For submission to The PracTEX Journal
Draft of October 17, 2014

Competititve Appropriation with Special Reference to Know-how

Louis Makowski* and Joseph M. Ostroy†

(December 2013)

Abstract A formulation of task assignments along with a proprietary specification of know-how replaces the traditional description of production. In the resulting model, the phenomenon of internal organization reflects the necessarily partial role of the price system in an expanded description of resource allocation, in contrast to the view that internal organization is evidence of the price system's deficiency. The employment contract, where workers agree to take direction from an employer, is based on the employer's know-how, the payment to the employer reflecting the value of proprietary knowledge. From the appropriation perspective, restraints on shirking are adaptations allowing the employer to appropriate a greater fraction of the value of know-how, rather than the essence of the employment contract. The relation between ownership and control and opportunistic issues underlying the hold-up problem are similarly addressed as variations on the theme of appropriability.

*Department of Economics, UC Davis: lmakowski@ucdavis.edu
†Department of Economics, UCLA: ostroy@ucla.edu

Contents

1 Introduction 1

2 From price-taking to full appropriation 2

3 The utility function as a black box 3
3.1 Household administration . . . 3

4 Production by single individuals 5
4.1 Coordination between consumer and producer . . . 6
4.1.1 Indecomposability . . . 7
4.2 A proto-employment contract . . . 8

5 Production involving more than one person 9
5.1 Personalized nonconvexities and contractual pricing . . . 9
5.2 Team production . . . 11
5.3 Formal model . . . 13
5.3.1 Team task assignments . . . 13
5.3.2 Consumption and production activities . . . 14
5.3.3 Allocations . . . 14
5.3.4 Alternative descriptions of equilibrium . . . 15

6 Competitive appropriation and theories of the firm 18
6.1 Appropriation and Incentives . . . 18
6.2 The employer's shirk-free marginal product . . . 19
6.3 Property rights and control: asset-specificity . . . 21
6.3.1 Appropriation problems in a small numbers setting . . . 23
6.4 Appropriation with respect to know-how . . . 25

7 Concluding comment 27

Perhaps unwittingly the literature of managerial behavior is enlarging the realm of formal economic theory to be applicable to more than conventional, individual property systems. A. Alchian (1965).

1 Introduction

The standard (neo-classical) formulation of technology is insufficiently specified to address issues relevant to internal organization. The influential framing by Coase [1937] casts internal organization and the price system as opposing methods of resource allocation where the need to make room for the former requires acknowledging deficiencies in the latter. In the formulation, below — in addition to an emphasis on the importance of indivisibilities underlying team production — production possibilities will include a description of how things get done along with a proprietary specification of who knows what. Internal organization will be understood as reflecting the necessarily partial role of the price system in an expanded description of resource allocation, rather than evidence of its deficiency. The goal of this paper is to show that the price system *and* internal organization mutually reinforce and enable individuals to fully appropriate what they can contribute.

Property rights establish the domain over which individuals compete. Full appropriation of the gains from property rights requires the full force of competition. Internal organization is often subject to an unavoidable absence of substitution possibilities with respect to behavior within and as well as transactions between firms. Recognition of these impediments has played a central role in addressing firm formation. (refs) Nevertheless, the rationale for internal organization will be set in the presence of perfect competition.

Despite differing perspectives that

- the price system should play only a partial role in a more complete description of resource allocation,

and the related view that

- internal organization is compatible with perfect competition,

another goal of the paper will be to show that

- by grounding internal organization in the logic of appropriability a bridge can be built to the contemporary focus on opportunistic behavior.

Section 2 contains a brief comparison of the appropriation perspective on competitive equilibrium compared to the standard price-centric view. Section 3 introduces know-how as part of the consumer's problem. Section 4 gives a more detailed model of know-how when an individual is both a consumer and producer. A hypothetical pricing scheme coordinating task assignments between consumer and producer is compared to a proto-employment contract. Section 5 introduces the importance of indivisibilities requiring team production as the essential way to exploit know-how. Competitive equilibrium is characterized as a the determination of who employs whom, with the rewards to employers determined by the marginal products of their know-how. Section 6 reviews shirking and asset specificity as sources of firm formation. The important incentive issues they entail are regarded from the appropriation perspective. In contrast to the large numbers competitive setting of Section 5, a characterization of incentive schemes promoting full appropriation in a small numbers setting is given. This framework is used to restate some conclusions from Grossman and Hart [1986]. The concluding Section 7 is a brief summary of the importance of know-how versus opportunistic behavior as sources of firm formation.

2 From price-taking to full appropriation

Prices guide all choices in the general equilibrium model of resource allocation. From that perspective: "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." (Arrow [1974, p. 69])

The price-centric view of resource allocation is framed as the circular flow of commodities between consumers and producers: Consumers supply inputs demanded by producers that are converted to the supply of outputs demanded by consumers. Consumers are the the ultimate wealth-holders in the model, while producers are more abstract constructions. In Walras' original formulation, technologies for converting inputs into outputs were regarded as non-proprietary, i.e., freely available. When technology is non-proprietary, production may be regarded as a form of arbitrage and elimination of profits is evidently consistent with the position that the reward to a non-scarce resource is zero. Interest in internal organization necessarily requires a different approach.

More recent formulations of general equilibrium (Arrow and Debreu [1954]) introduce scarce technologies subject to decreasing returns. Profit-maximization via price-taking is a well-defined objective. However, because the firm is an entity distinct from individuals (consumers), its profits must be redirected. This is accomplished by parametrically assigning ownership shares of firms to consumers. But there is no requirement that an individual's ownership share should be connected to his productive contribution to the firm's technology. Hence, when production is described by abstract firms with scarce technologies, the standard formulation provides insufficient information about property rights to address the issue of appropriation.

Rather than regarding the coordination role of market-clearing prices as the capstone from which the consequences for compensation are derived, determination of compensation will be an end in itself. Appropriation supersedes price determination as the *desideratum* of perfectly competitive equilibrium.

3 The utility function as a black box

The purpose of this section is to highlight an aspect of resource allocation that is suppressed: the price system provides only a part of the information required to get things done — the rest is provided by know-how.

3.1 Household administration

Consider the purchase of foods. The 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

1. The term is borrowed from Wicksteed [1910] who provides colorful illustration of the housewife's purchases as a derived demand and of her management skills in responding to contingent events such as reallocating the family's competing uses of milk when some of it has spoiled.

utility, i.e.,

$$\text{foods} \to \text{meals} \to \text{utility}.$$

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: the prices of foods do not tell the household how to prepare meals.

