longer and interest rates go to zero – hence our efficiency result is only asymptotic. The third complication is much harder to deal with since the meaning of high and low costs change over time as functions of worker strategies, the number of claims already made, and the number of periods/tasks remaining in the block. Specifically, if n periods remain in the block and the interest rate is zero, a worker who has k claims left will want to make one if the cost of the current task is larger than the expected value of the k'th highest out of n draws from the cost distribution. Compared to the case in which the worker claims high iff the cost is higher than the lower of the boss's two values, this adaptive strategy makes both players better off. It is not an equilibrium for the worker to use that strategy if interest rates are positive, but as they go to zero, it becomes an increasingly good approximation to the actual equilibrium strategy. The

[1] We will look at alternative communication protocols in Section III.

[2] The critical role played by the law of large numbers is consistent with the stylized fact that this type of contract is not used for individual tasks, for tasks that take a long time to complete, or when new tasks only are needed infrequently.

boss's equilibrium strategy approximates honest use of counterclaims as the block length goes to infinity.

So the prevalent practice of paying fixed wages at constant intervals can be asymptotically efficient and the behavior prescribed by the equilibrium behavior, in which the worker normally follows orders but occasionally asks to be relieved, mirrors casual observation as well.

Literature

The paper contributes to the literatures on authority, incomplete contracts, and quota mechanisms**.**

In spite of the widespread use of incomplete contracts with submission to authority and constant payments, we still do not have models that reflect the full complexity of order taking. The first paper on the topic is probably Simon (1951), who suggests that workers take orders in return for fixed payments when they are roughly indifferent between the tasks covered by the agreement. In the present paper, the costs can have a very large variance as long as their distribution is known. Another early contribution is Alchian and Demsetz (1972), who use an analogy to a customer buying products from a grocer. The latter situation differs from that considered here for two reasons: Each product has its own price and the set of products is finite and known ex ante. In the more recent literature several authors, e. g. Baker, Gibbons, and Murphy (2002), have like us looked at the employment relationship through the lens of relational contracting but make stronger informational assumptions, use bonuses, and often focus on moral hazard. The work closest to ours is Bolton and Dewatripont (2005, Ch. 12.5) who also allow payoffs to be ex post unobservable but assume that the boss has superior ex ante information about the worker's costs and is disciplined, by threat that the worker could quit, to pay ex post bonuses as compensation for costly tasks. All of these papers fail to explain use of constant payments. Similarly, constant payments have long been explained by risk sharing, for example by Baily (1974) and Marcus (1984), but these models do not explain submission to authority.

The study of incomplete contracts was pioneered by Grossman and Hart (1986) and Hart and Moore (1990), who assume that contracts necessarily are incomplete but allow ex post bargaining (renegotiation) such that pay can vary from task to task. Another stream, prominently associated with Williamson (1975, p. 66), assumes that agents are boundedly rational and that contracts necessarily are incomplete. He explains the prevalence of simple contracts by bounded rationality and the possibility that more complicated contracts could be exploited by opportunistic agents.[3] In contrast to this, the mechanism in the present paper does not rely on bounded rationality and is asymptotically optimal while still being very simple.

There is a small but recently growing theoretical literature on quota mechanisms. The first example was probably Radner's (1985) "review" strategies in a game in which two players sequentially and repeatedly report their private information (he looked at a Principal-Agent model in which the principal did statistical tests on the agent's output.) More recently Jackson and Sonnenschein (2007) and Ball, Jackson, and Kattwinkel (2022) derived some general efficiency results in games in which information arrives simultaneously, while Renault, Solan, and Vieille (2013), Escobar and Toikka (2013), Frankel (2016), and Ball and Kattwinkel (2025, Section 8.2) consider dynamic games such as ours. The case we consider is arguably closest to that of Escobar and Toikka except that our players move sequentially and one of them (the worker) has an infinite type space.[4] To the best of our knowledge this is the first paper on quota mechanisms in which one player has infinite type space. If only one of two players has an infinite type space, the mechanism works as if it was finite, since all that matters is the interval in which their type falls. However, the equilibrium messaging strategy of the player with an infinite type space is very different and quite interesting. As described in Lemmas 4 and 5 below, the decisions about when to send messages are solutions to a complicated dynamic optimization problem and have subtle implications for the efficiency of equilibrium play.

