Birds of a Feather: Teams as a Screening Mechanism*

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Abstract

This paper studies the informational content of elective teams in a dynamic agency framework with adverse selection. Two agents with different employment histories are paid their conditional expected marginal product. They observe their types (good or bad), and choose between working together or separately. We characterize the distributions on agents' types, nature and wages such that teams are formed exclusively by good-type agents, with and without side payments. As employment records matter when idiosyncratic contributions are difficult to isolate, a good-type agent prefers not to jeopardize his reputation by teaming up with a bad-type agent.

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1 Introduction

Despite many advantages, a major drawback of team production is the difficulty to isolate idiosyncratic contributions. This leads to at least two sources of inefficiencies. First, from a moral hazard perspective, individual effort level may be sub-optimal if the principal observes only joint output. Solutions to this problem include organizing production through the firm as an efficient monitoring institution [1], not distributing all *ex-post* output among team members [2], and randomization of arbitrary punishment for insufficient output levels [8]. Second, from an adverse selection standpoint, informational rents can arise when teammates' abilities are known by the agents, but not by the principal. Mechanisms designed to extract this rent include alternative payment schemes [4], monitoring [13] as well as partner sharing rules [5].

We focus on this second source of inefficiency from a peer grouping perspective. In particular, if group tasks are elective rather than imposed, and if agents have insider information about each other's types, we ask whether observing a team (or, by the same reasoning, *not* observing a team) can yield information to the principal on the team members' types (good or bad), beyond the information conveyed by the joint output.

Our answer to this question is that teams can be an efficient screening mechanism under three assumptions: first, wages are proportional to the expected probability of being of a good type conditional on all past employment records, i.e. wages reflect the agent's *reputation*; second, two agents with different work histories share information on each other's type; and finally, these two agents express a preference between working together or separately. In both single and team assignments, production is obtained as a function of the agent(s)' type(s) plus a random shock by nature, while only final output is observed by the principal. In this setting, observing a team rather than two separate outputs can reveal that at least one, and sometimes both agents must be of a good type. More interesting still, this result holds even in the presence of side payments, where a potential partner who gains from being in a team may compensate a reluctant teammate.

This separating property of elective teams arises because expected-utility maximizing agents care about their reputation, the reason being that it is persistent and that it is used by the principal to determine their lifetime wages. As a member of a team, if the joint output level is low, an agent risks being confused by the principal for someone else, i.e. he may inherit part of his partner's reputation. When his potential partner's reputation is sufficiently bad, the agent will join a team only if the partner resembles him. This 'birds-of-a-feather' effect runs to the detriment of bad type agents: if a team has been selected and one of the members' reputation is sufficiently bad, then it must be that both members are good-type agents. Put differently, the confusion about individual contributions actually helps separating good-type from bad-type agents.

Our first assumption that firms pay conditional probability of being a good type should be uncontroversial. In our setting, an agent's type is either zero or one and equals his marginal contribution, such that this remuneration scheme amounts to paying conditional expected marginal product. A corresponding optimization schedule would be for the principal to minimize a quadratic in informational rents. Admittedly, more complex payment schemes may also solve the particular agency problem that we consider in this paper;[1] the central issue that we address is whether the simpler conditional wage structure paired with elective team formation can produce a similar outcome.

The second hypothesis of 'local' information can be related to the vast literature on referrals. It has long been recognized that a significant proportion of firms prefer to use referrals made by their

[1] Such as paying an arbitrary large bonus in the event of an output only two good agents could have produced.

own employees on job candidates rather than using formal hiring channels [9, 10, 6]. Moreover, search models help explain why referred employees have higher entry wages, lower turnovers, and a flatter wage profile as indicating less uncertainty at the time of hiring [11]. These facts suggest that the referring employee has valuable information on the candidate's true abilities and is willing to make it available to the firm. To the extent that our elective teams involve members with different histories, it may be thought of as referral with commitment.[2]

The final assumption is that workers are free to choose under which type of assignment, team or single, they wish to be employed. This situation could be related to one in which group tasks have no clear advantage over individual organization as far as the firm is concerned [5]. One example is academic research, for which it may be argued that the benefits of team work (e.g. exposure to alternative approaches) may or may not be offset by its costs (e.g. coordination issues), with the result that elective rather than exogenous team formation is more likely the norm. Moreover, endogenous team formation has been used in situations where incentives to help partners are present [3]. Finally, workers are often asked to express their preferences over tasks in determining labor assignments: job applications and requests for re-assignments typically ask applicants to state for which job they wish to be considered. If job openings include both group and individual tasks, the applicant's ranking could be considered as representing a preference ordering over these assignments.

The rest of the paper is organized as follows. Section 2 presents the dynamic game, in which two agents of different ages and histories select team or individual contracts, and Section 3 outlines the players' equilibrium strategies. This is followed by a discussion of the steady-state results in

[2]Our setting is also relevant for analyzing employment in traditional societies. Here, the future of family members is a concern of the elders who intervene on the labor market on their behalf [7], the specific identity of employers and employees matters [14], and information is near perfect within a family [12]. All these characteristics fit our model and our conclusions provide some justification as why employers in traditional societies deal with the same families over generations.

Section 4. Finally, a conclusion reviews the main findings and suggests potential elements for future research. Most tables and figures, as well as a discussion of the numerical approaches, are in the appendix.

2 Model

We consider a three-period overlapping generations model where an agent is junior in the first period, sophomore in the second, and senior in the last period. Let the $(n \times 3)$ matrix $F_t \equiv [F_t^1\ F_t^2\ F_t^3]$ denote all agents employed by the infinitely-lived principal, where F_t^i is the i^{th} $(n \times 1)$ column vector of agents of age $i = 1, 2, 3$, in period t. Moving from period t to period $t+1$ yields as a new cohort F_{t+1}^1 of juniors, $F_{t+1}^2 = F_t^1$, and $F_{t+1}^3 = F_t^2$. We define a *family* $f_t \equiv [f_t^1\ f_t^2\ \ f_t^3]$, composed of a junior f_t^1, a sophomore f_t^2, and a senior f_t^3, as a row in F_t.

