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Decentralized Knowledge, Internal Organization, and the Limits of the Price System

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1 Introduction

Neo-classical economics addressed the problem of resource allocation taking the existence of firms for granted. Coase (1937) asked what determines their boundaries. More pointedly, he juxtaposed the spontaneous coordination of resources achieved via markets with the conscious control of individuals in firms, leading to a "supercession of the price system." To explain this phenomenon, he introduced the notion of transactions costs. In Coase's interpretation of neo-classical theory, markets could perform all the tasks accomplished in firms if there were no costs of transacting. Along similar lines, Arrow (1974) states: "We may take the very existence of an organization with a need for coordination as evidence of the infeasibility or at least the inefficiency of the price system."

We take a different position. Our premise is that organizations involving conscious control — specifically, employment contracts where workers agree to take direction from an employer in exchange for a salary, the employer to receive the residual — are essential components of efficient resource allocation. How do employment contracts and the price system complement each other? This is another way to pose Coase's question without necessarily taking the path of his suggested answer.

Following Hayek (1945), we shall emphasize that the price system is a remarkable response to decentralized knowledge — precisely because of its limitations. The neo-classical model was explicitly formulated to study the determination of market prices and was, therefore, implicitly designed to ignore those limitations. So, rather than adding transactions costs to what is regarded as an otherwise satisfactory description of the resource allocation problem, in our view the neo-classical model must be modified. The aim of the modification is to expose the limitations of the price system and, consequently, the advantages of conscious control as a necessary interface with it.

Ambiguities in the meaning of transactions costs and its connections to decentralized knowledge prompts the following three comments to help point to where we are heading.

1. The broad interpretations given to zero transactions costs in Coase's later "Problem of Social Cost" (1960) may invite the comment that decentralized knowledge fits within the rubric of transactions costs, i.e., no transactions costs would imply no decentralized knowledge. We regard such an inclusion as ill-advised. Decentralized knowledge is a basic scarcity akin to the scarcity of resources. The limitations of the price system and its relation to the role of firms follow from the need for direct communication of decentralized knowledge.

2. Coase began his essay with: "Economic theory has suffered in the past from a failure to state clearly its assumptions. Economists in building up a theory have often omitted to examine the foundations on which it is erected."

The neo-classical assumption that consumption sets (the source of labor supply) and production sets (the source of labor demand) are convex implies that the labor commodity can be measured by the number of hours of worked. For the worker, the hours may be spread over more than one firm; and, similarly for the firm, the hours supplied by workers are interchangeable. The price of labor is an hourly wage and at that price any worker or firm can choose as much as it likes.

A specific source of transactions costs for Coase is:

> The costs of negotiating and concluding a separate contract for each exchange which takes place on a market must also be taken into account. It is true that contracts are not eliminated when there is a firm but they are greatly eliminated. A factor of production (or the owner thereof) does not have to make a series of contracts with the factors with whom he is co-operating within the firm, as would be necessary, of course, if this co-operating were a result of the direct working of the price mechanism. For this series of contracts is substituted one.

This can be read as saying that the fixed cost of exchanging with each person is at the heart of transactions costs. And, when they are absent, the linear and anonymous characteristics of neo-classical pricing would suffice to allocate resources. Of course, there are other possible interpretations.

We shall point to a feature of technology called personalized nonconvexities in Makowski (1979) as the departure from the neo-classical model and the reason why a contract with one person should replace a series of contracts with several.

More specifically, we shall focus on one of its manifestations — team production — as an essential pre-condition to the value of conscious control. Therefore, an apparently key role for transactions costs has been co-opted.

3. The term "transactions costs" has been a beneficiary of the wave of attention paid in the last few decades to various forms of opportunistic or strategic behavior. Williamson (1985) describes it as operationalizing transactions costs. A summary of the contemporary approach is that the firm, in the words of Alchian and Woodward (1984), arises as a nexus of contracts to restrain opportunistic behavior, e.g., the need to monitor shirking, or as a rationale for preventing future hold-ups when incomplete contracts are made by independent transactors.

There is an evident similarity between decentralized knowledge and the term "asymmetric information" that is often associated with strategic behavior. Our approach might, therefore, appear to be a variation on the same theme. It is not. To distinguish, think of decentralized knowledge as emphasizing the choices among what goods and services will be supplied and the details of how things get done as a genuine challenge, whereas when asymmetric information points to those details it is primarily because they present opportunities for strategic behavior.

The goal of this paper is to elaborate on the following: An ideally functioning competitive price system records the social opportunity cost, i.e., the cost to others, of employing resources. While prices are summary statistics of others' decentralized knowledge, individuals are dependent on their own knowlege — superceding the price system — to employ those resources. An entrepreneur is someone with proprietary knowledge about how to get things done. As a single person producer, the entrepreneur need only communicate this information to himself. In a team production environment, however, the need for communication from the entrepreneur to other members is not the function, i.e., beyond the limits, of the price system. Rather, it is conveyed by direct control of team members' actions. Moreover, the entrepreneur's competitive reward measures the social value of his decentralized knowledge.

Section 2 is brief statement of background. Section 3 calls attention to actions that rely on decentralized knowledge other than prices. Section 4 contains the formal model. The issue of team production as a technological rather than a transaction cost phenomenon is taken up in Section 5. Section 6 is devoted to comparisons with alternative approaches to the theory of the firm.

2 The price system and planning in Hayek and Coase

Hayek's essay is a critique of central planning. The top-down approach underestimates the importance of dispersed information, i.e., "....knowledge of the kind which by its nature cannot enter into statistics and therefore cannot be conveyed to any central authority in statistical form. ...It follows that central planning based on statistical information by its nature cannot take direct account of these circumstances of time and place and that the central planner will have to find some way in which the decisions depending on them can be left to the 'man on the spot.' "

The other side of the problem is: "But the man on the spot cannot decide solely on the basis of his limited but intimate knowledge of the facts of his immediate surroundings. There remains the problem of communicating to him such further information as he needs to fit his decisions into the whole pattern of changes of the larger economic system." The basic division is between the detailed knowledge available to the individual about his own circumstances compared to the absence of detail the individual has about the circumstances of others:

> The problem is precisely how to extend the span of our utilization of resources beyond the span of control of any one mind; and, therefore, how to dispense with the need of conscious control and how to provide inducements which will make the individuals do the desirable things without anyone having to tell them what to do.