A realistic description of the complexities of meal preparation is not the issue. Our treatment is, therefore, abstract. Let $b = (b^1, b^2, \ldots, b^k)$ denote a sequence; and suppose each $b^h \in \{0, 1\}$, $h = 1, \ldots, k$, so that b is a binary sequence. Each b^h is 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 the existing 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.

For given knowledge of recipes and preparation skills/costs, there is a *derived* utility function for foods as

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

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., $U(e, b, m) = V(z, b) + m$, the individual's indirect utility can be written as a function of food prices,

$$v^*(p \mid B) = \max_z \{v(z \mid B) - p \cdot z\}.$$

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

Regard B as proprietary. Suppose, for example, individuals 1 and 2 with identical tastes for meals, but $B_2 = \emptyset$, indicating that 2 is incapable of meal preparation and is forced to consume foods directly, i.e, $e(z, \emptyset) \sim z$. Then $v^*(p \mid B_1) - v^*(p \mid B_2)$ measures the value added of B_1 over B_2 when market prices of foods are p.

The remarkable properties of the price system are exhibited by the fact that it fulfills its function even though information about the real goods, i.e., the meals and how they are prepared, is dispersed and hidden.

4 Production by single individuals

In the contemporary description of production, 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 positive 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 production function $y_1 = f(y_2)$, where y_1 is the maximum output from input y_2. Schematically, the neo-classical 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 by an individual,

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

Again, $b \in B$ is a binary sequence representing tasks. Denote by $y(b)$ the input/output combination y possible with b. The augmented description of technology is

$$\mathcal{Y}[B] := \{y(b) : b \in B\}.$$

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. Individual utility will continue to be written as $V(z, b) + m$ because task assignments for production may have utility consequences. The production $y(b)$ and commodity trades $\tilde{z}$ yields $z = \tilde{z} - y(b)$ as the individual's net trade. The derived utility of the consumer/producer underlying the trade z can be summarized as

$$v(z \mid \mathcal{Y}[B]) = \max_{\tilde{z}, b} \{V(z, b) : \tilde{z} - y(b) = z,\ \tilde{z} - y(b) \in Z,\ y(b) \in \mathcal{Y}[B]\}.$$

When market prices of all commodities (inputs and outputs) are given by p, $-p \cdot z = -p \cdot (\tilde{z} - y(b))$ is the market value of the individuals net trades with others, i.e., $-p \cdot \tilde{z}$ is the market value of non-produced purchases and sales and

$p \cdot y(b)$ is the revenue from outputs minus the cost of inputs, or profits from production. The individual's market behavior is explained by the desire to achieve

$$v^*(p \mid \mathcal{Y}[B]) = \max_z \{v(z \mid \mathcal{Y}[B]) - p \cdot z\}.$$

This is another instance of the supercession of the price system. Information about $\mathcal{Y}[B]$ can be suppressed because it is under the control of the consumer/producer.

4.1 Coordination between consumer and producer

Koopmans [1957, p. 16-23] uses the example of an individual consumer/producer as a canonical illustration of the decentralization role of the price system that coordinates decisions among households and firms. The demonstration shows that prices can be used to separate the individual into his consumer and producer sides with no loss in overall utility.

Consider what would be required to mimic this argument when there are task assignments. In Koopmans' setting, the commodity space defines the relevant choices and is assumed to be commonly known by the consumer and producer. Here, the "commodity space" includes the set B which may be a subset (or a superset) of the task assignments the consumer is capable of performing.[2] The situation is analogous to modelling commodity innovation, where the consumer's overall preferences are defined on a universal set of commodities, but knowledge of which commodities can be produced is known by the producer.

A pricing function $\mathfrak{P}(b)$ must be introduced to evaluate each b. Unlike commodity prices p that do not vary with the number of units exchanged or the individuals involved, $\mathfrak{P}(b)$ specifies a payment for a particular b from a producer/buyer to a consumer/seller. The coordination role of $\mathfrak{P}(\cdot)$ is to make the buyer of b (the producer) choose the same task assignment as the seller of b (the consumer). To guide production, profit maximization is

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

Utility maximization is

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

To fulfill their functions, $(p, \mathfrak{P})$ should satisfy This confirms that the consumer and producer sides of the individual do not have to communicate directly. They can achieve the necessary coordination through $(p, \mathfrak{P})$, although such an interpretation stretches the meaning of "prices" for $\mathfrak{P}$ well beyond its normal bounds.

2. To acknowledge that the consumer is not capable of $b \in B$, $V(z, b) = -\infty$.

4.1.1 Indecomposability

Suppose that for each $b = (b^1, b^2, b^3, \ldots, b^k)$, $y(b)$ could be decomposed into incremental changes as

$$(D) \qquad \sum_{h=1}^{k} [y(b^1, b^2, \ldots b^h) - y(b^1, b^2, \ldots b^{h-1})],\ h = 1, \ldots, k,$$

where $y(b_0) = 0$. Condition (D) says that the consequences of the sequence of task assignments can be additively separated into the consequences of each successive task. The profitability of proceeding from b^1 to b^2 could be determined by $p \cdot [y(b^1, b^2) - y(b^1)]$. Hence, there would be minimal need for coordination beyond what the price vector p already provides.

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 (D). Then, every step in the process of converting inputs to outputs results in a potentially marketable good that could be sold to another producer rather than be performed as the next step in the task assignment. Recall 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. The following interpretation of the example exhibits circumstances under which the allocation of individual tasks could, in principle, be coordinated by the price system.

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 headcutters, 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."

Ashton's account makes it clear that the tasks were performed by employees, not independent contractors. Nevertheless, pin production invites an alternative 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. Smith's example can be construed as carried out by single individuals and the price system could have transformed tasks into trades.

Our premise is that such a situation is exceptional and the failure of (D) is a ubiquitous feature of technology: intermediate stages in the assignment of tasks do not typically result in tradeable commodities.

4.2 A proto-employment contract

Like tastes, how to get things done is part of a person's characteristics, rather than a proprietary set of instructions that could be read, understood, and transferred to others. To reinforce its inalienability, let ω a signal having no direct implications for utility that is observed only by the producer. The realized productivity of task assignments is dependent on ω as $y(b, \omega)$. Know-how is the individual's ability to translate personal signals into productive task assignments.

Assuming ω is observed before task assignments are made, the objective is to find $b(\omega)$ and $\bar{z}$ such that

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

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

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

and utility maximization would be

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

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

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

Prices tell the consumer/producer that $\mathfrak{P}(\cdot|\omega)$ guides the choice of b.