The basic model and the main results are presented in Section II, a few extensions are sketched in Section III, and a discussion concludes the paper in Section IV.

II. MODEL AND ANALYSIS

[3] Consistent with this theory, Levin and Tadelis (2010) argue that a contract on time is easier to administer than a contract on quality and use this to explain several empirical regularities.

[4] In our application it is clearly a realistic assumption that costs have infinite support and our treatment of that case constitutes a small theoretical contribution. The existence proof relies on the fact that the player with finite type space has a dominant strategy such that the opponent can be assumed to maximize against that. We are then able to characterize that maximum in enough detail to derive a limiting efficiency result as the discount rate goes to zero.

Time is discrete and infinite and nature randomly chooses one of an infinite number of tasks at the start of each period. The task can be performed during that period but not later. The boss (she) derives value from having tasks performed and the worker (he) can do it but incurs costs in the process. The value of task i is v_i where $v_i \epsilon \{v, V\}$ and its cost is c_i where c_i is drawn from the distribution F with support $[0,V]$. Using f to denote the density of F, we define $c \equiv \int_0^v xf(x)dx/F(v)$ and $C \equiv \int_v^V xf(x)dx/[1-F(v)]$, such that c is the mean cost if costs are below v, and C is the mean cost if costs are above v. The probability of $c_i > v$ is $1 - F(v) \equiv p$ and the probability of $v_i = v$ is q. Values and costs are independently drawn and trade is inefficient iff $c_i > v$ and $v_i = v$ such that the first best expected per-period surplus is $(v-c)(1-p)q + (V-C)p(1-q) + (V-c)(1-p)(1-q) \equiv \Gamma^*$. Value and cost realizations are, even ex post, known only to the boss and worker respectively, although F, v, V, and q are common knowledge. Within each block the players recall the histories of their own valuations as well as the claims and counterclaims made. There is transferable utility, the players are risk neutral and discount future payments at the same rate $r \geq 0$ per period.

We will describe a mechanism with order taking and constant payments that asymptotically implements the first best outcome. Other mechanisms can implement the first best as well but do not explain order taking and constant pay. In addition, they may have hidden costs. One possibility is that the parties engage in independent negotiations every period. It is reasonable to assume that they bargain efficiently but it is also reasonable to assume that the individual negotiations are not completely costless (because of the associated delays and other costs). These costs will be unimportant in many settings particularly if costs and values are high and periods are long. They will, however, cumulate to a non-trivial factor if individual trades are small and frequent as is often the case for trades in human asset services. In such circumstances, as when an executive needs a stream of different services from her secretary, it seems reasonable to conjecture that the surplus achievable with trade-by-trade negotiation is less than Γ^*. Alternatively, the traders could try to write a complete contingent long-term contract, but since the number of possible tasks is infinite (or very large), this cannot be done.

We will, however, show that they can agree to a relational contract that exhibits the main characteristics of the employment contracts such that (1) the boss gives an order every time a new task is needed, (2) the worker is paid an ex ante agreed-upon constant wage in every period, (3) in the limit, the worker obeys the order unless trade is inefficient, and (4) the contract is at will.

The idea is to use *quota strategies* as a point of reference. These strategies are defined on blocks of tasks (or equivalently, periods) as follows: A block consists of b periods. The worker can claim that cost is "high" up to pb times per block. If the worker makes a claim, the boss can respond with the counterclaim that value is "high" up to $(1 - q)\, pb$ times per block, and if either trader exceeds their quota the parties terminate their relationship and get their outside options which we have normalized to zero.