To effectively extend the span while dispensing with the need for control to be conscious, it suffices to measure the opportunity cost (to others) of employing resources. Prices communicate this information.

Coase pointed to the limitations of the price system because there is a considerable amount of planning and conscious control in firms. "In view of the fact that while economists treat the price mechanism as a co-ordinating instrument, they also admit the co-ordinating function of the 'entrepreneur,' it is surely important to enquire why co-ordination is the work of the price mechanism in one case and the entrepreneur in another."

The price system is the interface between the importance of dispensing with conscious control and its indispensability. To combine the Hayek and Coase perspectives, we shall define the supercession of the price system as occurring whenever conscious control is exercised. Hayek's reference to "any one mind" or "the man on the spot" highlights the fact that the individual's decentralized knowledge supercedes the price system. Coase's claim is that, without transactions costs, this is all that is needed.

3 Varieties of individual supercession

To emphasize the resource allocation problems beyond the determination of market prices, we call attention to examples of conscious control in individual decision-making.

3.1 Household administration

Consider the buying and selling of foods. A conventional presumption is that foods are consumed directly. Schematically,

$$\text{foods} \rightarrow \text{utility.}$$

Consequently, an individual's market behavior reveals information directly about his tastes and, following Samuelson (1938), we can hope to identify an individual's utility for foods from information about his market choices.

An alternative scenario, called household administration, is that the choice of what foods to buy is only a part of the overall problem of what meals to consume.[1] In that case, there can be a significant gap between foods purchased and meals consumed depending on the individual's knowledge of recipes and the personal costs and skills involved in meal preparation. In the household administration scenario, foods are ingredients in the preparation of meals, the actual source of utility, i.e.,

$$\text{foods} \rightarrow \text{meal preparation} \rightarrow \text{utility.}$$

Compared to the conventional setting where foods are consumed directly, the actions involved in household administration call attention to the fact that sources of information other than the price system are being used — prices do not tell the household what and how to prepare meals.

A realistic description of the complexities of meal preparation is impractical. Our treatment is, therefore, abstract. Let $b = (s^1, s^2, \ldots, s^k)$ denote a sequence s^h, $h = 1, \ldots, k$. And, more specifically, suppose each $s^h \in \{0, 1\}$ so that b is a binary sequence. The first five elements of the b might stand for the recipe(s)

1. The term is borrowed from Wicksteed (1910) who provides colorful illustration that the housewife's purchases are a derived demand.

chosen while the remaining ones correspond to the binary code for the various tasks involved in the preparation of meals. However, to further simplify, we shall regard each s^h, $h = 1, \dots, k$, as the h^{th} task in a meta-temporal sequence.

An individual is endowed with a set B of recipe/preparation tasks. In addition, the individual has a feasible set $Z \subset \mathbb{R}^\ell$ of possible trades in foods, e.g., $Z = \{z : z \geq -w\}$, where $w \in \mathbb{R}^\ell_+$ is his endowment of foods.

Applying $b \in B$ to vector of foods z yields meals $e(z, b)$. The resulting utility is

$$U(e(z,b), b) := V(z, b),$$

indicating that b enters utility directly because tasks may be onerous, as well as indirectly through their influence on e.

Of course, one may still hope to obtain a derived utility function for foods from market choices as long as knowledge of recipes and preparation skills/costs remain constant. Thus, define

$$v(z) = \max\{V(z, b) : b \in B\}.$$

Letting $m = -p \cdot z$ be the money payment for z at market prices p, and assuming that overall utility is quasi-linear in the money commodity, i.e., $\tilde{U}(e, b, m) = V(z, b) + m$, the individual's indirect utility can be written as a function of food prices,

$$v^*(p) = \max_z \{v(z) - p \cdot z\} = \max_z \max_b \{V(z, b) - p \cdot z\}.$$

Thus, $v(\cdot) + m$ is the utility function for the individual as far as his interactions with others are concerned.

We shall regard B as proprietary. Suppose, for example, individuals 1 and 2 with otherwise identical tastes, but $B_2 = \emptyset$, indicating that 2 is incapable meal preparation and is forced to consume foods directly, i.e, $y(z, \emptyset) = z$. Then $v_1^*(p) - v_2^*(p)$ measures 1's consumer's rent from B.

Note that by introducing meal preparation, the price system fulfills its function even though no one knows what the goods, i.e., the meals and how they are prepared, really are.

3.2 Production by single individuals

In the contemporary description of the neo-classical model, technology is described as a set $Y \subset \mathbb{R}^\ell$ of feasible input/output vectors y, with the convention that negative components represent inputs and positve components are outputs. For example, if $\ell = 2$ and $y \in Y$ implies that $y_1 \geq 0$ and $y_2 \leq 0$, the set Y may be summarized by the neo-classical production function $y_1 = f(y_2)$, where y_1 is the maximum output from input y_2. Schematically, the neo-clasical description of technology

$$\text{inputs} \rightarrow \text{outputs}$$

is called a "black box" because it does not specify what lies in between. In preparation for the analysis below, consider an extension of household administration to production carried out by individuals,

$$\text{inputs} \rightarrow \text{task assignments} \rightarrow \text{outputs}.$$

Again, $b \in B$ is a binary sequence representing tasks the individual can perform. The difficulties in dividing time and energy between household administration and production will be avoided by assuming in this and the following sections that task assignments are for production only. Denote by $Y(b)$ those input/output combinations y possible with b. Individual utility continues to be written as $V(z, b) + m$ because task assignments may have utility consequences.

When market prices of all commodities (inputs and outputs) are given by p, $p \cdot y$ is the revenue from outputs minus the cost of inputs, or profits. The individual's objective at prices p is

$$\max\{V(z, b) - p \cdot z + p \cdot y : z \in Z,\, y \in Y(b),\, b \in B\}.$$

Denote by

$$B(z)/\sim = \{(b, b') \in B \times B : V(z, b) = V(z, b')\}$$

the utility equivalent task assignments at z. The sensitivity of V to b will be regarded as coaser than its productivity implications. Utility indifferent task assignments may have a significant influence on output, i.e., while $(b, b') \in B(z)/\sim$, $Y(b) \neq Y(b')$. A useful special case, employed below, occurs when all task assignments are utility indifferent, i.e., $B/\sim = B \times B$. Hence, $V(z, b)$ can be written as $V(z)$, while $Y(\cdot)$ depends on b.