An important feature of task assignments is that utility insignificant differences can have significant productivity consequences, i.e., the sensitivity of $y(b,\omega)$ to b is often greater than the utility implications for $V(z,b)$ of changes in b. To simplify, suppose

$$V(z,b) = V_1(z) + V_2(b).$$

Let $\mathcal{I}$ be a disjoint family of subsets of B such that if $E \in \mathcal{I}$ and $b, b' \in E$, then $V_2(b) = V_2(b')$; hence, an $E \in \mathcal{I}$ is a collection of utility-indifferent task assignments. In the extreme case that $B \in \mathcal{I}$, all tasks are utility indifferent. We presume that for any $E \in \mathcal{I}$, $y(b,\omega)$ is not productivity indifferent on E.

To illustrate how communication between the producer and consumer could be implemented, let $q : \mathcal{I} \to \mathbb{R}$ be a payment schedule relevant to the consumer. The producer maximizes profits by choosing $b[\omega]$ to satisfy

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

The consumer's objective is

$$\max\{V_1(z) + V_2(E) - p \cdot z + q(E) + \pi(p|\omega) : z \in Z, E \in \mathcal{I}\}.$$

Unlike $\mathfrak{P}(b|\omega)$, prices $q(E)$ do not tell the producer or the consumer how to choose b. That is left to the producer.

5 Production involving more than one person

5.1 Personalized nonconvexities and contractual pricing

Divisibility of commodities is another feature of the standard description of resource allocation. If $d_i, s_j \in \mathbb{R}_+$ are the demands and supplies of $i = 1, \ldots, H$ and $j = 1, \ldots, K$, total demand and supply balance when

$$\sum_{i=1}^{H} d_i = \sum_{j=1}^{K} s_j.$$

It is immaterial how the equality is fulfilled; e.g., 1's demands can be satisfied by any $\alpha_j \in [0,1]$ such that

$$d_1 = \sum_{j=1}^{K} \alpha_j s_j.$$

Trading is impersonal since it allows participants to divide their purchases and sales willy-nilly among sellers and buyers. Divisibility in the supply of labor services implies they are impersonal, suppressing a relevant feature of internal organization.

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 for some other commodities." They arise from personalized nonconvexities, i.e., person-specific fixed costs.[3] Whereas 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 exchange must be person specific and that competitive pricing will be non-linear. 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.

Personalization may be distinguished by the extent of the nonconvexity. 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 where an individual supplies all of his labor to one demander. The examples may also be distinguished by the origin of the 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. To increase the extent of personalization in the business card example, suppose the printer must specialize his entire production facility to serve one customer. Each of these forms of personalization is the source of separate lines of inquiry in the theory of the firm, further discussed in Section 6.

3. Economies of scale are defined by impersonal nonconvexity with respect to commodities.

Remark: Non-linear pricing for commodities with personalized non-convexities is the logical counterpart to the linear anonymous pricing of impersonal commodities. Because it specifies the transfer of specific quantities among specific individuals, another name for it is contractual pricing. Contractual pricing can take on the formal appearance of linearity and anonymity in a larger space by exploiting the idea of indivisible commodities. To illustrate, 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 method of redefining commodities is applicable to the pricing of complex packages. Moreover, as shown in Makowski [1980], Cole and Prescott [1997] and Ellickson, Grodal, Scotchmer, and Zame [1999], these packages can be defined as roles in teams or memberships in clubs. ....explain the difference between role in team and specific task assignment within that role..... The function $\mathfrak{P}$ in Section 4.1-2 exploits this form of pricing to exhibit an extreme example of contractual pricing.

5.2 Team production

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.[4]

Resource allocation has to broaden its focus from commodity pricing to take on the responsibility for determining which teams form and, once formed, which task assignments are undertaken. The feasible ways to combine inputs into outputs depends on who the members are and how tasks are assigned. To illustrate

4. See Gawande [2012] for a detailed description of meal preparation and delivery in a chain restaurant.

with a team consisting of two persons where the first row is the tasks assigned to 1 and the second row is the tasks assigned to 2, two different task assignments are

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

The B for one pair is unrelated to another pair even when one of the members is the same. Tasks are idiosyncratic to the team.

The productivity of the team depends on the coordinated participation of its members. In that respect, it is similar to the complementary inputs of neo-classical production function. But the methods 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 and 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., $p_2 = p_1 f'(y_2)$. Marginal analysis to determine the quantity of labor does not make sense in this setting. The separate tasks that individuals perform are neither infinitesimal nor homogeneous. Indeed, an essentially defining feature of team production is that if each of the tasks were rewarded with its marginal product, the sum of the payments would be significantly greater than the total output. Marginal product refers to the contribution of the team member.

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, the sole-proprietor, who uses his knowledge to implement task assignments. 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 of types 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. Equilibrium determines whose knowledge is utilized and, therefore, who is directed by 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 control based on his know-how. These, and many other, issues are part of a richer picture of internal organization. This is an *a fortiori* simplification of the treatment of know-how.

5.3 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. Assume the conflicts are so severe that an individual can only be a member of one team.

In contrast with the more parsimonious general equilibrium description of what constitutes an allocation of resources, the added detail in the specification, below, calls attention to the incompleteness of the standard description.

5.3.1 Team task assignments

Denote by $T \subseteq I$ the members of a team. A team task assignment b includes the types of individuals involved, given by $T(b) \subset I$.

The informational endowment of all types is

$$\boldsymbol{\omega} = (\omega_1, \omega_2, \ldots, \omega_n).$$

The task assignments initiated by i as the director are

$$B_{ii}(\omega_i) = \{b : i \in T(b),\, b = b(\omega_i)\}.$$

The information source ω_i is 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. The set of task assignments directed by j in which $i \neq j$ could participate as a follower is

$$B_{ji}(\omega_j) = \{b : i \in T(b),\, b \in B_{jj}(\omega_j)\}.$$

To illustrate, if there are 4 types and $i = 1$, then

$$b = \begin{pmatrix} 1 & 0 & 0 & \cdots & 1 & \omega_1 \\ 0 & 1 & 0 & \cdots & 1 & \emptyset \\ \emptyset & \emptyset & \emptyset & \cdots & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & \cdots & \emptyset & \emptyset \end{pmatrix} \in B_{11}(\omega_1) \cap B_{12}(\omega_1)$$

represents a task assignment in the team consisting of individuals of types 1 and 2 directed by 1. A self-employed person is represented by a matrix with one non-null row, i.e., a b with $T(b) = \{i\}$.