The traders first engage in an exogenous bargaining process and make a once-and-for-all agreement on a constant per-period price which is consistent with participation in the quota mechanism. They then play the following stage game each period:

1. The boss learns the identity and value of the next task.
2. She orders the worker to perform it and he learns its cost.
3. The worker may claim that the costs are high by announcing C.
4. If he does, the boss may make the counterclaim that the value is high by announcing V.
5. The worker may or may not perform the task. If he does not perform the task after announcing high costs and not getting a counterclaim, the game continues. Otherwise it ends.
6. The boss pays the agreed-upon per-period price. If he does not, the game ends.
7. If either player exceeds their quota in a block, the relationship ends, and the players get their outside options.
8. After b periods, a new block commences and the counting of claims and counterclaims restarts from zero.

We aim to show the following:

Proposition: *If $\Gamma(e)$ is the expected per-period surplus in the perfect Bayesian equilibrium e,*
$\forall \varepsilon > 0\ \exists b' > 0\ \forall b > b'\ \exists r' > 0\ \forall r < r'\ \exists e\colon \Gamma(e) + \varepsilon > \Gamma^*$

It is helpful to start with the non-equilibrium *simple quota strategies*:

(a) If possible, the worker claims high cost the first pb times $c_i > v$. If he, towards *the end of a block,* has k claims left when k tasks remain in the block, he ends by making k straight claims for a total of pb regardless of his actual costs in those periods. (So workers use up their quotas exactly; in some cases by making false claims and in others by not making true claims, both at the very end of a block.)

(b) If possible, the boss responds to a worker's claim by making the counterclaim that value is high whenever $v_i = V$. If she, towards *the end of a block*, has K counterclaims left when the worker has K claims left, she ends by making K straight counterclaims for a total of $(1-q)pb$ regardless of her values in those periods. (Bosses know that they will get pb chances to counterclaim and they will use up their quotas exactly; in some cases by making false counterclaims and in others by not making true counterclaims.)

(c) The worker follows the order unless he has claimed high cost and the boss has not made a counterclaim.

The proof works by first showing that the simple quota strategies asymptotically implement the first best as blocks get longer and discount rates get smaller (because the frequencies with which high cost and value occur converge to p and $1 - q$, respectively). We next characterize a pair of *equilibrium quota strategies* and show that their expected per-period surplus converges to that from the simple quota strategies, and thus the first best, as blocks get longer and discount rates get smaller.

Lemma 1: *If $\Gamma(e_p)$ is the expected per-period surplus when both players follow the simple quota strategies,* $\forall\, \varepsilon > 0\ \exists\, b' > 0\ \forall\, b > b'\ \exists\, r' > 0\ \forall\, r < r' : \Gamma(e_p) + \varepsilon > \Gamma^*$

Proof: If in each block there are exactly pb realizations where costs are greater than v and exactly $(1-q)pb$ of these where per-period values are V, then the expected surplus created by the above strategies are $(v-c)(1-p)q + (V-C)p(1-q) + (V-c)(1-p)(1-q) = \Gamma^*$ per-period. However, since the cost and value realizations are random, there will in many blocks be deviations from the mean and consequently some end-of-block payoff losses. As described in the previous paragraph, these come in four variants: (i) If the worker has to make false claims, some trades with expected gains $v - c$ will be missed, (ii) if the worker cannot make enough claims, some trades with expected gains $v - C$ will be made, (iii) if the boss has to make false claims, some trades with expected gains $v - C$ will be made, and (iv) if the boss cannot make enough claims, some trades with expected gains $V - C$ will be missed. As is obvious, only one of (i) and (ii) and only one of (iii) and (iv) can happen in any one block. Relative to the first best, the expected per-period loss from these inefficiencies depends on *F, v, V, q, r,* and *b.* In particular, since the standard error of a sum of *b* binomial variables is proportional to $b^{1/2}$, the expected error per-period is proportional to $b^{-1/2}$ and we can bring the expected undiscounted per-period loss below any ε simply by choosing a sufficiently large *b*.

QED

Remembering that the inefficiencies are caused by histories with surprisingly many or surprisingly few high cost or high value realizations, we now proceed to show that there exists a perfect Bayesian equilibrium in which expected per-period surplus converges to the first best as blocks get longer and discount rates get smaller.