The behavior of the consumer/producer can be succinctly summarized as

$$v(\tilde{z}) = \max_b\{V(z, b) : z + y = \tilde{z}\},$$

the utility function derived from V and the production possibilities $\{Y(b) : b \in B\}$. Then the individual's market behavior is explained by the desire to achieve

$$v^*(p) = \max_{\tilde{z}}\{v(\tilde{z}) - p \cdot \tilde{z}\}.$$

This is another instance of the supercession of the price system. Information about b and $Y(\cdot)$ can be suppressed because it is under the conscious control of the producer/consumer.

The producer/consumer example, but without task assignments, is used in neo-classical theory to illustrate the decentralization role of the price system, i.e., prices that can be relied upon to coordinate the decisions of the consumer and the producer, as if they acted independently. (Koopmans [1957 p. 16-23]) Hence, there is no advantage in merging the two sides of the individual.

To mimic the neo-classical argument with task assignments, a pricing function $P(b)$ must be introduced to evaluate the costs of each b. Call $P(b)$ a contractual price because, unlike commodity prices p that do not vary with the number of units exchanged or the individuals involved, it specifies a payment for particular b between a particular buyer and seller.

The role of P is to make the buyer of b, the producer, choose the same task assignment as the supplier of b, the consumer. To guide production, profit maximization is

$$\pi(p,P) = \max\{p \cdot y - P(b) : y \in Y(b), b \in B\}.$$

Utility maximization is

$$V^*(p,P) = \max\{V(z,b) - p \cdot z + P(b) : z \in Z, b \in B\}.$$

To fulfill its function, P should satisfy

(i) there is $\bar{y} \in Y(b)$ and $b_p \in B$ such that $p \cdot \bar{y} - P(b_p) = \pi(p,P)$

(ii) there is $\bar{z}$ and $b_c \in B$ such that $V(\bar{z}, b_c) - p \cdot \bar{z} + \pi(p,P) = V^*(p,P)$

(iii) $b_p = b_c$.

The key condition for P is (iii) that the utility maximizing supply b_c of the consumer equals the profit maximizing demand of the producer. Conditions (i)–(iii) imply that the joint maximizing decision can be separated in the sense that

$$\begin{aligned}
V^*(p,P) + \pi(p,P) &= V(\bar{z}, b) - p \cdot \bar{z} + P(b) + p \cdot \bar{y} - P(b) \\
&= \max\{V(z,b) - p \cdot z + \pi(p|b) : z \in Z, b \in B\}, \\
&= \max\{v(\tilde{z}) - p \cdot \tilde{z}\}, \\
&= v^*(p)
\end{aligned}$$

Unlike the neo-classical argument that relies on market prices p only, here separation is achieved through internal pricing P that is idiosyncratic to the individual.

The complexity of task pricing that will appear, below, in teams can be illustrated at the individual level. The value of a sequence of tasks cannot be separately imputed to its constituent parts. Thus, if $b = (s^1, s^2, s^3, \ldots, s^k)$, there will generally not exist functions $P_h(s^h)$, $h = 1, \ldots, k$ satisfying the additivity condition

$$(A.1) \qquad P(s^1, s^2, s^3, \ldots, s^k) = P_1(s^1) + P_2(s^2) + P_3(s^3) + \cdots + P_k(s^k).$$

Hence, when the length of the sequence is k, it may be necessary to allow for as many prices as there are sequences, i.e., 2^k. We shall focus on technology (rather than tastes) as the principal source of complexity.

Suppose, to the contrary, that for each $b = (s^1, s^2, s^3, \ldots, s^k)$, $Y(b)$ could be written as

$$(A.2) \qquad Y(s^1, s^2, s^3, \ldots, s^k) = Y_1(s^1) + Y_2(s^2) + Y_3(s^3) + \cdots + Y_k(s^k).$$

Condition (A.2) says that the consequences of the sequence of task assignments can be additively decomposed into the consequences of each task. The profitability of proceeding, for example, from s^1 to s^2 could be determined by comparing $p \cdot y_2$, where $y_2 \in Y_2(s^2)$, with the cost of s^2. Hence, there is minimal need for coordination beyond what the price vector p already provides. In particular, there would exist task pricing functions $P_h(s^h)$, $h = 1, \ldots, k$ satisfying (A.1).

One might be tempted to say that with the appropriate definition of goods — e.g., each task results in a change in physical state — every technology satisfies condition (A.2). Then, the elimination of transactions costs would imply that every step in the process of converting inputs to outputs results in a potentially marketable good that could either be sold or continued on to the next step in the task assigment. Our premise is that the failure of (A.2) originates in technology, not transactions costs: intermediate stages in the production process do not necessarily result in tradeable commodities. The reason (A.1) does not hold is due to the failure of (A.2).

3.3 A proto-employment contract

We shall regard decentralized knowledge of technology — how to get things done — as part of a person's characteristics, rather than a proprietary set of blueprints that could be transferred.

To model the inalienable origins of technical knowledge, let $\omega = (\omega_1, \omega_2 \ldots, w_k)$ be a sequence of signals having no direct implications for utility. Instead of $Y(b)$, the realized productivity of task assignments is dependent on ω, $Y(b,\omega)$. Only the producer side sees ω. Decentralized knowledge about technology is the ability to translate signals into productive task assignments.

As an initial hypothesis, suppose ω is observed all at once before task assignments are made. The objective is to find $b(\omega)$ such that

$$V(\bar{z}, b(\omega)) - p \cdot \bar{z} + p \cdot y(b(\omega)) = \max\{V(z,b) - p \cdot z + p \cdot y : z \in Z, y \in Y(b,\omega), b \in B\}$$

How can the producer communicate his knowledge to the consumer? The obvious answer is that upon observing ω, the producer tells the consumer to perform $b(\omega)$.

By expanding the definition of $P(\cdot)$ to $P(\cdot|\omega)$, such information could be formally communicated by prices. Profit-maximization would be

$$\pi(p, P|\omega) = \max\{p \cdot y - P(b|\omega) : y \in Y(b,\omega), b \in B\},$$

and utility maximization would be

$$V^*(p, P|\omega) = \max\{V(z,b) - p \cdot z + P(p|\omega) + \pi(p, P|\omega) : z \in Z, b \in B\}.$$

Knowing ω and $P(\cdot|\omega)$, prices could communicate information to coordinate both sides, i.e.,

$$V^*(p, P|\omega) + \pi(p, P|\omega) = V(\bar{z}, b(\omega)) - p \cdot \bar{z} + p \cdot y(b(\omega)).$$

In effect, the producer says to the consumer: "When I know ω, I will tell you what to do by selecting the function $P(\cdot|\omega)$ to guide your choice of b." Of course, such prices are not a substitute for conscious control. They are simply mirror images of it because they are constructed to directly reflect decentralized knowledge.