The set of task assignments in which i can participate either as a leader or a follower is

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

5.3.2 Consumption and production activities

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

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

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

The productive consequences of all possible task assignments are collected as

$$A_0(\boldsymbol{\omega}) = \{(y, b) : b \in \cup_i B_{ii}(\omega_i),\ y = y(b, \omega_i)\}$$

Each possible y is directed by some i in conjunction with the other members of $T(b)$. The tasks the members of $T(b)$ are capable of performing and their productive consequences are known to i.

5.3.3 Allocations

An allocation of activities among consumers of type i is described statistically by $x_i \in M(A_i(\boldsymbol{\omega}))$, the non-negative measures on $A_i(\boldsymbol{\omega})$, i.e., $x_i(z, b)$ is the mass of individuals of type i engaging in the activities (z, b). Similarly, let $x_0 \in M(A_0(\boldsymbol{\omega}))$ 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

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

The remainder of this section describes the conditions for a feasible allocation.[5]

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 individual can be either an employers or an employee. 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.

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

5. Without loss of generality, attention can be confined to measures with finite support.

Equation (1) describes an aggregate matching condition. The following two restrictions describe finer matching restrictions:

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

$$\sum_z x_i(z,b) - \sum_y x_0(y,b) \;=\; 0,\ \forall b \in B_{ji}(\omega_j),\ \forall i \in T(b)\backslash\{j\},\ \forall i \tag{3}$$

(2) says that the number of individual consumers of any type directing a specific task assignments equals the number directing the same task assignment in the production sector. Similarly, (3) stipulates that those consumers participating as directed in a specific task assignment equal the number in the production sector.

The final condition is the standard equality with respect the circular flow of commodities between producers and consumers.

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

Note the difference between the aggregation underlying (4) versus the disaggregation describing (2)–(3). Equation (4) reflects the anonymity of commodities: 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. Equations (2) and (3) are much more specific. For example, the task assignment $b = b(\omega_i)$ directed by i must be matched by the participation of individuals $j \in T(b)$, $j \neq i$, as followers, in the same assignment.

To further simplify, assume that individuals are indifferent among task assignments,

$$V_i(z,b) = V_i(z),\ \forall b \in B_i(\boldsymbol{\omega}),\ \forall i. \tag{A}$$

Hence, the only cost to i of participating in $b \in B_i(\boldsymbol{\omega})$ is the foregone opportunity of participation in any other $b' \in B_i(\boldsymbol{\omega})$.

5.3.4 Alternative descriptions of equilibrium

One way to emphasize why the price system should play only a partial role in the allocation of resources is to describe what prices would look like if they were responsible for directing all economic activity.

To this end, let $(p, (\mathfrak{P}_i))$ be a price system where $p \in \mathbb{R}^\ell$ is a vector of commodity prices and $\mathfrak{P}_i(b)$, $b \in B_i(\boldsymbol{\omega})$ is the payment to i for each task assignment in which i might participate. When $p \cdot y > \sum_{i \in T(b)} \mathfrak{P}_i(b)$, the market valued-added of (y, b) exceeds the payments to those who produced it, implying an entrepreneurial "free lunch." Candidate price systems $(p, (\mathfrak{P}_i))$, below, are limited to those such that

$$p \cdot y \leq \sum_{i \in T(b)} \mathfrak{P}_i(b), \quad \forall (y, b) \in A_0(\omega).$$

Utility maximizing demands for i at $(p, \mathfrak{P}_i)$ are based on the objective

$$V_i^*(p, \mathfrak{P}_i) = \sup\{V_i(z) - p \cdot z + \mathfrak{P}_i(b) : z \in Z_i, b \in B_i(\boldsymbol{\omega})\}$$

Aggregate demand among individuals of type i at prices $(p, \mathfrak{P}_i)$ is represented by a measure $x_i(p, \mathfrak{P}_i) := x_i(\,\cdot\,; p, \mathfrak{P}_i)$, $i = 1, \ldots, n$, whose support consists only of those who are maximizing with respect to those prices:

$$x_i(z, b\,; p, \mathfrak{P}_i) > 0 \Longrightarrow V_i(z) - p \cdot z + \mathfrak{P}_i(b) = V_i^*(p, \mathfrak{P}_i).$$

Aggregate supply at $(p, (\mathfrak{P}_i))$ is a measure $x_0(p, (\mathfrak{P}_i)) := x_0(\,\cdot\,; p, (\mathfrak{P}_i))$ whose support requires that all profits be distributed to those who contributed:

$$x_0(y, b; p, (\mathfrak{P}_i)) > 0 \Longrightarrow p \cdot y = \sum_{i \in T(b)} \mathfrak{P}_i(b)$$

Definition: The pair $\langle (x_0, x_1, \ldots, x_n), (p, (\mathfrak{P}_i)) \rangle$ is a *price-directed equilibrium* if $x_i = x_i(p, \mathfrak{P}_i)$, $i = 1, \ldots, n$, $x_0 = x_0(p, (\mathfrak{P}_i))$, and $(x_0, x_1, \ldots, x_n)$ is feasible.

Price-directed equilibrium follows the Walrasian prescription that all economic activity is coordinated through prices. Evidently, the price system is called upon to do too much. More specifically, the function $\mathfrak{P}_i(\cdot)$ flouts the usual meaning of prices because personal, proprietary information with respect to know-how is publicly evaluated.

Instead of focusing on prices to balance demand and supply, start with the premise that the only allocations considered are those that are feasible: teams have been formed, tasks assigned, the resulting production is purchased for consumption, and the rewards from sale are distributed to team members. Equilibrium is achieved when all further profit opportunities have been eliminated. A perfectly competitive equilibrium is a special case of that condition in which individuals have fully appropriated what they can contribute. In this setting, perfectly competitive equilibrium can be characterized with the aid of the following:

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

Definition: The feasible allocation $(x_0, x_1, \ldots, x_n)$ is a *perfectly competitive equilibrium* if there exists a (p, q, r) such that

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

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

(ii) $x_i(z, b) > 0$ 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 $r_i \geq q_i$,

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

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

and $r_i \leq q_i$.