Lemma 2: *In any equilibrium in which neither player quits, both players will exhaust their quotas in each block.*

Proof: The worker clearly prefers to make as many claims as allowed since each claim gives him a chance of getting paid in spite of incurring zero costs. He can avoid more onerous tasks by making a claim when costs are high but even when costs are low, it is better to claim than not. Similarly, the boss prefers to counterclaim high value (and get a task performed) if the value in fact is high, but even if the value is low, it is still more attractive to counterclaim than not.

QED

Lemma 3: *If the worker never quits and r is sufficiently low, the simple quota strategy is dominant for the boss*.

Proof: Given a value of *b,* this condition is satisfied if two things are true. First, *r* has to be so small that it will be a bad idea to spend a counterclaim on a *v* realization before the end-of-the-block. While doing so could give the boss a v (rather than a 0) earlier, it comes at the cost of a later V with probability $1 - q$. Second, if possible, she will not refrain from making a true counterclaim. The boss faces the strongest such temptation if the very first task is (high cost, V), the worker makes a claim, and she believes that he will react to her making a counterclaim by claiming high costs in each of the next $pb - 1$ straight tasks - the harshest punishment available to him. It is most attractive to stay quiet if she further believes that any further counterclaims will go unpunished. In that case, if she does make the counterclaim, she gets V but then faces $pb - 1$ tasks with an average of $q0 + (1 - q)V$ followed by $(1 - p)b$ realizations with average of $qv + (1 - q)V$. So r has to be sufficiently small to ensure that getting the early V is worth more than the expected cost of delaying the $(1 - p)qbv$. If r meets these two conditions, the simple quota strategy is dominant for the boss and the worker knows that she will play it.

QED

This means that the existence of equilibrium is not an issue: The worker can maximize against the simple quota strategy and since a maximization problem with bounded values needs to have a solution, such an equilibrium exists. Because costs are a continuous variable, the worker can do better than simply claim iff costs are above v. The reservation value above which he will claim depends on how many claims are left in his quota and the number of periods left in the block. Let us now characterize the worker's equilibrium strategy and its implications for the expected surplus.

Lemma 4: *Suppose that $r = 0$, that the worker just learned the cost of a new task, that $n < b$ tasks remain in the block, and that he has $k \leq pb$ claims left. As $b \to \infty$, the worker's reservation value for using one of those claims now goes to the expected cost of the k'th most costly task among the n yet to be revealed. If $r > 0$, the reservation value will be lower.*

Proof: If $r = 0$ and all claims had the same chance of being met by a counterclaim, the behavior suggested by the Lemma maximizes his expected payoffs. Unfortunately, the second premise is only approximately true. The problem is that the boss, at the end-of-the-block, may have run out of counterclaims or may have "too many" left such that she will counter every claim even if her value is v. The worker's strategy in these regions is described in the proof of Lemma 5 below, but the point here is that these possibilities, as $b \to \infty$, weigh less in the worker's calculations such that the postulated decision rule approximates equilibrium (optimal) behavior more closely.

If $r > 0$, the future costs should be discounted such that the current nominal reservation value should be lower.

QED

Before getting to Lemma 5, it helps to look at an example in which we use the standard result (from the theory of order statistics[5]) that the mean of the k'th highest element in a sample of size n from $U[0, 1]$ is $(n+1-k)/(n+1)$.

Example. Suppose that $r = 0$, $F = U[0, 1]$, and that $v = 2/3$ (such that $p = 1/3$). Suppose that the worker has one claim left $(k = 1)$. If one further task remains in the block $(n = 1)$, he will make a claim now if his costs are above $1/2$ - the expected cost of the single task still to be revealed. If two further tasks remain ($n = 2$), the expected maximum cost of the last two tasks and thus the reservation value is exactly v (= 2/3) and if three tasks remain it is $3/4$. At the start of the block $n = b - 1$, $k = pb$, and the reservation value is $(b - 1 + 1 - pb)/(b - 1 + 1) = 1 - p = v$, as it should be.