Denote by $\eta_{f\,t}^i$ the type of an agent of age i in family f_t. We assume that $\eta_{f\,t}^1$ is drawn from a Bernoulli distribution, with support $I \equiv \{0, 1\}$ and $\Pr(\eta_{f\,t}^1 = 1) = \phi$. Furthermore, types are time-invariant, i.e. $\eta_{f\,t}^1 = \eta_{f\,t+1}^2 = \eta_{f\,t+2}^3$ for all $f_t \in F_t$ and t. Observe that types are purely independent random events; in particular, an agent's type does not depend on the other family members'.

Up to a linear transformation, output of the unique non-storable consumption good can be obtained under one of two assignments, single $(\mathcal{S})$:

$$y(\eta_{f\,t}^i, \epsilon_t) = \eta_{f\,t}^i + \epsilon_t \tag{1}$$

for $i \in \{1, 2, 3\}$, or team $(\mathcal{T})$:

$$x(\eta_{f\,t}^1, \eta_{f\,t}^2, \epsilon_t) = \eta_{f\,t}^1 + \eta_{f\,t}^2 + \epsilon_t, \tag{2}$$

where ϵ_t is a shock from nature drawn from a Bernoulli distribution with support I and $\Pr(\epsilon_t = 1) = \mu$. We assume that only juniors and sophomores may be hired under $\mathcal{T}$ or $\mathcal{S}$, while seniors are restricted to $\mathcal{S}$. The production technologies (1) and (2) are as in [5].[3]

The informational structure is asymmetric. In particular, let Ω_t denote the information set of the principal in period t, such that

$$\Omega_t \equiv \{\{z_{f\,j}\}_{j=0}^{t}\}_{f \in F_t} \tag{3}$$

where $z_{f\,j}$ is the set of outputs by members of family f in period j:

$$z_{f\,j} = \begin{cases} \left\{ y(\eta^1_{f\,j}, \epsilon_j), y(\eta^2_{f\,j}, \epsilon_j), y(\eta^3_{f\,j}, \epsilon_j) \right\}, & \text{if } \mathcal{S} \text{ at time } j; \\ \left\{ x(\eta^1_{f\,j}, \eta^2_{f\,j}, \epsilon_j), y(\eta^3_{f\,j}, \epsilon_j) \right\}, & \text{if } \mathcal{T} \text{ at time } j. \end{cases}$$

Let $\omega^i_{f\,t}$ denote the information set of f^i_t, and $\omega_{f\,t} \equiv \omega^1_{f\,t} \cap \omega^2_{f\,t} \cap \omega^3_{f\,t}$ denote the information set shared by the three members of family f_t. Then,

$$\begin{gathered} \omega_{f\,t} = \{z_{f\,j}, \eta^1_{f\,j}\}_{j=0}^{t}, \\ \omega_{f\,t} \cap \omega_{g\,t} = \emptyset, \end{gathered} \tag{4}$$

for $f_t, g_t \in F_t$ and $f_t \neq g_t$. We assume the principal observes only outputs and the kind of contracts, but neither agents' types nor nature. Furthermore, he observes only joint output under the team contract. In comparison, agents in the same family observe all past and current juniors' types. By time invariance, the types of the junior, sophomore and senior are known by members of a given family. Finally, information is local in the sense that it is not observed by members of other families.

[3]Note that a linear transformation may be applied to (1) and (2) such that they both yield identical unconditional expected profits.

Agent f^i's wages in period t are denoted $W(t, f^i)$, and are given by the conditional probability that f^i is a type-1 worker:

$$\begin{aligned} W(t, f^i) &= \Pr(\eta^i_{f\,t} = 1 \mid \Omega_{t-1}) \\ &\equiv p^i_{f\,t}. \end{aligned} \tag{5}$$

for $i = 1, 2, 3$. Because types are binary, the payment scheme implies that the principal pays expected marginal product, conditional on the family's entire employment history. As in [5], the value of the information on types to the principal is left implicit (e.g. for subsequent promotion decisions). Observe that a junior has no personal employment records and is paid the unconditional probability of being of type 1 since types are genetically independent. We also consider below a modification of the payment scheme (5), where a junior hired under $\mathcal{T}$ receives the same wage as his sophomore teammate. This modified assumption captures payment schemes where firms pay the same wage to all teammates and where the wage is calculated from the incumbent's performance.

Definition 1 (ITP) *Under an incumbent team payments scheme, a junior's wage is:*

$$W(t, f^1) = \begin{cases} \phi, & \text{if } \mathcal{S} \text{ in } t; \\ p^2_{f\,t}, & \text{if } \mathcal{T} \text{ in } t. \end{cases} \tag{6}$$

Sophomore, and senior agents' wages remain as in (5).

All agents are risk-neutral. Juniors and sophomores choose $\mathcal{S}$ and/or $\mathcal{T}$ to maximize their discounted expected utility, with subjective discount factor $\beta \in (0, 1]$, conditional on the family information set (4). A team forms only if both junior and sophomore select $\mathcal{T}$; otherwise, single contracts are chosen. Moreover, we allow for bargaining to take place between potential teammates. Compensation to a reluctant family member implies that teams arise as a Pareto-dominating equilibrium.

To close the model, we assume the following sequence of events. At the beginning of period t, the principal computes $(p^1_{f\,t}, p^2_{f\,t}, p^3_{f\,t})$ using last period's output and makes the corresponding wage offers. Juniors and sophomores then choose between $\mathcal{S}$ or $\mathcal{T}$, possibly after bargaining takes place. Uncertainty is resolved: nature ϵ_t is drawn from the probability density function μ, and output is observed by the principal. At the end of the period, a new cohort F^1_{t+1}, with types drawn from the probability density function ϕ, is hired and aging takes place.

3 Decision rules

By Bayesian updating, the principal summarizes the entire history of a family by the last set of conditional wages, and the new information contained in their most recent output.[4] From the technological assumptions, output provides only partial information on agents' types when $y(\eta^i_t, \epsilon_t) = 1$, or when $x(\eta^1_t, \eta^2_t, \epsilon_t) = 1$ or 2. Tables 3 and 4 in the Appendix report the Bayesian updates on sophomore and senior wages in period $t+1$, conditional on output in period t, and current sophomore conditional probability p^2_t.[5]

In each period, an agent $i \in \{1, 2\}$ chooses either $\mathcal{S}$ or $\mathcal{T}$. His decision is based on the following relevant information: the employer's estimate of the sophomore's type, p^2_t, and the types η^1_t and η^2_t in his family. Define an agent's decision space as $A \equiv \{\mathcal{S}, \mathcal{T}\}$ and the relevant state space as $S \equiv [0, 1] \times I^2$, such that an agent of age i uses policy $\delta^i : S \longrightarrow A$, for $i = 1, 2$. Denote the space of all policies by Δ. A *stationary* strategy for player i, also denoted δ^i, consists in using the policy δ^i

[4]Henceforth, we focus on a single family, and drop the subscript f, such that an agent is solely identified by his age i in the current period.