Consider a more complex and realistic scenario. The signal ω_h arrives just prior to the assignment of task s^h, $h = 1, \ldots, k$. In this setting, the method of communication will be more direct. Write $\omega^h = (\omega_1, \omega_2, \ldots, \omega_h)$. Upon observing ω^h prior to the h^{th} task assignment, $h = 1, \ldots, k$, the producer tells the consumer to carry out 0 or 1. Define

$$b[\omega] = (s^1(\omega^1), s^2(\omega^2), \ldots, s^k(\omega^k))$$

as the sequence of task assignment conditional on the realization of ω as it unfolds. Now, when the first task is assigned, the producer does not know what tasks he will want the consumer to carry out later.

The producer uses his knowledge of production possibilities, the sequential arrival of ω_h and knowledge of the consumer's tastes to maximize the consumer's welfare. Knowing this, the consumer follows the producer's direction.

To illustrate how communication could be implemented, assume that all task assignments are utility indifferent, i.e., $V(z, b) = V(z)$. A solution to the producer/consumer problem is for the consumer to be given a constant schedule $P(b) = q$, for all b. The producer maximizes profits by choosing $b[\omega]$ to satisfy

$$\pi(p|\omega) = \max\{p \cdot y - q : y \in Y(b[\omega], \omega), b[\omega] \in B\}.$$

The consumer's objective, provided he supplies any one of the mutually exclusive task assignments, is

$$\max\{V(z) - p \cdot z + q + \pi(p|\omega) : z \in Z\}.$$

The consumer receives q for carrying out $b[\omega]$, but prices p do not tell the producer or the consumer how to choose $b[\omega]$. In that respect, it is similar to the example of household administration.

The more complex model of information arrival parallels Coase. "The details of what the supplier is expected to do is not stated in the contract but is decided later by the purchaser. When the direction of resources (within the limits of the contract) becomes dependent on the buyer in this way, that relationship which I term a 'firm' may be obtained."

The supercession of the price system described by Coase involves the conscious control of one person by another, whereas in this example the consumer follows instruction because he knows the producer is a part of him. So, while the example may be suggestive, it is not dispositive.

4 Team production with employment contracts

There is team production when

$$\text{inputs} \rightarrow \text{multi-person task assignments} \rightarrow \text{outputs}.$$

To illustrate, consider team production in a restaurant: Customers place orders with servers, who communicate them to the expediter, who calls it out to the various station chefs (saucier, fish cook, roast cook, pastry chef), who prepare and plate the orders and pass them to the expediter, who gives it to the runners to deliver to the customers.

Unlike single-person producer/consumers, if the price system is to coordinate production, it will also have to be responsible for which teams form. This, in turn, will imply that the valuation of task assignments cannot be suppressed in the specification of the resource allocation problem. Consequently, contractual pricing must also be part of the definition of equilibrium.

Each team will have a set of feasible ways to combine inputs into outputs that depends on how tasks are assigned. To illustrate with a team consisting of two persons, let

$$b = \begin{pmatrix} 1 & 0 & 0 & \cdots 1 \\ 0 & 1 & 0 & \cdots 1 \end{pmatrix}$$

be a specific sequence of tasks, where the first row is the tasks assigned to 1 and the second row is the tasks assigned to 2. The task assigment also specifies the sequential ordering of the simultaneous tasks undertaken by 1 and 2. Thus,

$$\begin{pmatrix} 1 & 0 & 0 & \cdots & 1 \\ 0 & 1 & 0 & \cdots & 1 \end{pmatrix} \neq \begin{pmatrix} 1 & 0 & 0 & \cdots & 1 \\ 1 & 0 & 0 & \cdots & 1 \end{pmatrix}.$$

For a specific pair of individuals, there is a specific set B of paired, sequential task assignments. Because they are simply binary codes, the B for one pair is unrelated to another pair even when one of the members is the same. Tasks are completely idiosyncratic to the team. This contrasts with the neo-classical description of technology, Y, with its quantities of impersonal inputs and outputs that can be transferred from one consumer or producer to another.

The productivity of the team depends on the coordinated participation of its members. In that respect, it is similar to a neo-classical production function involving complementary inputs. But the tools for determining factor rewards are not applicable. In the neo-classical model, where $y_1 = f(y_2)$, the factor of production has a market price p_2. Hence, the cost of y_2 is $p_2 y_2$. This yields the familiar marginal conditions that inputs should be employed such that the value of their marginal product equals their cost., e.g., $p_2 = p_1 f'(y_2)$. When labor inputs are team task assignments, the use of marginal analysis to determine the quantity of labor employed via the value of the marginal product of labor does not make sense. There is no margin to evaluate in b because the separate tasks that individuals perform are neither infinitesimal nor homogeneous.

The phenomenon of team production raises issues that are not dealt with in the neo-classical model. Chief among these is the question of how profits — the difference between revenue from the sale of commodity outputs and the cost of commodity inputs — are divided among its members.

There is a difference between a team and its technology. No one owns the team. But ownership of a team technology will be attributed to a single member, called the employer, who uses his knowledge to implement task assignments. In a two person team, we distinguish between ω_1 implying that the sequence of signals $(\omega_{11}, \omega_{12}, \ldots, \omega_{1k})$ is due to 1's knowledge, or 2's knowledge ω_2. Similarly, letting $\omega_1^h = (\omega_{11}, \omega_{12}, \ldots, \omega_{1h})$

$$b[\omega_1] = (b_1(\omega_{11}), b_2(\omega_1^2, \ldots, b_k(\omega_1^k)),$$

where

$$b_h(\omega_1^h) \in \left\{ \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \end{pmatrix} \right\},$$

is the h^{th} element in the sequence of task assignments for both members that is directed by individual 1. In a two person team, $b[\omega_1]$ refers to entirely different tasks from $b[\omega_2]$. The only thing they have in common is that individuals 1 and 2 participate in both.

Everyone is endowed with technical knowledge, so each individual is a potential employer. Competition implies that employers will bid against each other for employees. Competitive equilibrium determines whose knowledge is utilized and, therefore, who works for whom.