Equation (2), above, defining a feasible allocation implies that if there is any production activity, then some fraction of the population must be directing the underlying task assignments. Condition (i) says that r_i is the maximum profit i can earn among all possible teams i can direct given the prices q_j for hiring others. If $r_i \geq q_i$ for all i, then everyone is self-employed, and team production is not profitable. There is team production if for some j, $r_j < q_j$. Hence, there exists $x_0(y, b) > 0$ such that $b \in B_{ii}(\omega_i)$ and $T(b) \neq \{i\}$. The presence of team production implies that some types of individuals can profitably direct others because the reward from their know-how is greater than what they would be paid as an employee.[6]

Perfectly competitive equilibrium is a pared down version of price-directed equilibrium. To move from the latter to the former: If $x_0(y, b; p, (\mathfrak{P}_i)) > 0$ and $b \in B_{ii}(\omega_i)$, set $\mathfrak{P}_i(b) = r_i \geq \mathfrak{P}_i(b'), b' \in B_i(\omega)$; and if $x_0(y, b; p, (\mathfrak{P}_i)) > 0$ and $b \in B_{ji}(\omega_j)$, set $\mathfrak{P}_i(b) = q_i \geq \mathfrak{P}_i(b'), b' \in B_i(\omega)$.

6. The symmetry of the model makes no presumptions about relative scarcities, e.g., it allows for the possibility that some employees can earn more than some employers, i.e., $r_i > q_i$ and $r_j < q_j$, but $q_j > r_i$.

Assuming it is positive,

$$\begin{aligned} r_i - q_i &= \text{Marginal Product of } B_{ii}(\omega_i) \\ &= \text{Market Value of } i\text{'s Know-How} \end{aligned}$$

The statement applies whether or not i is self-employed. In either case, the price system (p, q, r) does not transmit information on how to get things done. Rather, it provides information to those whose know-how can be put to profitable use.

REMARK: The statement that $r_i - q_i$ is the marginal product of i's know-how is a demonstrable conclusion of the model. The marginal product is a directional derivative, defined as the rate at which the total gains in the economy would change if an infinitesimal fraction of individuals with i's know-how were replaced by individuals like i, but without any know-how, i.e., $B_{ii}(\omega_i) = \emptyset$. The mathematical condition that $r_i - q_i$ measures the marginal product does not necessarily follow from the hypothesis that individuals are infinitesimal. Nevertheless, it can be established as the typical conclusion. See, for example, Gretsky, Ostroy and Zame [1999].

6 Competitive appropriation and theories of the firm

Features of the standard formulation of competitive equilibrium such as

(1) emphasis on price determination,

(2) identification of perfectly competitive behavior with price-taking,

(3) impersonal description of commodity trades, and

(4) impersonal description of firms

are reasons why the integration of internal organization with competitive equilibrium might look like a unprofitable merger. But these are legacies of a model in which (2)–(4) were useful simplifications allowing a sharper focus on (1), rather than the defining characteristics of perfectly competitive equilibrium.

6.1 Appropriation and Incentives

Alchian [1984] provides a succinct summary of the contemporary view of the firm as "a nexus of contracts restraining the behavior of individuals." In more detail, “A firm is a coalition of interspecific resources owned in common, and some generalized inputs, whose owners are paid, because of the difficulty output of measurability, according to criteria other than directly measured marginal productivity, and the coalition is intended to increase the wealth of the owners of the inputs by producing salable products.” The term “interspecificity” is meant to be comprehensive: it includes the person-specificity implied by team production as well as the asset-specificity associated with interdependent long-lived non-human capital investments. In either case, once the focus shifts to interpersonal and strategic relations as the underlying rationale for the firm, price determination issues that figure prominently in (1)–(4), above, appear to be less relevant.

A different perspective emerges when competition is based on appropriation. The discussion, below, will focus on two claims. The first is:

(i) the employment contract can be meaningfully addressed as an instance of full appropriation.

This stands in specific contrast to the attention given to shirking and, more broadly, to the view that the presence of firms represents a failure of the price system.

Full appropriation occupies a boundary position in the space of economic environments. As an organizing principle, it also serves to delineate the interior. Full appropriation is another name for individuals receiving their marginal products, i.e., extracting all the gains the individual contributes. Its implications for efficiency are familiar as the reason a perfectly discriminating monopolist would not, and a simple monopolist would, withhold supply. More systematically, the full appropriation description of perfect competition points to the consequences of imperfect competition as: *What are the implications for incentives arising from various forms of incomplete appropriation*? The second claim is an interpretation of this theme relating to the boundaries of a firm:

(ii) the hold-up problem, predicated on the absence of substitution possibilities, addresses implications of the failure of full appropriation.

6.2 The employer’s shirk-free marginal product

Alchian and Demsetz [1972], along with Coase [1937], Simon [1951] and others, regard the employment contract, where workers agree to take direction from an employer in exchange for a fixed payment, as a defining characteristic of a firm. This real-world feature is in evident contrast to the the neo-classical formulation where individuals take direction from prices.

The phenomenon of team production is invoked as a necessary condition, but team production, by itself, is not the source of employment contracts. "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])." Their explanation calls attention to the need to monitor shirking by team members. And, in particular, the *residual claimant* status of the person responsible for monitoring as the key to understanding the organization of productive activity in a firm. The entrepreneur/employer is "the centralized contractual agent in a team production process. ... 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*." (Italics added.)

Their definition of monitoring is broad. "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.) This raises a question about the relation between the form of the contract and the employer's reward. Alchian and Demsetz emphasize that the payment to the employer is the value-added from reduction in shirking, as if that kind of monitoring could be isolated from the know-how on which it is based. But the broader definition of monitoring leaves room for the employer to have a shirk-free marginal product. Instead of "earn his residual through the reduction in shirking he brings about," the employer's reward can be derived from communicating know-how via the italicized descriptions, above, and: "The employer, by virtue of monitoring many inputs, acquires special information about their productive talents. This aids his *directive* (i.e., market hiring) efficiency. He 'sells' his information to employee-inputs as he aids them in ascertaining good input combinations for team activity. .... Efficient production with heterogeneous resources is a result not of having *better* resources but in *knowing more accurately* the relative productive performances of these resources." (Original italics.)

The authors highlight the residual claimant feature of the contract as providing the incentive for the monitor not to shirk in performing his duties. The same conclusion follows when monitoring is interpreted as directions based on know-how. The payment is properly regarded as a residual since it based on the outcome of the employer's instruction which is proprietary information. The incentive to direct is straightforward: the less detailed, the lower its value, and therefore the lower the employer's reward.

The employment contract can be founded on know-how without appeal to shirking. Of course this does not deny the importance of such complications. But the restraints these complications impose can be viewed as adaptations to accommodate the more mundane, but essential, reasons for employment contracts — rather than viewing the adaptations as the essence of the problem. From the appropriation perspective, the contribution of Alchian and Demsetz is reinterpretated as: Monitoring (policing) opportunistic behavior allows the employer to realize more of the value from monitoring (directing) based on know-how.[7]

6.3 Property rights and control: asset-specificity

Smith ([1776], Cannan ed. [1937], p. 366-69) recounts a development in British economic history illustrating a familiar theme in the theory of the firm.