[5]Only the output (team or single) is used as conditioning information. Incorporating the agents' equilibrium decisions within the principal's payment scheme would be a natural extension to the linear rule that we adopt. However, this approach proves particularly challenging when side payments between agents in an OLG setting are allowed. We therefore leave nonlinear wage decisions on the research agenda.

in all periods. Define a pair of strategies as $\delta = (\delta^1, \delta^2)$. We wish to compute an equilibrium pair of strategies δ^*, in the sense of Nash (to be defined below). Let $v^i_\delta(s)$ denote agent's i expected future utility function under the probability distribution over future states induced by the strategy pair δ and the starting state $s \in S$. Moreover, $f^i_\delta(s) \equiv \max_\gamma v^i_{(\delta^{-i},\gamma)}(s) \quad \text{for} \quad i = 1,2$ where (δ^{-i}, γ) is the strategy vector obtained by replacing the ith component of δ by $\gamma \in \Delta$.

Definition 2 (equilibrium) *An equilibrium δ^* is a vector of strategies $(\delta^{1*}, \delta^{2*})$ such that $f^i_{\delta^*}(s) = v^i_{\delta^*}(s)$ for $i = 1, 2$.*

Suppose that an equilibrium strategy δ^* exists. By analogy with static games, we define a value multi-function $w : S \longrightarrow \Re^2_+$ such that $w(s) = (w^1(s), w^2(s))$ and $w^i(s) \equiv f^i_{\delta^*}(s) = v^i_{\delta^*}(s)$, for $i = 1, 2$. The pair of values $w(s)$ represents the value of the dynamic game for each player when the starting state is s. Generally, the functions v^i_δ and f^i_δ are defined recursively and do not admit closed forms. We therefore resort to numerical methods and briefly describe the method used to compute equilibrium strategies.

For all s, Table 1 defines a static bi-matrix game where the junior and the sophomore decide to team up or work singly. Each agent's payoff $r^i_{\delta^i}$, for $i = 1, 2$ and $\delta^i \in A$, is the sum of his instantaneous wage and future expected utility computed from any arbitrary multi-function which maps $S \longrightarrow \Re^2_+$. Notice that the payoff pair $(r^1_{\mathcal{T}}, r^2_{\mathcal{T}})$ is only attained when both players choose action $\mathcal{T}$. In all other cases, the payoff is $(r^1_{\mathcal{S}}, r^2_{\mathcal{S}})$. Let H be the operator which returns the Nash equilibrium pair of payoff of this static bi-matrix game, as a function of s. Finally, use the updating rule $w^{(k+1)}(s) = (Hw^{(k)})(s)$ to iterate on the value multi-function until it converges. The Appendix provides a complete description of the algorithm.

Table 1: Bi-matrix Game

	Player 1	
Player 2	$\mathcal{S}$	$\mathcal{T}$
$\mathcal{S}$	$(r^1_{\mathcal{S}}, r^2_{\mathcal{S}})$	$(r^1_{\mathcal{S}}, r^2_{\mathcal{S}})$
$\mathcal{T}$	$(r^1_{\mathcal{S}}, r^2_{\mathcal{S}})$	$(r^1_{\mathcal{T}}, r^2_{\mathcal{T}})$

Note: r^i_j, $i \in \{1,2\}$, $j \in \{\mathcal{S}, \mathcal{T}\}$, is agents i's payoff if he chooses strategy j.

4 Equilibrium Strategies

4.1 No side payments

Tables 3 and 4 allow us to express our first result.

Lemma 1 *Under payment scheme (5), the functions $v^1_\delta(p,\cdot,\cdot)$ and $f^1_\delta(p,\cdot,\cdot)$ are non-increasing in p, while the functions $v^2_\delta(p,\cdot,\cdot)$ and $f^2_\delta(p,\cdot,\cdot)$ are non-decreasing in p.*

Proof.

Denote by a and b two distinct employer's current estimates of the sophomore's type (i.e the first component of the state variable), with $a < b$ and P_a and P_b the corresponding random variable denoting the value of this first component after one transition. It is easy to see, using Table 3, that P_a is stochastically larger than P_b under both contracts. [6] Since the sophomore's wage is a non-decreasing function of the state variable component p^2, by induction, this implies that $v^2_\delta(p,\cdot,\cdot)$ and $f^2_\delta(p,\cdot,\cdot)$ are non-decreasing in p and that $v^1_\delta(p,\cdot,\cdot)$ and $f^1_\delta(p,\cdot,\cdot)$ are non-increasing in p for all $\delta \in \Delta$. ∎

[6] Observe that $P_a \geq P_b$ if $Pr(P_a \geq c) \geq Pr(P_b \geq c) \forall c \in \Re$. This is equivalent to $E(f(P_a)) \geq E(f(P_b))$ for any non-decreasing function f.

Let $g_{\delta^1} : [0,1] \times I \longrightarrow [0,1]$ denote the sophomore's wage if he chose action δ^1 when he was junior, and $h_{\delta^2} : [0,1] \times I \longrightarrow [0,1]$ denote the senior's wage if he chose action δ^2 when he was sophomore. For all p, ϕ, μ, we have (from Tables 3 and 4):

$$\begin{aligned} 0 \le g_{\mathcal{T}}(p,1) \le \quad & g_{\mathcal{S}}(p,1) \le g_{\mathcal{T}}(p,2) \le 1 \\ 0 \le h_{\mathcal{T}}(p,1) \le \quad & h_{\mathcal{S}}(p,1) \le h_{\mathcal{T}}(p,2) \le 1 \end{aligned} \tag{7}$$

For any function $v : S \to \Re$, define $\Phi v : [0,1] \times I \longrightarrow \Re$ as follows:

$$\Phi v(p,\eta) = \phi v(p,1,\eta) + (1-\phi) v(p,0,\eta). \tag{8}$$

Notice that, if v is non-decreasing (resp. non-increasing) in p, then Φv is also non-decreasing (resp. non-increasing) in p.