Remark: We focus on competing methods of organization and attribute them to the proprietary knowledge of single individuals. Hence, we ignore complementarities in what team members may know. This precludes partnerships, as well as the fact that in any organization every member will be the "man on the spot" with respect to some tasks for which he will exercise conscious control based on his particular decentralized knowledge. These, and other issues, are part of a richer picture of internal organization that is beyond the scope of this paper.

4.1 Formal model

There is a finite set of types of individuals denoted $I = \{1, \ldots, n\}$. A production team consists of a subset of I. Thus, no team contains two or more of the same type. This is not especially restrictive since the initial specification of types might include duplication. The more important qualification is that a team contains a finite number of individuals.

The number of teams an individual can join and the intensity of a member's participation is constrained by time and place. We simplify by assuming the conflicts are so severe that an individual can only be a member of one team.

4.1.1 Team task assignments

Denote by $T \subseteq I$ the members of a team. A team task assignment b includes information about the types of individuals involved, given by $T(b) \subset I$. The set of T of which i is a member is $\mathcal{T}_i = \{T : i \in T\}$.

For each i, $\omega_i \in \Omega_i$ is the signals individual i might receive. The informational endowment of all types at any one time is

$$\omega = (\omega_1, \omega_2, \ldots, \omega_n) \in \Omega_1 \times \Omega_2 \times \cdots \times \Omega_n.$$

We divide task assignments into those initiated by i as the employer, defined by following ω_i, and those in which i is an employee. Let

$$B_{ii}(\omega_i) = \{b : T(b) \in \mathcal{T}_i,\, b = b[\omega_i]\}.$$

We interpret $b = b[\omega_i]$, $i \in T(b)$, to be a task assignment for the members of T (including i) based on the sequential arrival of the signals in ω_i. The elements of the information source Ω_i are applicable to all of the teams i might direct. The assumption that i can be a member of only one team means that each i can direct at most one team. The set of task assignments directed by j in which $i \neq j$ could participate as a follower is

$$B_{ij}(\omega_j) = \{b : T(b) \in \mathcal{T}_i \cap \mathcal{T}_j,\, b = b[\omega_j]\}.$$

Given ω, the set of task assignments in which i can participate either as a leader or a follower is

$$B_i(\omega) = \bigcup_{j \in I} B_{ij}(\omega_j).$$

4.1.2 Activities of producers and consumers

We continue to regard the set of feasible commodity input/output combinations as a function of task assignments, $Y(b[\omega_i], \omega_i)$, for some $i \in T(b)$. Given the signals ω, the set of all productive activities is the feasible pairings of task assignments with commodity input/output combinations,

$$A_0(\omega) = \{(y, b) : y \in Y(b[\omega_i], \omega),\, b \in \bigcup_i B_{ii}(\omega_i)\}$$

Denote by $Z_i \subset \mathbb{R}^\ell$ the set of feasible commodity trades for i. As a consumer, i can participate in the activities

$$A_i(\omega) = \{(z,b) \in Z_i \times B_i(\omega)\}.$$

His quasilinear valuations of these activities along with transfers m of the money commodity is $V_i(z,b) + m$.

4.1.3 Allocations

Let $\mu_i > 0$ denote the mass of individuals of type i and $\mu = (\mu_i) \in \mathbb{R}^I_+$ the population of types. An allocation of activities among consumers of type i is described statistically by $x_i \in M(A_i(\omega))$, the non-negative measures on $A_i(\omega)$. i.e., $x_i(z,b)$ is the mass of individuals of type i engaging in the activities (z,b). Similarly, let $x_0 \in M(A_0(\omega))$ be the allocation of team production activities where $x_0(y,b)$ denotes the mass of team activity (y,b). An allocation of activities among consumers and producers is

$$x = (x_0, x_1, \ldots, x_n) \in M(A_0(\omega)) \times \prod\nolimits_{i\in I} M(A_i(\omega)).$$

The remainder of this section describes the conditions for a feasible allocation.

Individuals are either employers or employees. The first condition defining a feasible allocation is that the mass of individuals of each type occupying one or the other of these two roles should equal the total population of that type.

$$\sum_{(z,b)\in B_i(\omega)} x_i(z,b) = \sum_{j\in I} \sum_{(z,b)\in Z_i\times B_{ij}(\omega)} x_i(z,b) = \mu_i,\ \forall i \tag{1}$$

The following two restrictions describe matching conditions:

$$\sum_z x_i(z,b) - \sum_y x_0(y,b) \quad = \quad 0,\ \forall b \in B_{ii}(\omega),\ \forall i \tag{2}$$

$$\sum_z x_i(z,b) - \sum_y x_0(y,b) \quad = \quad 0,\ \forall b \in B_{ij}(\omega),\ \forall j \neq i,\ \forall i \tag{3}$$

(2) says that the number of individual consumers of any type directing task assignments equals the number directing task assignments as producers; and, similarly, (3) stipulates that those consumers participating as employees equal the numbers required in the production sector.

The final condition is equality with respect to commodities transferred between producers and consumers.

$$\sum_i \sum_{(z,b)\in Z_i\times B_i(\omega)} z\, x_i(z,b) - \sum_{(y,b)\in A_0(\omega)} y\, x_0(y,b) = 0 \tag{4}$$

We call attention to the difference between the aggregation underlying (4) versus the disaggregation describing (2)–(3). Condition (4) says that commodities are impersonal: any portion of the commodity input/output vector y for any $(y, b) \in A_0(\omega)$ may be used to offset some portion of z for any i such that $(z, b') \in A_i(\omega)$ provided the corresponding components of z and y are of opposite sign. The equalities (2) and (3) are much more specific. For example, the task assignment $b = b[\omega_j]$ directed by i must be matched by the participation of individuals $i \in T(b)$, $i \neq j$, as followers, in exactly the same assignment.

4.2 A simplified model of equilibrium

The description of a feasible allocation takes note of who employs whom and what sequence of task assignments each employer adopts. All of this is essential to determine what the output of each team will be and, therefore, the aggregate output $\sum_{(y,b)} y\, x_0(y, b)$.