> To the slave cultivators of ancient times, gradually succeeded a species of farmers known at present in France by the name of Metayers. .... The proprietor furnished them with the seed, cattle, and instruments of husbandry, the whole stock, in short, necessary for cultivating the farm. The produce was divided equally between the proprietor and the farmer, after setting aside what was judged necessary for keeping up the stock, ... It could never, however, be the interest even of this last species of cultivators to lay out, in the further improvement of the land, any part of the little stock which they might save from their own share of the produce, because the lord, who laid out nothing, was to get one half of whatever it produced. ....To this species of tenancy succeeded, though by very slow degrees, farmers properly so called, who cultivated the land with their own stock, paying a rent certain to the landlord. When such farmers have a lease for a term of years, they may sometimes find it for their interest to lay out part of their capital in the further improvement of the farm; because they may sometimes expect to recover it, with a large profit, before the expiration of the lease. The possession even of such farmers, however, was long extremely precarious, and still is so in many parts of Europe. ...[I]t was not till ... that the action of ejectment was invented, by which the tenant recovers, not damages only but possession, ... In England, therefore, the security of the tenant is equal to that of the proprietor.... There is, I believe, nowhere in Europe, except in England, any instance of the tenant building upon the land of which he had no

7. Demsetz (1992) 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."

> lease, and trusting that the honour of his landlord would take no advantage of so important an improvement. Those laws and customs so favourable to the yeomanry, have perhaps contributed more to the present grandeur of England than all their boasted regulations of commerce taken together.

This passage describes (a) the inefficiencies of share tenancy as a consequence of the farmer's inability to appropriate more than one-half of his contribution, (b) the discouragement of investment by farmers due to insecurity of appropriation [expropriation of quasi-rents], and (c) the importance of establishing and enforcing long-term leases to promote full appropriation. Part (c) illustrates how asset specificity and fear of hold up can be resolved. The landlord owns the land, but all of the know-how for undertaking investments in the land and in farming are attributable to the farmer. Competition among landlords and farmers results in "rent certain to the landlord," allowing the farmer to gain what he can from the soil. The landlord owns the land, but sells the control of it to the farmer. Here the complete contract, i.e., the long-term lease, is straightforward.

The contemporary formulation is more comprehensive. Williamson calls it the "fundamental transformation" associated with long term investments, which may be ex ante competitive because there are several potential buyers and sellers that, nevertheless, become ex post bilateral monopolies when the investments must be personalized. A prominent explanation why ex ante competition does not suffice is that the interspecificities are too complex to be readily forseeable and written into a contract. Otherwise, ex ante competition could be relied upon to determine which interpersonal investments were made and how the detailed, contingent distribution of the surplus was split. From that perspective, recognition that contracts are necessarily incomplete implies that property rights are effectively incomplete.

Essentially the same problem arises when ex ante competition is imperfect. For example, Alchian emphasizes the costs of search as a reason why, once interspecific resources are assembled, it would be impractical to find substitutes. Further, even without search costs, good substitutes might not exist. For whatever reason, if substitutes are not available to allow the coercive power of competition to achieve full appropriation, the distribution of the surplus is not well-defined. Call this an appropriation problem.

6.3.1 Appropriation problems in a small numbers setting

Section 5 described full appropriation when there are large numbers of individuals and some, but not all, activity is directed by prices. Here the concept will be defined in a small numbers setting without reference to prices based on a game in normal form defined by $[A, (\pi_i)]$: $A = A_1 \times \cdots \times A_n$, A_i is the set of actions/strategies available to individual i, and $\pi_i : A \to \mathbb{R}$ is the payoff function for i. Denote by $\mathbf{a} = (a_1, \ldots, a_n)$ a typical element of A. The total gains from $\mathbf{a}$ are

$$g(\mathbf{a}) := \pi_1(\mathbf{a}) + \cdots + \pi_n(\mathbf{a}).$$

From $\mathbf{a} = (a_i, a_{-i}) \in A$, the change in i's payoff when he chooses $b_i \in A_i$ and its consequences for total gains are:

$$\frac{\Delta \pi_i(\mathbf{a})}{\Delta a_i} := \pi_i(b_i, a_{-i}) - \pi_i(\mathbf{a}); \quad \frac{\Delta g(\mathbf{a})}{\Delta a_i} := g(b_i, a_{-i}) - g(\mathbf{a}).$$

An *individual maximum* of g is an $\mathbf{a}$ such that

$$\frac{\Delta g(\mathbf{a})}{\Delta a_i} \leq 0, \quad \forall \Delta a_i := b_i - a_i, \quad \forall i.$$

The game $[A, (\pi_i)]$ exhibits *full appropriation* at $\mathbf{a}$ if

$$\frac{\Delta \pi_i(\mathbf{a})}{\Delta a_i} = \frac{\Delta g(\mathbf{a})}{\Delta a_i}, \quad \forall \Delta a_i, \quad \forall i.$$

A key feature of full appropriation is that it precludes mis-aligned incentives,

$$\frac{\Delta \pi_i(\mathbf{a})}{\Delta a_i} \cdot \frac{\Delta g(\mathbf{a})}{\Delta a_i} < 0,$$

where the change in individual gains $\frac{\Delta \pi_i(\mathbf{a})}{\Delta a_i}$ points in the opposite direction from the social gains $\frac{\Delta g(\mathbf{a})}{\Delta a_i}$.

A *non-cooperative equilibrium* for $[A, (\pi_i)]$ is an $\mathbf{a} \in A$ for which

$$\frac{\Delta \pi_i(\mathbf{a})}{\Delta a_i} \leq 0, \quad \forall \Delta a_i, \quad \forall i.$$

It readily follows that:

Proposition 1. *If $[A, (\pi_i)]$ exhibits full appropriation at $\mathbf{a}$, then $\mathbf{a}$ is a non-cooperative equilibrium if and only if it is a individual maximum.*

The *social maximum* gains from the game, denoted by $G([A,(\pi_i)])$, is achieved at an $\mathbf{a}$ such that

$$\frac{\Delta g(\mathbf{a})}{\Delta \mathbf{a}} := g(\mathbf{b}) - g(\mathbf{a}) \leq 0, \quad \forall \Delta \mathbf{a} := \mathbf{b} - \mathbf{a}.$$

The social maximum is especially meaningful when, as in the analysis below, transfer payments are allowed.