Proposition 1 (Separation) *Under payment scheme (5), in the absence of side payments between agents, elective teams are separating: a team is observed if and only if two agents are of type 1.*

Proof.

For any strategy $\delta \in \Delta, f_\delta^i, i = 1,2$ satisfy:

$$\begin{aligned} f_\delta^1(p,\eta^1,\eta^2) = \quad & \phi + \beta \max\{E[\Phi f_\delta^2(g_{\mathcal{S}}(p,\eta^1+\epsilon),\eta^1)], E[\Phi f_\delta^2(g_{\mathcal{T}}(p,\eta^1\eta^2+\epsilon),\eta^1)]\} \\ f_\delta^2(p,\eta^1,\eta^2) = \quad & p + \beta \max\{E[h_{\mathcal{S}}(p,\eta^2+\epsilon)], E[h_{\mathcal{T}}(p,\eta^1\eta^2+\epsilon))]\} \end{aligned} \tag{9}$$

Using equations (7), it is easy to verify, since $f_\delta^2(p,\cdot,\cdot)$ is non-decreasing in p that the optimal actions for any p are as given in Table 2.

∎

Table 2: Optimal actions (junior, sophomore) as functions of η^1 and η^2

		η^1 0	1
η^2	0	$(\mathcal{S}, S)$	$(\mathcal{S}, T)$
	1	$(\mathcal{T}, S)$	$(\mathcal{T}, T)$

Hence, in the absence of side payments, no mixed teams arise for all non-degenerate unconditional distributions. Note that separation is partial: not observing a team reveals only that at least one family member is type 0, without identifying which ones(s). The next step is to investigate how *ITP* and bargaining affect the separating equilibrium.

Under *ITP*, a junior suffers an initial loss in teaming-up with a bad-reputation sophomore ($p_t^2 < \phi$), whereas the latter receives the same current wage independent of his decision. In the absence of side payments, a large second-period gain is needed to induce the junior to accept a team, while equation (7) shows that a sophomore always gains in the next period from teaming-up with a good-type junior. Table 5 reports, for various combinations of ϕ and μ, and for $\beta = 0.5$, the minimum value of p^2 for which the $\delta^* = (\mathcal{T}, \mathcal{T})$ and teammates are exclusively of the good type. Otherwise, for all $p^2 < p^2_{min}$, $\mathcal{S}$ is optimal. Hence, the $\mathcal{T}$ contract is separating, i.e. teams are observed if and only if the junior and the sophomore are type 1. For example, the number 45 reported for $\phi = \mu = 0.5$ means that $\delta^*(p^2, 1, 1) = (\mathcal{T}, \mathcal{T})$ for $0.45 \leq p^2 < 1$, and $(\mathcal{S}, \mathcal{S})$ is an equilibrium otherwise. Similarly, a value of 1 indicates $\delta^*(p^2, 1, 1) = (\mathcal{T}, \mathcal{T})$ for $0 < p^2 < 1$, while $\mathcal{S}$ is the optimal strategy otherwise.

Table 5 suggests that the degree of discrimination against sophomores is increasing in ϕ since the junior must incur a larger initial loss under *ITP*. In addition, the discrimination is convex in

μ, the probability that $\epsilon_t = 1$. The reason is that polar distributions on ϵ_t reduce next-period's gain for the junior. Conversely, output is least informative when $\phi \simeq \mu$. In this case the gain in the next period increases and a good-type junior is willing to accept a team offer from a good-type sophomore with a bad reputation. Indeed, for ϕ low enough, the initial loss for the junior is so low that separating teams are observed regardless of the sophomore's reputation.

4.2 Side payments

Next, we allow for side payments and calculate the separating ranges as a function of ϕ and μ. Table 6 is equivalent to Table 5 with bargaining taking place between family members. The results must be read as follows. For all combinations of ϕ and μ, two numbers are reported: the top number is $p^2_{\min}$, while the bottom one is $p^2_{\max}$. Teams are composed *exclusively* of good-type agents for $p^2_{\min} \leq p^2 \leq p^2_{\max}$. We also report in Table 7 the 'semi-separating' ranges, that is where teams are made up of good-type sophomores while the junior member is of any type.

With side payments a losing teammate is compensated for any reputation loss. Hence, when the sophomore's reputation (p^2) is sufficiently high, teams start losing their separating properties, that is if $p^2 > p^2_{\max}$, mixed teams arise as optimal strategies. For low values of p^2, mixed teams involve a bad-type junior and a good-type sophomore, followed by all but two bad-type agents, and finally $\mathcal{T}$ is chosen all agents regardless of their types when p^2 approaches 1.

Comparing the results reported in Tables 5 and 6, we first observe that whenever comparable separating teams exist, $p^2_{\min}$ is always lower in the presence of side payments. When we allow for compensation, a junior is less discriminating against a type-1 sophomore with a bad reputation. Moreover, with side payment, the separating range is followed by a semi-separating range. The reason is intuitive: sophomores have only one remaining employment period and are willing to suffer a reputation loss provided they are sufficiently compensated. Conversely, type-1 juniors reject team offers from type-0 sophomores, since their reputation determine their wages for two remaining employment periods. If they were to team up with a bad-type sophomore the loss cannot be sufficiently compensated. As a result, no type-0 sophomore finds a teammate, unless his reputation is excellent (p^2 approaching 1). Secondly, as in Table 5, the same argument holds when ϕ approaches μ.

To summarize, our results indicate that side payments reduce separating ranges obtained without bargaining. On the one hand, with side payments, $p^2_{\min}$ falls, pointing towards less discrimination by good-type juniors against good-type sophomores with bad reputations, and on the other hand, $p^2_{\max}$ falls as well, indicating less discrimination against bad-type agents. We also find that sophomores suffer the most from discrimination since juniors at entry levels stand to lose more from a loss of reputation than a sophomore with only one remaining employment period. Nevertheless, despite the high degree of discounting, nonempty separating and semi-separating ranges are still obtained for most unconditional distributions.