The sequential arrival of information in $b[\omega_i]$ means that $Y(b[\omega_i], \omega_i)$ may be uncertain to i because when, for example, making the first task assignment, he cannot predict ω_{ih}, $h \geq 2$. To avoid this complication, assume that individual employers can make adjustments "on the fly" to compensate for their uncertainty about how ω_i will unfold. More formally, let $b(\omega_i)$ be a task assignment based on knowledge of ω_i. Assume that $\forall i$, $\forall \omega_i$ and $b(\omega_i)$, there exists $b[\omega_i] \in B_{ii}(\omega_i)$, $T(b(\omega_i)) = T(b[\omega_i])$ such that

$$(I) \qquad Y(b(\omega_i), \omega_i) = Y(b[\omega_i], \omega_i)$$

Consequently, employer i knows after observing ω_{i1} what his input/output possibilities are with respect to commodities, even though he cannot say what sequence of task assignments he will make to carry out his objectives until ω_i unfolds.

To this we add the assumption that individuals are completely indifferent among task assignments,

$$(II) \qquad V_i(z, b) = V_i(z),\ \forall i.$$

This immediately implies that if an individual is an employee, he will offer his services to the highest bidder. The determination of equilibrium will, therefore, depend on the rewards each type receives as employer or an employee, with each type choosing the one that is greater.

Let $q = (q_i)$ be the payments individuals receive working for someone else and $r = (r_i)$ their rewards as employers.

Definition: Assuming (I) and (II), (x, p, q, r) is an equilibrium with employment contracts if

(i) x is a feasible allocation

(ii) $x_0(y, b) > 0$ and $b \in B_{ii}(\omega_i)$ implies

$$r_i = \max\{p \cdot y - \sum_{\substack{j \in T(b) \\ j \neq i}} q_j : y \in Y(b, \omega_i),\, b \in B_{ii}(\omega_i)\}.$$

(iii) $x_i(z, b) > 0$ and $b \in B_{ii}(\omega_i)$ implies

$$V_i(z) - p \cdot z + r_i = \max\{V_i(z') - p \cdot z' + r_i : z' \in Z_i\},$$

and

$$r_i \geq q_i,$$

(iv) $x_i(z, b) > 0$ and $b \in B_{ij}(\omega_i)$, $j \neq i$ implies

$$V_i(z) - p \cdot z + q_i = \max\{V_i(z') - p \cdot z' + q_i : z' \in Z_i\}.$$

(ii) says that the r_i is the maximum profit i can earn among all possible teams he can direct given the prices q_j for hiring employees. Condition (2), above, defining a feasible allocation implies that some fraction of the population must be employers if there is any production activity. If everyone is an employer, hence no employees, then everyone is self-employed — there is no team production. In that case, $r_i \geq q_i$ for all i. The presence of team production in equilibrium implies that some types of individuals can afford to hire others as employees because their ability to direct individuals is sufficiently productive, at least relative to their productivity as employees.

Coase ended his essay by observing that "this analysis enables us to state more exactly what is meant by the 'marginal product' of the entrepreneur. But an elaboration of this point would take us far from our comparatively simple task of definition and clarification." We began with the goal of establishing the marginal productivity principle for team members' profit shares and ended by addressing the issue that was Coase's starting point. An entrepreneur's marginal product and the way the entrepreneur communicates his decentralized knowledge by superceding the price system are inseparably linked.

5 An addendum

Is team production a technological phenomenon or is it a consequence of transactions costs? Coase raises a similar issue. "It is sometimes said that the reason for the existence of a firm is to be found in the division of labour." After citing M. Dobb on the need for entrepreneurs as an "integrating force" to hold together the differentiation implied by division of labor, Coase responds: "The 'integrating force in a differentiated economy' already exists in the form of the price mechanism. ... What has to be explained is why one integrating force (the entrepreneur) should be substituted for another integrating force (the price mechanism)."

To address the issue, we review Adam Smith's description of pin making where the tasks of drawing, straightening, cutting, pointing, and grinding are "all performed by distinct hands." To the modern reader, the example of pin "manufactory" evokes the picture of a factory. In fact, this example exhibits circumstances under which the allocation of individual tasks could be coordinated by the price system.

The key observation is that before the latter half of the 19^{th} century when it became more mechanized, the manufacture of pins was organized through the putting out system (Pratten (1980)). The description in Ashton (1925) reveals that some of the tasks were carried out in workhouses and others at home. "The head-cutters, unlike the drawers and pointers, worked in their own homes with blocks, spinning wheels, shears, tins and stools provided by the firm." The better grades of pins were sold by the sheet. The task of attaching them was performed by women. "Pins and paper were given out to her each week and work was brought in as soon as finished..." The worker performing the next task was handed the product of the previous task rather than paying for it, but the employer paid the worker for his output. "All classes of workers were paid piece rates: material was weighed and given out, and the finished work and waste returned was set against the books. ...The piece rates paid to the wire-drawers were subject to deductions for vitriol supplied by the firm ....the pointers were paid a rate which varied with the grade of the pin." Adopting our previous notation, pin-making could be described as satisfying the analog of condition (A.2), above,

$$Y(s^1, s^2, s^3, \ldots, s^k) = Y_1(s^1) + Y_2(s_2) + Y_3(s^3) + \cdots Y_k(s^k),$$

where s^1 is cutting, s^2 is drawing, etc.

Ashton's account makes it clear that the tasks were performed by employees, not independent contractors. Nevertheless, pin production invites a Coasian interpretation. If workers had better access to capital, etc., tasks performed at home could have been by the self-employed. Similarly, if the workhouse facility were expanded to accommodate several drawers and pointers under the same roof — like a bazaar, there could have been a competitive market for their products. Hence, taking some liberties, Smith's example can be construed as not requiring team production, and the price system could have transformed tasks into trades.

Condition (A.2) described task assignments for a single individual. A single stage in pin production such as grinding may involve many more specific tasks that do not satisfy (A.2). Nevertheless, the grinder's conscious control can compensate for that fact. However, once it is granted that (A.2) might not hold at the individual level, the door is open to acknowledging that it does not hold more widely. "...(T)he manufacture of pins does not afford the ideal illustration of the division of labor; and one may echo Dr. Clapham's regret 'that Adam Smith did not go a few miles from Kirkaldy to the Carron Works to see them turning and boring cannonades instead of to his silly pin factory.' "[2]

In our view it would require a metaphysical interpretation of transactions costs to conclude that the origins of team production are not technological.

6 Personalized nonconvexities

We call attention to the concept of personalized nonconvexities as the point of departure from the neo-classical model. This will provide a framework for comparisons with contemporary theories of the firm.