Grossman and Hart [1984] take the appropriation problem as their point of departure to highlight the importance of distinguishing between ownership and control.[8] Their model is formulated as a two-stage game between two individuals, 1 and 2. Conditional on the commitments $\mathbf{a} = (a_1, a_2) \in A = A_1 \times A_2$ by the two individuals made at the first stage, the payoffs with respect to their actions $q = (q_1, q_2) \in Q = Q_1 \times Q_2$ at the second stage are $u_i(\phi_i(q) \mid a_i)$, $i = 1, 2$, where u_i is increasing in ϕ_i. Once the second stage actions are determined, payoffs can be written as functions of $\mathbf{a}$. The second stage actions are determined via the following:

$q^*[\mathbf{a}] : A \to Q$ satisfies

$$\frac{\Delta\{u_1(\phi_1(q^*[\mathbf{a}]) \mid a_1) + u_2(\phi_2(q^*[\mathbf{a}]) \mid a_2)\}}{\Delta q} \leq 0,\ \forall \Delta q = (q_1', q_2') - (q_1^*[\mathbf{a}], q_2^*[\mathbf{a}])$$

$q^0[\mathbf{a}] : A \to Q$ satisfies

(no control) $$\frac{\Delta u_i(\phi_i(q^0[\mathbf{a}] \mid a_i)}{\Delta q_i} \leq 0,\ \forall \Delta q_i = q_i' - q_i^0[\mathbf{a}], \quad i = 1, 2.$$

$q^i[\mathbf{a}] : A \to Q$, $i = 1, 2$ satisfies

(i controls) $$\frac{\Delta u_i(\phi_i(q^i[\mathbf{a}]) \mid a_i)}{\Delta q} \leq 0, \forall \Delta q = (q_1', q_2') - (q_1^i[\mathbf{a}], q_2^i[\mathbf{a}])$$

The function q^* stipulates that the second stage actions maximize the total gains given $\mathbf{a}$; q^0 assumes the actions are a non-cooperative equilibrium for the two-person game $u_i(\phi_i(q) \mid a_i)$ parameterized by $\mathbf{a}$; and q^i assumes the actions in the second stage are chosen to maximize the utility of i conditional on $\mathbf{a}$. Writing $g(\mathbf{a}) = u_1(\phi_1(q^*[\mathbf{a}])\,;\, a_1) + u_2(\phi_2(q^*[\mathbf{a}]); a_2)$ as the maximum total gains given $\mathbf{a}$, these functions are used to defined the payoffs π_i^κ, $\kappa = 0, 1, 2$, where

$$\pi_i^\kappa(\mathbf{a}) = \frac{1}{2}\Big\{g(\mathbf{a}) + u_i(\phi_i(q^\kappa[\mathbf{a}]) \mid a_i) - u_j(\phi_j(q^\kappa[\mathbf{a}]) \mid a_j)\Big\},\ i \neq j.$$

8. "...there are large amounts of surplus to be divided ex post and in which, because of the impossibility of writing a complete, contingent contract, the ex ante contract does not specify a clear division of the surplus."

Hence, depending on the three ways control may be exercised, the data of the two stage model $[A, Q, (u_i)]$ is reduced to the games $[A, (\pi_i^\kappa)]$, $\kappa = 0, 1, 2$.

By construction, the total gains conditional on $\mathbf{a}$ are as high as they can be, i.e., $\pi_1^\kappa(\mathbf{a}) + \pi_2^\kappa(\mathbf{a}) = g(\mathbf{a})$, but how they are distributed varies with κ. A non-cooperative equilibrium for $[A, (\pi_i^\kappa)]$ is an $\mathbf{a}^\kappa$ such that

$$\frac{\Delta\pi_i^\kappa(\mathbf{a}^\kappa)}{\Delta a_i} \leq 0,\ \forall \Delta a_i, \quad i = 1, 2.$$

Denoting the maximum gains as $G([A, (\pi_i^\kappa)])$, the objective is to choose κ to minimize $G([A, (\pi_i^\kappa)] - [\pi_1^\kappa(\mathbf{a}^\kappa) + \pi_2^\kappa(\mathbf{a}^\kappa)]$.[9] Because the set of feasible choices is the same no matter who is in control, $G([A, (\pi_i^\kappa)])$ is the same for all κ. The issue is how κ affects equilibrium choices.

In their Proposition 1, the authors give conditions in which the objective can be fully achieved. Restating their conclusion, it is readily demonstrated that

$$\frac{\Delta\phi_i(q_1, q_2)}{\Delta q_j} = 0 \Longrightarrow \frac{\Delta\pi_i^0(\mathbf{a}^0)}{\Delta a_i} = \frac{\Delta g(\mathbf{a}^0)}{\Delta a_i}, \quad i = 1, 2,\ i \neq j.$$

I.e., if j's action at the second stage does not influence the payoff to i, full appropriation will be achieved if neither party is in control. Similarly,

$$\frac{\Delta\phi_2(q_1, q_2)}{\Delta q} = 0 \Longrightarrow \frac{\Delta\pi_i^1(\mathbf{a}^1)}{\Delta a_i} = \frac{\Delta g(\mathbf{a}^1)}{\Delta a_i}, \quad i = 1, 2.$$

I.e., if 2's payoff is not influenced by what occurs at the second stage, full appropriation will be achieved if 1 is in control.[10] The authors describe conditions where the trade-offs are more complex and the conclusions are more qualified. Nevertheless, the lessons for minimizing losses are consistent with the goal of minimizing departures from full appropriation.

6.4 Appropriation with respect to know-how

Communication of know-how is evidently not limited to internal organization. Consider vocational education provided by a cooking school that specializes in basic training for food preparation. How those skills will be used is left to the relevant knowledge of the student, for example in the choice of where to work.

9. "We assume that the parties allocate ownership rights in such a way that ex ante investment distortions are minimized."

10. The individual maximum achieved via full appropriation is also a social maximum.

Having obtained the vocational training to carry out relevant tasks, when the former student accepts a job as a cook in a restaurant, the market acquisition of know-how is superseded by internal direction. The employer who is responsible for the continually changing menu tells the cook what and how to prepare the dishes. To continue the example, the restaurant owner may find that demand for his distinctive meals extends beyond his original location to a wider market.

The know-how versus shirking explanations of employment contracts carries over to the economics of franchising. As posed by Williamson [1985, p. 180], the problem is: "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." Because franchisees are given exclusive locations, they do not bear the full cost of reducing the quality of their products with the usual consequences for their joint profitability. Williamson emphasizes that franchisees might, therefore, want to hire the franchisor to monitor product quality in order to police themselves; or, the franchisor could write such a monitoring feature into contracts with franchisees.