4.3 Steady-state distributions

The previous section computed the steady-state equilibrium strategy for elective team formation as a function of all p^2, η^1 and η^2. In practice, because of the relatively short time range considered, it is possible that p^2 always lie outside the separating ranges. Hence two issues need to be considered: (i) what are the characteristics of the *ex-post* sophomore probability distribution and (ii) what is the *ex-post* distribution on errors on types made by the principal? To answer these questions, we compute the steady-state *ex-post* distribution of p^2 using the method described in Appendix D for $\beta = 0.5$, $\phi = 0.4$ and $\mu = 0.6$, and graph that distribution in Figure 1. For these parameter values, teams are fully separating if $0.27 \leq p^2 \leq 0.35$ (Table 6), and teams are semi-separating if $0.27 \leq p^2 \leq 0.45$ (Table 7). The steady-state distribution of p^2 reported in Figure 1 shows that for these parameter values p^2 falls in the fully separating segment 13% of the time, and in the semi-separating range 2% of the time, indicating that more than half of the contracts ($0 \leq p^2 \leq 0.45$) reveal information on at least one member of the family.

We next computed the large-sample distribution for the differences between the sophomore's actual type and his conditional probability, $(\eta^2 - p^2)$, i.e. the pricing error made by the principal. Recall that paying a wage equal to the conditional expected type is optimal if the employer minimizes a quadratic function in informational rent. Therefore, to compare the performance of our model, we computed the second to fourth moments of the asymptotic distribution on errors for three alternative strategies: (i) single contracts are imposed ($\mathcal{S}$), (ii) teams are elective ($\mathcal{E}$) and (iii) teams are imposed ($\mathcal{T}$).[7] The results reported in Table 9 indicate that regardless of the informational content of teams, using elective contracts rather than compulsory single or team contracts is sensible if the objective of the employer is to minimize a quadratic function of informational rent. From the self-selection inherent in elective teams, allowing workers to choose between the single or team contracts yielded lower estimates for the squared errors on types than compulsory single or team contracts. Moreover, while the elective contract produced a slightly more right-skewed distribution than the compulsory team contract, it is less subject to making large errors than both compulsory alternatives, as can be seen from the lower kurtosis estimates.

[7] Specifically, we used an experiment consisting of 20,000 replications in which types and shocks by nature were drawn, and optimal employment strategies selected according to the equilibrium rules obtained from the previous discussion.

5 Conclusion

This paper focuses on the informational content of elective teams. We show that when a worker's reputation is at stake, and when, unlike his employer, he observes his co-worker's type, elective teams can support a (partially) separating equilibrium. In the absence of side payments, a team involves exclusively two good-type agents; no agent wishes to jeopardize his reputation which is used to determine current and future wages. With side payments, teams are either fully or semi separating. Our model suggests a rationale for the conjecture that good agents regroup while bad agents are ostracized: the good agent fears being mistaken for the bad one in the event of an adverse outcome.

The equilibrium assignments that we find are consistent with several stylized facts identified with referrals, in particular, the observation that referees tend to refer agents with similar characteristics, that referred workers tend to earn higher entry wages and have a flatter wage profile, and more generally that firms value subjective information concerning applicants supplied by workers. To the extent that our elective team structure can be seen as a referral with commitment, our results are encouraging.

A number of simplifying assumptions could be revised for further development. The absence of uncertainty on types in a team might be replaced by a noisy observation – albeit one with smaller variance than the principal – or a sequential learning process. Moreover, we implicitly assumed that the information on types was valuable to the principal without explicitly introducing this valuation into the model. Finally, it would be of interest to account for moral hazard issues in the context of elective teams.

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A Transition Probabilities

Table 3: Period $t+1$'s sophomore wages (p^2_{t+1})

output in t	$\mathcal{S}$ in t	$\mathcal{T}$ in t
0	0	0
1	$\frac{\phi(1-\mu)}{\phi(1-\mu)+(1-\phi)\mu}$	$\frac{(1-p^2_t)\phi(1-\mu)}{p^2_t(1-\phi)(1-\mu)+(1-p^2_t)\phi(1-\mu)+(1-p^2_t)(1-\phi)\mu}$
2	1	$\frac{(1-p^2_t)\phi\mu+p^2_t\phi(1-\mu)}{(1-p^2_t)\phi\mu+p^2_t(1-\phi)\mu+p^2_t\phi(1-\mu)}$
3	—	1

Table 4: Period $t+1$'s senior wages (p^3_{t+1})

output in t	$\mathcal{S}$ in t	$\mathcal{T}$ in t
0	0	0
1	$\frac{p^2_t(1-\mu)}{p^2_t(1-\mu)+(1-p^2_t)\mu}$	$\frac{p^2_t(1-\phi)(1-\mu)}{p^2_t(1-\phi)(1-\mu)+(1-p^2_t)\phi(1-\mu)+(1-p^2_t)(1-\phi)\mu}$
2	1	$\frac{p^2_t(1-\phi)\mu+p^2_t\phi(1-\mu)}{(1-p^2_t)\phi\mu+p^2_t(1-\phi)\mu+p^2_t\phi(1-\mu)}$
3	—	1

Note: $\mathcal{S}$ denotes the single contract, $\mathcal{T}$ is the team contract, $\phi = \Pr(\eta^1 = 1)$, $\mu = \Pr(\epsilon = 1)$ and t is the time index.

B Method used to compute optimal strategies

This section describes the equilibrium algorithm which computes agents' steady-state optimal strategies as discussed in Section 3. The intuition behind the procedure is as follows. We discretize the state space and initialize the value function to some arbitrary value, which we then use to compute agents' expected payoffs under either the team and the single contract. Each agent subsequently chooses the strategy which yields either the highest expected utility (no side payments) or that strategy where their combined utility is maximized (with side payments). Given agents' choice, the value function is updated. We repeat this procedure and iterate on the value function until it converges. In practice, for any parameter value, the value function converged in at most six iterations. We now provide a more detailed description of the algorithm.

1. Initialization: for all $s = \left(p^2, \eta^1, \eta^2\right) \in S$, $\left(w^1(s), w^2(s)\right) = (0, 0)$.
2. Expected utility of the junior if:

(a) $\delta^1(s) = \mathcal{S}$

$$r^1_{\mathcal{S}}(s) = \phi + \beta\,[\mu\phi\, w^2(p^2(\eta^1+1),1,\eta^1) + \mu(1-\phi)\, w^2(p^2(\eta^1+1),0,\eta^1) + (1-\mu)\phi\, w^2(p^2(\eta^1+0),1,\eta^1) + (1-\mu)(1-\phi)\, w^2(p^2(\eta^1+0),0,\eta^1] \quad (10)$$

where the probability function p^2 is given in the second column of Table 3.