6.1 Personalized nonconvexities and contractual pricing

A personalized commodity has only one potential buyer or seller. We illustrate with two examples from Makowski (1979).

- Business cards printed for an individual have a fixed cost of typesetting the person's name and a constant marginal cost.
- Firm-specific labor services require the supplier to spend a fixed amount of time training before having a positive marginal product.

The key property of personalized commodities is that "once an agent begins to trade with another, that agent becomes his natural (i.e., least cost) trading partner

2. Ashton (1925, p. 281)

for some other commodities." They arise from personalized nonconvexities, i.e., person-specific fixed costs. The commodities in the neo-classical model do not have this property; they are impersonal.

The supplies of impersonal commodities can be regarded as brought to a central market and anonymously redistributed to demanders. Personalized commodities are necessarily non-anonymous. Personalized nonconvexities imply that competitive pricing will be non-linear.

Rather than trading impersonal commodities on a market, the combination of non-anonymity and non-linearity implies that exchange will be in the form of a contract. For business cards, there is a sales contract between a particular buyer and seller in which the buyer chooses from a schedule exhibiting quantity discounts. Similarly, working half-time would yield less than half the pay. Hence, the buyer and seller have to agree on the number of hours worked that is based on a wage schedule with quantity bonuses.

Contractual pricing for personalized commodities is the logical counterpart to the linear anonymous pricing of impersonal commodities. Depending on the environment, each can be an expression of perfect competition.

Nevertheless, by exploiting the idea of indivisible commodities, the above departures from neo-classical pricing can be transformed to take on the formal appearance of linearity and anonymity in a larger space. Regard each quantity of business cards from a seller to a buyer as a different commodity. Hence, there is no requirement that the commodity consisting of ten cards to one buyer should be priced at ten times the commodity consisting of one card. However, because a specific quantity supplied to a single buyer is an indivisible package, the revenue from supplying ten one-card packages to ten different individuals is ten times the revenue from supplying one one-card package, i.e., the price system is linear in packages. While straightforward in simple cases such as business cards, this transformation is also the source of virtual pricing for arbitrarily complex packages.

6.2 Varieties of personalized nonconvexity

The examples above may be distinguished by the extent of personalization. For example, the printer of business cards serves many customers and each customer might use other printers for different printing demands such as party invitations. Hence, the extent of personalization is small compared to the labor market example when an individual supplies all of his labor to one demander.

The examples may also be distinguished by the origin of the personalized nonconvexity. For business cards, it is physical capital — the print machine has to be reset for each customer, whereas in the labor example, the personalization is with respect to human capital. Each of these sources have played separate, important roles in the theory of the firm. While the focus of this paper is labor, for purposes of comparison, we briefly describe some issues related to non-human capital.

To increase the extent of personalization in the business card example, suppose that a printer must specialize his entire production facility to serve one customer. Moreover, assume that personalization of the customer's needs are such that production facilities cannot be used to serve another. This is an instance of what Williamson (1971, 1985) and Klein, Crawford and Alchian (1978) call asset specificity.

The increased extent of personalization sets up a contrast between ex ante competition among buyers and sellers of printing services followed by ex post bilateral dependence, especially by the printer whose investment, once undertaken, has no value elsewhere. Williamson calls this a fundamental transformation common to many types of investment. The transformation exposes the parties to, in the words of Klein, Crawford and Alchian, ex post appropriation of quasi-rents.

There are two components to asset specificity, personalized nonconvexity and the opportunities this creates for strategic behavior. These opportunities could be foreclosed if, before investments are made, enforceable contracts could be written covering all possible contingencies. Then, the allocation of resources could be determined at the competitive ex ante stage, and the personalized nonconvexity feature by itself would not have the implications that have come to be associated with asset specificity. It is the impracticalities of such contracts, interpreted as transactions costs, that is the sticking point: anticipation of ex post hold-up as a result of incomplete contracting discourages productive investment.

The twin features of asset specificity therefore provide a rationale for vertical integration, i.e., a transactions costs reason why, to promote efficient investment, certain decisions should be taken under common ownership rather than being left to the market. Ideally, if vertical integration could be accomplished without reducing competition and without loss in efficiency, the re-location of the investment decision from the market to a firm would overcome the potential impediments introduced by transactions costs, thereby providing a concrete example of Coase's theme.[3]

The team production model, above, treats all non-human resources as impersonal commodities. Hence, asset specificity is precluded. In fact, the role of physical capital such as electrical generating capacity as a source of the economies of team production is ignored because, although relevant, our argument does not rely on it.

But the assumption that each individual can only be a member of one team does imply that the supply of labor is subject to the maximum degree of personalization. Yet, ex post bargaining problems do not arise because the labor commodity combines what is, from the asset specificity perspective, two contradictory features: there is (1) a transformation from ex ante competition to ex post specificity along with (2) ex post flexibility.

With respect to (1), just as there are advantages to custom designed machines to produce particular outputs, the specific sequencing of interdependent tasks among team members is essential to realized productivity. For example, consider team production in a restaurant: Customers place orders with servers, who communicate them to the expediter, who calls it out to the various station chefs (saucier, fish cook, roast cook, pastry chef), who prepare and plate the orders and pass them to the expediter, who gives it to the runners to deliver to the customers.

If personalized nonconvexities did not exist, tasks would become impersonal. Then, other individuals could be inserted into this mix. For example, there could be minute-by-minute competitive market transactions between sauciers and fish cooks. That there are no such markets and that each person should be responsible for an indivisible package of tasks is a feature of technology. Consequently, the competitive pricing system assigns a price to the person's entire role in a team, rather than separate unit prices to all the many tasks that constitute a role. Note that while the details may be quite complicated, we do not appeal to transactions costs to limit what might be included in these contractual arrangements.

With respect to (2), above, even though individuals are employed in very specific ways, their capacities to perform these tasks are malleable — individuals can adapt to other tasks in the same or other teams. Being a pastry chef in one restaurant does not preclude a similar role in another restaurant or switching to roast cook. Of course, individuals vary in their ability to perform various tasks.

3. But Coase (2006) uses the prevalence of incompleteness as an argument against opportunism. Commenting on his investigation of long-term supply contracts in 1945, "Such incompleteness, as was found in these contracts, would not commonly exist unless opportunism was rare."