Lemma 5: *Compared to that resulting from the simple quota strategy, the equilibrium distribution of claim times differs in two ways: The worker's expected end-of-block payoff losses are smaller and if $r > 0$ claims are made earlier.*

Proof: The simple quota strategy requires that the worker, except for end-of-block effects, make claims iff his costs exceed v. However, as we saw in the example, he can do better by making claim decisions as functions of the number of remaining claims and tasks. Equilibrium reservation values change over time as the worker reacts to the evolving history of high-cost tasks. If he has made fewer (more) claims than expected, he lowers (raises) the expected reservation cost below (above) v and thereby increases (slows) the expected speed, leading to smaller expected end-of-block payoff losses. Additionally, if $r > 0$, the worker prefers to get his breaks earlier and equilibrium reservation values will be lower than if $r = 0$, causing claims to be made earlier.

QED

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[5] Se e.g. David and Nagaraja, 2004.

The reduction in expected end-of-block payoff losses helps the boss as well, while the shift to earlier claims hurts her. We are now ready to show:

Proposition: *If $\Gamma(e)$ is the expected per-period surplus in the perfect Bayesian equilibrium e,* $\forall\, \varepsilon > 0\ \exists\, b' > 0\ \forall\, b > b'\ \exists\, r' > 0\ \forall\, r < r'\ \exists\, e': \Gamma(e') + \varepsilon > \Gamma^*$

Proof: Comparing equilibrium payoffs to those when both play their simple quota strategies, the worker does better by definition. The comparison is more complicated for the boss: She will lose exactly $p(1-q)b$ tasks in both cases but the difference between the worker's strategy and the simple quota strategy means that her losses will differ in two ways: She will face smaller end-of-block losses and the worker will make claims earlier in the blocks. As $r \to 0$, the mutually beneficial reduction in end-of-block payoff losses remains, but the downward shift of the claim distribution vanishes and with it the negative effect on the boss. So her expected per-period equilibrium payoffs converge towards those when both parties use simple quota strategies. Recalling that the worker does better in equilibrium than if both use simple quota strategies, we see that their combined expected per-period surplus converges towards the first best as $r \to 0$.

QED

III. EXTENSIONS

The model is obviously very simple and we will now suggest several ways in which it can be generalized to fit more stylized facts.

Periods with no work

On some such occasions, the boss has no immediate needs, although she surely will have some in future periods. We assume that it would be costly for the traders to find alternative partners, such that it is efficient for them to continue the relationship through periods in which the boss has no needs. Specifically, suppose that the value of task i is v_i where $v_i \in \{0, v, V\}$. When the boss has no needs, which happens with probability z, values and costs are 0 and c_o, respectively. In all other cases, values and costs are determined as in the main model and the maximum achievable per-period surplus is $(1 - z)[(v - c)(1 - p)q + (V - C)p(1 - q) + (V - c)(1 - p)(1 - q)] - zc_o$. We can now proceed as in the main model.

The tasks differ in duration

Suppose that the duration of task *i,* call t_i, is common knowledge once *i* is identified. Assume further that t_i is drawn independently of v_i and c_i from a multinomial distribution with support *(0, T)*. The simplest way to treat this is to define separate quotas for tasks of different durations and then proceed as in the main model.

Correlation between duration and per-period cost

This can be treated in the same way as above except that the quotas now are defined on different cost distributions.[6]

Granting the worker more time

Consider a task *i* with per-period value and cost (v, C) and suppose that the boss can reduce the worker's per-period cost to c' by granting him $1 + \Delta$ periods instead of just one to complete the task. Specifically, we assume that the total value remains v, but that the cost goes to $(1 + \Delta)c'$. By analogy to the equilibrium looked at in the main model, the boss allows the worker to claim C a total of pb times per block, and the worker in turn allows the boss to counterclaim V a total of $p(1 - q)b$ times per block. If the boss does not claim V, she gives the worker an additional Δ periods to complete the task and he accepts that offer. This may well be more efficient than dropping the trade: When inefficient trades are dropped, the maximum per-period surplus is Γ^*. To find the same number when workers may be granted more time, imagine that we pick a random period. The probability that value and costs are either $(V - C)$, $(V - c)$, or $(v - c)$ is proportional to $1 - pq$ and the probability that the period is one in which the worker works on a task for which he has been granted more time is proportional to $pq(1 + \Delta)$. So the probabilities that our random period is of the former or latter kind are $[1 - pq]/[1+pq\Delta]$ and $pq(1 + \Delta)/[1+pq\Delta]$, respectively. Since the value created in the two cases are Γ^* and $[v/(1 + \Delta) - c']$, the maximum surplus when the boss can grant more time is $\{[1 - pq]\Gamma^* + pq(1+\Delta)[v/(1+\Delta) -$