(b) $\delta^1(s) = \mathcal{T}$:

$$r^1_{\mathcal{T}}(s) = p^2 + \beta\;\{\mu\phi\, w^2(p^2(\eta^1+\eta^2+1),1,\eta^1) + \mu(1-\phi)\, w^2\left(p^2(\eta^1+\eta^2+1),0,\eta^1\right) + (1-\mu)\phi\, w^2\left(p^2(\eta^1+\eta^2+0),1,\eta^1\right) + (1-\mu)(1-\phi)\, w^2\left(p^2(\eta^1+\eta^2+0),0,\eta^1\right)\} \quad (11)$$

where the probability function p^2 is given in the third column of Table 3.

3. Expected utility of sophomore if:

(a) $\delta^2(s) = \mathcal{S}$:

$$r^2_{\mathcal{S}}(s) = p^2 + \beta\{\mu p^3(\eta^2+1) + (1-\mu)p^3(\eta^2+0)\} \quad (12)$$

where the probability function p^3 is given in the second column of Table 4.

(b) $\delta^2(s) = \mathcal{T}$:

$$r^2_{\mathcal{T}}(s) = p^2 + \beta\{\mu p^3(\eta^1+\eta^2+1) + (1-\mu)p^3(\eta^1+\eta^2+0)\} \quad (13)$$

where the probability function p^2 is given in the third column of Table 4.

4. Decision rules:

(a) No side payments:
- $\delta^1(s) = \delta^2(s) = \mathcal{T}$ if $r^1_{\mathcal{T}}(s) > r^1_{\mathcal{S}}(s)$ and $r^2_{\mathcal{T}}(s) > r^2_{\mathcal{S}}(s)$.
- $\delta^1(s) = \delta^2(s) = \mathcal{S}$ otherwise.

(b) Side payments:
- $\delta^1(s) = \delta^2(s) = \mathcal{T}$ if $r^1_{\mathcal{T}}(s) + r^2_{\mathcal{T}}(s) > r^1_{\mathcal{S}}(s) + r^2_{\mathcal{S}}(s)$.
- $\delta^1(s) = \delta^2(s) = \mathcal{S}$ otherwise.

5. Candidate value function $\tilde{w}(s) = (\tilde{w}^1(s), \tilde{w}^2(s))$:

(a) if $\delta(s) = \mathcal{T}$:

$$\tilde{w}(s) = \left(r^1_{\mathcal{T}}(s), r^2_{\mathcal{T}}(s)\right), \quad (14)$$

(b) else,

$$\tilde{w}(s) = \left(r^1_{\mathcal{S}}(s), r^2_{\mathcal{S}}(s)\right), \quad (15)$$

6. Grid: repeat steps 2 to 5 for all s on the grid.

7. Stopping rule:

 - If $\max_s |\tilde{w}(s) - w(s)| > \varepsilon$, $w = \tilde{w}$, set $(f_\delta^1(s), f_\delta^2(s)) = w(s)$, and start again at step 2.
 - Otherwise $\delta^* = \delta$, stop.

C Separating Regions

Table 5: Minimum separating sophomore wage $p^2_{\min}$, *ITP*, no bargaining

	μ																
ϕ	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	7
15	1	1	1	1	1	1	1	1	1	1	1	1	1	6	9	11	13
20	16	12	1	1	1	1	1	1	1	1	1	7	10	13	15	16	18
25	23	20	17	14	11	7	5	6	8	10	12	15	16	18	20	21	23
30	29	27	25	22	21	19	18	18	18	19	20	21	22	24	25	27	28
35	35	33	31	30	28	27	26	26	25	26	26	27	28	29	31	32	33
40	40	39	38	37	35	34	33	32	32	32	32	32	34	35	36	37	38
45	45	44	44	42	41	40	40	39	38	38	38	38	39	40	41	42	43
50	50	50	49	48	47	47	46	45	45	44	44	44	45	45	46	47	48
55	56	55	54	54	53	52	52	51	51	50	50	50	50	51	51	52	53
60	60	60	60	59	59	59	58	57	57	56	56	56	56	56	57	58	58
65	65	65	65	65	64	64	64	63	62	62	61	61	61	62	62	63	64
70	70	71	70	70	69	69	69	68	68	68	67	67	67	67	68	68	69
75	75	75	75	75	75	75	74	74	74	73	73	73	73	73	73	73	74
80	81	81	81	80	80	80	80	79	79	79	79	79	79	79	79	79	79
85	86	86	86	85	86	85	85	85	85	85	84	84	84	84	84	84	84
90	91	91	91	90	90	90	90	91	90	90	90	90	90	90	90	90	90

Note: minimum p^2 (in %) required for equilibrium team formation involving two type-1 agents in function of unconditional probabilities ϕ (rows) and μ (columns). Positive discounting of future utility, with $\beta = 0.5$. No side payments, incumbent team payment scheme.

Table 6: Separating sophomore's wage $[p^2_{\min}, p^2_{\max}]$, *ITP* with bargaining