To summarize, the neo-classical model prices labor as it does other commodities, linearly and impersonally. The introduction of personalized nonconvexities changes the focus from the number of hours of labor bought and sold at a given price per unit to contracts among particular buyers and sellers in which the price varies with the package of labor hours. Extending personalized nonconvexities to team production, agreements can be for quite complex packages involving interpedendent sequencing of tasks. The valuation of this package is a labor contract, a key step on the way to an employment contract.

6.3 The marginal product of the residual claimant entrepreneur

Along with Knight (1921), Coase (1937), Simon (1959) and others, Alchian and Demsetz (1972) regard the employment contract — where workers agree to take direction from an employer in exchange for a salary, the employer to receive the residual — as the distinguishing feature of a firm. Their explanation pairs team production with shirking. The timing of their contribution is significant. The authors presented a sophisticated application of agency and contract theory before either of these topics were recognized as fields of specialization. And, once these fields were established, their formulation became a reference point for future developments.

In parallel with asset specificity, where the purely technological aspect without its opportunistic implications is of little interest, so, too, is their treatment of team production. "Although the nature of teamwork and its relation to what we call a firm has been explored and found illuminating, (Alchian and Demsetz [1972]) teamwork is not the essence of the firm (Alchian [1984], and Williamson [1985]). Rather, the essence is the nexus of contracts restraining the behavior of transactors." (Alchian and Woodward [1987].) The purpose of this section is to dispute this claim.

Consider an apposite example in Williamson (1989): "Suppose that an entrepreneur develops a distinctive, patentable idea that he sells outright to a variety of independent, geographically dispersed suppliers, each of which is assigned an exclusive territory. Each supplier expects to sell only to the population within its territory, but all find to their surprise (and initially to their delight) that sales are also made to a mobile population. Purchases by the mobile population are based not on the reputation of individual franchisees but on customers' perceptions of the reputation of the system. A demand externality arises in this way."

So, franchisees do not bear the full cost of reducing the quality of their products with the usual consequences for their joint profitability. In the example, the franchisor has already sold his interest. The franchisees might, therefore, want to hire the franchisor to monitor product quality in order to police themselves. And if the franchisor had leased rather than sold his idea, he would have a reason to write such a monitoring feature into contracts with franchisees.

The lesson we draw is that while particular features of the contract are explained as responses to opportunistic behavior, the rationale for franchise contracting is not. That is based on the gains from the transfer of knowledge. Monitoring plays a role in this example of franchise contracting similar that of vertical integration when there is asset specificity. In idealized form, each allows what would otherwise be an obstacle to efficiency to be overcome. Here, the monitoring feature of the contract allows the franchisor to realize the full value of his idea.

The transition to the problem Alchian and Demsetz analyze is evident: replace demand externality with interdependence in team production, quality deterioration with shirking, and a franchisor who leases with an entrepreneur. The latter is "the centralized contractual agent in a team production process." The features of the employment contract follow, according to the authors, from the need to monitor shirking, both by team members as well as the person responsible for monitoring. "If owners of cooperating inputs agree with the monitor that he is to receive any residual product above prescribed amounts (hopefully, the marginal value products of the other inputs), the monitor will have an added incentive not to shirk as a monitor."

Like the franchise contract, monitoring in the employment contract is regarded as overcoming an obstacle that would otherwise prevent the entrepreneur from receiving his marginal product. "The specialist who receives the residual rewards will be the monitor of the team (i.e., will manage the use of cooperative inputs). The monitor earns his residual through the reduction in shirking that he brings about, not only by the prices he agrees to pay the owners of the inputs, but also by observing and directing the actions or uses of these inputs." Questions arise at this juncture in the argument.

What is the source of the entrepreneur's shirk-free marginal product? And why does monitoring include two rather different functions, reducing shirking and "observing and directing the actions or uses of others"? According to the authors: "We use the term monitor to connote several activities in addition to its disciplinary connotation. It connotes measuring output performance, apportioning rewards, observing the input behavior of inputs as a means of detecting or estimating their marginal productivity and *giving assignments or instructions in what to do and how to do it*." (Italics added.) As a description of real-world complexity, we can stipulate to this broad definition of monitoring.

Our critique is that the employment contract can be given a more elementary and more immediate rationale. It is more elementary because the definition of monitoring is simply the italicized part, above. Moreover, the elementary definition is directly connected to the entrepreneur's marginal product. Rather than regarding the function of the employment contract as restraining opportunistic behavior, thereby permitting the monitor to "earn his residual through the reduction in shirking he brings about," the entrepreneur earns his residual exactly by transferring knowledge via the italicized description above. The incentive to provide such monitoring is straightforward: the less accurately the information is conveyed, the less it is worth, and therefore the lower the entrepreneur's residual.

The Alchian and Demsetz definition of monitoring combines opportunistic and non-opportunistic rationales.[4] Once their definition of monitoring is recognized as including these different functions, it is natural to ask:

– Can the opportunistic and non-opportunistic parts be usefully separated?

– Is one more important to the theory of the firm than the other?

Our answer to the first question is unequivocal. We do not regard the existence of a firm (i.e., an employment contract) as evidence of opportunism. Rather, it is evidence of the limitations of the price system — as illustrated, for example, by the need for household administration. These limitations are dormant in the neoclassical model because it was designed to focus exclusively on market behavior. The goal of this paper has been to provide a rationale for the employment contract as a necessary complement to those limits, without which the price system could not function properly.

It is beyond the scope of this paper to answer the second question, but not to raise it. The authors' use of a sports metaphor to illustrate their broad definition of monitoring is suggestive. "Perhaps the contrast between a football coach and

4. Judged by how it has been interpreted, their message is that monitoring deals only with shirking. Demsetz (1992), however, has modified his position. "Directability allows specialized information by some team members to enhance the productivity of other team members without requiring these others to learn this specialized information themselves. It is in this sense that I now believe that the shirking rationale for monitoring behavior is overstated."

a team captain is helpful. The coach selects strategies and tactics and sends in instructions about what plays to utilize. The captain is essentially an observer and reporter of the performance at close hand of the members. The latter is an inspector-steward and the former a supervisor manager. For the present all these activities are included in the rubric 'monitoring.' "

The coach is responsible for the non-opportunistic functioning of the team and the captain for detecting shirking. Answering the questions above based on this example, the positions of coach and captain are evidently separate. And, while the appointment of a team member as captain serves a purpose, it is dominated by that of the coach. In our view, that also applies to a firm.