[6] Suppose that the duration of a random task is T or t with probabilities s and $1 - s$, respectively and that the probability of $c_i = C$ is P in the former case and p in the latter. In that case a similar equilibrium exists except that the quotas depend on the commonly known duration such that the worker can claim sPb times in a block if the duration is T and $(1 - s)pb$ times if it is not. The boss can respond to these claims by announcing V a total of $qsPb$ and $q(1 - s)pb$ times, respectively. We can now fill in the details as in the main model.

$c']\}/[1+ pq\Delta]$ and this is greater than Γ^* iff $v/(1 + \Delta) - c' > \Gamma^*$. Intuitively, the left side is the per-period value if the worker is given extra time and the right side is the opportunity cost of that time. So small values of c', Δ, and Γ^*, as well as large values of v makes it more attractive to grant extra time.

The value distribution is multinomial.

The result continues to hold but the messages need to be richer and the blocks longer. For example, if values can be v_l , v_m, and v_h, the worker's messages need to specify whether costs are between v_l and v_m or higher than v_m and the buyer's messages need to differentiate between v_m and v_h. Suppose that the probabilities of v_l , v_m, and v_h are q_l, q_m, and $1 - q_l - q_m$, respectively, and that costs are above v_m with probability p_m, between v_l and v_m with probability p_l, and below v_l with probability $1 - p_m - p_l$. In this case the worker can claim that costs are above v_m a total of $p_m b$ times per block and that they are between v_l and v_m a total of $p_l b$ times per block. The boss can claim that value is v_h and v_m a total of $(p_m + p_l)(1 - q_m - q_l)b$ and $p_l q_m b$ times, respectively.

Since a smaller fraction of tasks on the average falls in each pair of realizations, per-cell convergence will be slower and a larger block size is needed.[7]

Different communication protocols

The mechanism also works under different communication protocols but they require more frequent communication under reasonable assumptions about p and q . Note first that the average number of messages per period under the assumed protocol are $p + p(1 - q)$. (a) If the worker goes first and makes a claim when costs are high, the same information can be extracted if the boss sends a message if value is low and the average number of messages per period are $p + pq$. (b) If the worker goes first and sends a message when costs are low, the boss can follow by messaging if value is high or if it is low. The average number of messages in these two cases are $1 - p + p(1 - q)$ and $1 - p + pq$, respectively. (c) If the boss goes first and makes a claim if value is high, the worker can follow by messaging if costs are low or if they are high. The average number of messages under these two protocols are $1 - q + q(1 - p)$ and $1 - q + qp$, respectively.

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[7] The worker's messages still need to specify intervals if the value function has continuous support, but the length of those intervals introduces a loss of surplus in addition to that caused by randomness.

(d) Finally, If the boss goes first and sends a message when value is low, the worker can follow by messaging if costs are low or if they are high. The average number of messages under these protocols are $q + q(1 - p)$ and $q + qp$, respectively. If we make the reasonable assumption that $p < 1 - q < q$ (high costs are less common than high value and that the latter is less common than low value), the protocol analyzed in the paper is most economical in terms of communication.

IV. DISCUSSION

The mechanism shares many properties with typical employment contracts:

-The per-period wage is agreed upon before any work is done and the agreement includes a job description that helps the worker estimate the difficulty of the job as a whole, here captured by F.

-New orders are given very frequently.

-The orders are generally obeyed without new negotiations.

-Some individual tasks may not be worth the wage, but the average completed task is.

-Too much complaining, too many hard tasks, or refusal to follow an order will lead one of the parties to terminate the contract.

-The contract is open ended.

The environment depicted in the model is similar to those in which employment contracts are used. In particular, new tasks are needed very frequently, are drawn from an extremely large set, and vary in difficulty and duration.

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