Patentability suggests that the franchisor's know-how can be completely transferred at the beginning, leaving the franchisee with only the opportunity to shirk during the remainder of the contract. This suppresses an alternative scenario in which maintaining "the reputation of the system" involves continuing direction, much as the restaurant owner might provide to company-owned outlets. Franchising allows the menu, preparation, and management know-how of the franchisor to combine with the franchisee's knowledge of local conditions.

Of course, the franchisee's greater autonomy enlarges opportunities for misaligned incentives. Klein [1980, p. 359] illustrates how the use of short-term contracts can be applied in franchise contracting to establish better alignment. "... the franchisor may require franchisees to rent from them short term (rather than own) the land upon which their outlet is located. This lease arrangement creates a situation where termination implies that the franchisor can require the franchisee to move and thereby impose a capital loss on him up to the amount of his initial nonsalvageable investment. Hence a form of collateral to deter franchisee cheating is created." Note the comparisons with Smith's example of long-term contracts: both are rationalized as instruments enhancing appropriation. The earlier one was the result of government enforcement of specific performance — an institutional change, while the other, taking enforcement for granted, is the result of private contractual arrangement.

The logic of franchising can be founded on know-how in the absence of shirking. And, as with the employment contract, the private policing of opportunistic behavior can provide the franchisor with the ability to appropriate more of its value. Here, again, it is important to call attention to the role of competition in establishing the efficacy of the latter conclusion. Recalling the notation of Section 6.3.1, let κ denote one of a number of contractual arrangements between franchisor and franchisee and suppose $G([A, (\pi_i^\kappa)] - [\pi_1^\kappa(\mathbf{a}^\kappa) + \pi_2^\kappa(\mathbf{a}^\kappa)] \geq 0$ represents the loss from κ. For resource allocation problems subject to Williamson's Fundamental Tranformation, it is the agreed upon contractual relations, control rights, etc. established at the ex ante stage that determines the losses from ex post appropriation problems. Appeal to substitution possibilities at the ex ante stage ensure that these losses are minimized.

7 Concluding comment

Replacing the price-directed view of perfect competition with full appropriation fosters a closer connection with property rights: in particular, know-how as a property right in the allocation of resources. Emphasizing the phenomenon of personalized non-convexity and the attendant gains from team production, an elementary rationale for internal organization can be based on the appropriation of individual know-how that is communicated through specific direction — a rationale consistent with the well-established principle that competitive rewards are based on marginal productivity, applied to indivisible individuals. Opportunistic behavior is not a necessary condition for the existence of internal organization, but exploring its consequences is consistent with the focus on appropriation adopted here, without it.

References

Alchian, A. A., "The Basis of Some Recent Advances in the Theory of Management of the Firm," *Journal of Industrial Economics*, 1965, *14* (1), 30–41.

——, "Specifity, Specialization, and Coalitions," *Journal of Institutional and Theoretical Economics*, 1984, *140*, 34–49.

—— **and H. Demsetz**, "Production, Information Costs, and Economic Organization," *American Economic Review*, 1972, *65* (2), 777–795.

Arrow, K. J., *The Limits of Organization*, New York: W. W. Norton & Co., 1974.

Ashton, T. S., "The Records of a Pin Manufactory, 1824–21," *Economica*, 1925, *15*, 281–292.

Coase, R. H., "The Nature of the Firm," *Economica N. S.*, 1937, *4*, 386–405.

Cole, H. L. and E. C. Prescott, "Valuation Equilibrium with Clubs," *Journal of Economic Theory*, 1997, *74*, 19–39.

Debreu, G., *Theory of Value*, New York: Wiley, 1959.

Demsetz, H., "The Emerging Theory of the Firm," in "Uppsala Lectures in Business," Uppsala: Acta Universitatis Upsaliensis, 1992.

Ellickson, B., B. Grodal, S. Scotchmer, and W. R. Zame, "Clubs and the Market," *Econometrica*, 1999, *67* (5), 1185–1217.

Gawande, A., "Big Med: Restaurant chains have managed to combine quality control, cost control, and innovation. Can health care?," *The New Yorker*, 2012.

Gretsky, N., J. Ostroy, and W. Zame, "The Nonatomic Assignment Model," *Journal of Economic Theory*, 1999, *88* (60–118).

Grossman, S. J. and O. Hart, "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy*, 1986, *94* (4), 691–719.

Klein, B., "Transaction Cost Determinants of "Unfair" Contractual Arrangements," *American Economic Review*, 1980, *70* (2), 356–362.

——, **R. G. Crawford, and A. A. Alchian**, "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process," *Journal of Law and Economics*, 1978, *21* (2), 297–326.

Koopmans, T., *Three Essays on the State of Economic Science*, New York: McGraw Hill, 1957.

Makowski, L., "Value Theory with Personalized Trading," *Journal of Economic Theory*, 1979, *20*, 194–212.

——, "A characterization of perfectly competitive economies with production," *Journal of Economic Theory*, 1980, *22* (2), 208–221.

——, "A General Equilibrium Theory of Organization," Technical Report, Cambridge Discussion Paper 1980.

—— **and J. M. Ostroy**, "The Existence of Perfectly Competitive Equilibrium à la Wicksteed," in D. Gale, O. Hart, and E. Maskin, eds., *Economic Analysis of Markets and Games*, MIT Press, 1991, pp. 370–403.

Ostroy, J. M., "The no-surplus condition as a characterization of perfectly competitive equilibrium," *Journal of Economic Theory*, 1980, *22* (2), 183–207.

——, "A Reformulation of the Marginal Productivity Theory of Distribution," *Econometrica*, 1984, *52*, 599–630.

—— **and W. R. Zame**, "Nonatomic Economies and the Boundaries of Perfect Competition," *Econometrica*, 1994, *62* (3), 593–633.

Pratten, C. F., "The Manufacture of Pins," *Journal of Economic Literature*, 1980, *XVIII*, 93–96.

Samuelson, P. A., "A Note on the Pure Theory of Consumer's Behavior," *Economica, N.S.*, 1938, *5*, 61–71.

Simon, H. A., "A Formal Theory of the Employment Relation," *Econometrica*, 1951, *19* (3), 293–305.

Smith, A., *Wealth of Nations*, E. Cannan ed., The Modern Library, 1937.

Stigler, G., "Perfect Competition, Historically Contemplated," *Journal of Political Economy*, 1957, *LXV*.

Wicksteed, P. H., *The Common Sense of Political Economy*, London: Macmillan and Company, 1910.

Williamson, O. E., *The Economic Institutions of Capitalism*, Free Press, 1985.