		μ																
ϕ	$p^2_{\min}$ $p^2_{\max}$	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
10		–	–	–	–	0	0	0	0	0	0	0	1	–	–	–	–	–
		–	–	–	–	2	3	3	4	4	4	4	2	–	–	–	–	–
15		–	–	–	0	0	0	0	0	0	0	0	0	0	3	6	8	–
		–	–	–	2	5	7	8	9	9	9	9	9	9	9	8	9	–
20		–	–	–	0	0	0	0	0	0	0	0	3	6	9	11	14	–
		–	–	–	7	9	11	13	14	14	14	14	14	15	14	14	14	–
25		–	–	6	2	0	0	0	0	0	2	7	10	12	14	16	19	–
		–	–	7	12	14	16	16	19	19	19	19	19	19	19	19	20	–
30		–	–	–	13	11	9	8	8	9	10	14	16	18	20	22	24	–
		–	–	–	17	19	20	23	24	24	24	24	25	25	24	25	24	–
35		–	–	–	–	21	18	17	17	17	17	20	22	23	25	27	29	–
		–	–	–	–	24	25	28	29	29	29	29	30	30	29	30	30	–
40		–	–	–	–	29	27	25	24	24	26	27	28	29	31	33	34	–
		–	–	–	–	29	33	33	35	34	35	35	35	35	35	35	34	–
45		–	–	–	–	37	35	33	32	31	33	34	34	35	36	38	40	–
		–	–	–	–	38	38	39	40	39	40	40	41	41	40	40	40	–
50		–	–	–	–	–	43	41	39	39	40	40	40	41	42	43	45	47
		–	–	–	–	–	43	45	45	45	45	45	46	46	49	45	47	49
55		–	–	–	–	–	49	48	47	46	47	46	46	47	48	49	50	52
		–	–	–	–	–	49	50	51	50	51	51	50	53	54	54	54	55
60		–	–	–	–	–	–	55	54	53	53	53	53	53	53	54	55	56
		–	–	–	–	–	–	55	56	54	55	55	59	59	59	59	60	60
65		–	–	–	–	–	–	–	60	59	60	59	59	59	59	59	60	62
		–	–	–	–	–	–	–	60	59	60	63	64	64	65	65	66	65
70		–	–	–	–	–	–	–	–	–	66	65	65	64	64	65	66	67
		–	–	–	–	–	–	–	–	–	68	69	70	70	71	70	71	71
75		–	–	–	–	–	–	–	–	–	72	72	71	70	70	71	71	72
		–	–	–	–	–	–	–	–	–	73	74	75	75	76	76	77	76
80		–	–	–	–	–	–	–	–	–	–	78	77	77	77	77	77	78
		–	–	–	–	–	–	–	–	–	–	79	80	80	81	82	82	82
85		–	–	–	–	–	–	–	–	–	–	84	83	83	83	83	83	83
		–	–	–	–	–	–	–	–	–	–	–	85	86	87	87	88	88
90		–	–	–	–	–	–	–	–	–	–	–	89	89	89	89	89	89
		–	–	–	–	–	–	–	–	–	–	–	90	90	92	92	93	93

Note: minimum p^2 (first line, in %) and maximum p^2 (second line) required for equilibrium team formation involving one type-1 sophomore, and one type-1 junior, in function of unconditional probabilities ϕ (rows) and μ (columns). Positive discounting of future utility, with $\beta = 0.5$. Side payments allowed; incumbent team payment scheme.

Table 7: Semi-separating sophomore's wage $[p^2_{\min}, p^2_{\max}]$, *ITP* with bargaining

		μ																
ϕ	$p^2_{\min}$ $p^2_{\max}$	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		7	7	7	8	9	9	10	10	10	10	10	10	10	10	10	10	10
15		0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	8	10
		12	12	12	13	13	14	16	16	16	16	16	15	15	15	15	15	15
20		0	0	0	0	0	0	0	0	0	0	0	3	6	9	11	14	16
		18	14	18	18	19	20	20	21	22	21	21	20	20	20	20	20	20
25		0	0	6	2	0	0	0	0	0	2	7	10	12	14	16	19	20
		25	24	24	24	25	25	26	27	27	26	26	26	25	25	25	25	25
30		14	14	16	13	11	9	8	8	9	10	14	16	18	20	22	24	25
		31	30	29	29	30	30	31	32	30	31	32	32	32	30	30	30	30
35		23	22	23	24	21	18	17	17	17	17	20	22	23	25	27	29	30
		37	36	35	35	36	36	37	35	36	36	39	38	37	36	35	35	35
40		29	28	29	29	29	27	25	24	24	26	27	28	29	31	33	34	35
		43	41	41	41	41	41	40	40	41	44	45	44	43	42	41	41	40
45		34	34	34	34	37	35	33	32	31	33	34	34	35	36	38	40	40
		49	47	47	47	46	44	46	46	47	50	51	51	49	48	47	46	45
50		41	39	39	39	44	43	41	39	39	40	40	40	41	42	43	45	47
		54	53	51	49	50	50	51	52	53	55	56	57	56	54	53	51	50
55		45	45	50	49	49	49	48	47	46	47	46	46	47	48	49	50	52
		54	54	55	55	55	56	57	57	58	61	61	62	63	61	65	57	56
60		57	56	55	55	55	56	55	54	53	53	53	53	53	53	54	55	56
		60	60	61	61	61	62	62	63	63	66	66	68	66	66	65	63	61
65		62	61	61	60	60	61	61	60	59	60	59	59	59	59	59	60	62
		64	65	66	66	66	67	67	68	69	71	71	70	72	73	73	70	67
70		67	67	65	65	65	66	67	67	68	66	65	65	64	64	65	66	67
		70	71	71	71	72	72	73	73	74	76	76	76	78	74	79	77	74
75		72	72	71	71	71	71	72	72	71	72	71	70	70	71	71	72	72
		75	76	77	77	77	78	78	78	79	81	80	82	83	85	86	86	81
80		78	77	76	76	76	76	77	75	78	79	78	77	77	77	77	77	78
		81	81	82	82	83	83	84	84	84	85	86	87	88	90	93	99	90
85		83	82	81	81	81	81	78	82	83	84	84	83	83	83	83	83	83
		86	87	87	87	88	88	89	89	90	90	90	91	93	95	100	100	100
90		88	87	87	86	85	82	86	87	88	89	90	89	89	89	89	89	89
		92	93	94	94	94	94	95	95	95	95	95	95	96	100	100	100	100

Note: minimum p^2 (first line, in %) and maximum p^2 (second line) required for equilibrium team formation involving one type-1 sophomore, regardless of the junior's type, in function of unconditional probabilities ϕ (rows) and μ (columns). Positive discounting of future utility, with $\beta = 0.5$. Side payments allowed; incumbent team payment scheme.

D Steady-State Probability Distribution

This section describes the method used to compute the steady-state distribution of p^2.

1. Choose $E \in \mathcal{N}$ sufficiently large (e.g. 100), and let $l = \frac{1}{E}$
2. Let $i, j, s, s' \in \{0, l, 2l, \dots, 1\} \times \{0,1\} \times \{0,1\} \equiv S_d$ where s and s' denote current and next period state respectively.
3. Construct a transition matrix $\mathcal{M}$ of dimension $4(E+1) \times 4(E+1)$ such that a typical element on the i^th line and j^th column, $\mathcal{M}_{ij} = \Pr(s' = j | s = i)$.
4. For each $s \in S_d$, $\delta^1_*(s)$ is obtained from section 4.
5. Given $\delta^1_*(s)$, use Table 3 to calculate p^2 in the next period. Note that this probability corresponds in fact to the current junior's, and that
   - it depends on today's realization of nature (good or bad), and
   - the junior can be either of the good type or bad type.

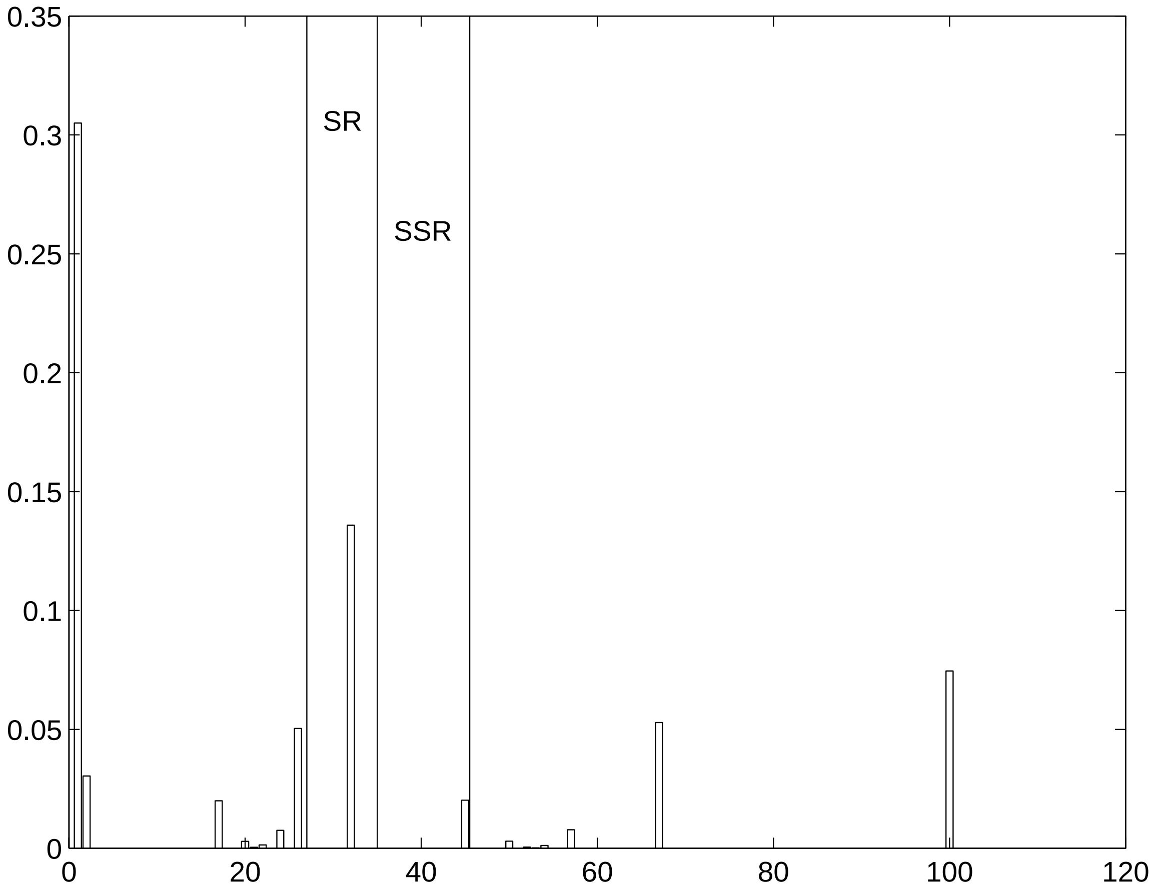
   Hence s' is restricted only to four possibilities each weighted by the appropriate probability as given below:

   Table 8: Feasible states

Nature	Junior's type	state	Probability
0	0	$(p^2_0, 0, \eta_1) \equiv s_{00}$	$(1-\mu)(1-\phi)$
0	1	$(p^2_0, 1, \eta_1) \equiv s_{01}$	$(1-\mu)\phi$
1	0	$(p^2_1, 0, \eta_1) \equiv s_{10}$	$\mu(1-\phi)$
1	1	$(p^2_1, 1, \eta_1) \equiv s_{11}$	$\mu\phi$

6. Let $s_f \equiv \{s_{00}, s_{01}, s_{10}, s_{11}\}$ and use Table 8 to fill in the transition matrix $\mathcal{M}$ as follows:
   (a) If $s' \in s_f$, $\mathcal{M}_{ss'}$ equals the corresponding transition probability as given in the Table 8.
   (b) If $s' \notin s_f$, $\mathcal{M}_{ss'} = 0$.
7. The steady-state distribution of p^2, which we denote Π, is obtained by solving the system of $4(E+1)$ equations $(\mathcal{A}' - I)\Pi = V$, where I is the identity matrix, V is a $4(E+1)$ column vector of 0, except for $V_{4(E+1)} = 1$.

Figure 1: Steady-state *ex-post* distribution for p^2



Note: Fixed parameters: $\beta = 0.5, \phi = 0.4$ and $\mu = 0.6$. SR: separating range (teams only if both type-1 agents). SSR: semi-separating range (teams only if type-1 sophomore).

E Large-sample distribution

Table 9: Moments of the error distribution

moments	$\mathcal{S}$	$\mathcal{E}$	$\mathcal{T}$
$E(\eta^2 - p^2)^2$	0.110	0.103	0.131
$E(\eta^2 - p^2)^3$	0.042	0.034	0.031
$E(\eta^2 - p^2)^4$	0.039	0.035	0.048

Note: Sample means of the second, third and fourth moments of the errors on sophomore's type $\eta^2 - p^2$, based on Monte-Carlo experiment, with 20,000 replications. Fixed parameters: $\beta = 0.5, \phi = 0.4$ and $\mu = 0.6$, *ITP*, with bargaining. Types of contracts: $\mathcal{S}$, singles only, $\mathcal{T}$ teams only, and $\mathcal{E}$ agents choose between the $\mathcal{S}$ and $\mathcal{T}$ contracts.