

**Wealth Effects, Distribution and
The Theory of Organization**

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Wealth Effects, Distribution and the Theory of Organization*

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Abstract

We construct a general equilibrium model of firm formation in which organization is endogenous. Firms are coalitions of agents providing effort and investment capital. Effort is unobservable unless a fixed monitoring cost is paid, and borrowing is subject to a costly state verification problem. Because incentives vary with an agent's wealth, different types of agents become attractive firm members under different circumstances. When borrowing is not costly, firms essentially consist of one type of agent and are organized efficiently. But when the costly state verification problem is sufficiently severe, firm organization will depend on the distribution of wealth: with enough inequality, it will tend to be dictated by incentives of rich agents to earn high returns to wealth, even if the chosen organizational form is not a technically efficient way to provide incentives.

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1 Introduction

What is the role of organization in a market economy? What determines the form that an organization assumes? These are among the central questions that the theory of the firm has sought to answer at least since Coase raised them some sixty years ago. In market economies, firms form by voluntary association: utility-maximizing individuals are free to move among them, create and dissolve them, and choose the way they are organized, subject, of course, to the constraints of technology, information, and the wishes of other individuals. Any explanation for organization — whether based on transaction costs, agency and incentive problems, or difficulties of coordination and information transmission — must therefore take account of the competitive forces which voluntary association generates.

The theory of incentives, with the principal-agent model as its chief analytical tool, has dominated the economic analysis of organization (see, e.g., Hart [10], Hart-Holmström [11], Holmström-Tirole [14], and Radner [26] for surveys). This framework accommodates voluntary association through two exogenous pieces of information: the opportunity cost (individually rational utility level) of the agent, and the assignment (or “match”) of the principal to the agent. As a rule, these data are essential for determining the nature of the contracts selected, the types of technology (productive and information-gathering) chosen, and the efficiency of the organization. But the data of the principal-agent model are not economic fundamentals; a complete theory of organization would make the matches and individually rational utilities endogenous to tastes, technology, and endowments, and would therefore need to take account of the general equilibrium effects which inhere in this problem. The purpose of this paper is to construct a simple version of such a theory.

We study a model of firm formation in which the firms, their membership, and their organization are endogenous, and do so for an environment in which agents’ payoffs feature a significant nontransferability: wealth effects.¹ Production requires a fixed capital invest-

¹By wealth effects, we mean simply changes in marginal incentives that accompany changes in wealth; in the present paper they arise from nonnegativity constraints on income.

As is well known (see, for instance, Milgrom-Roberts [24]), there is one special case where little is gained by endogenizing the individually rational utilities, namely when individuals’ payoffs are fully transferable. There, a partial equilibrium approach suffices: one finds the contractual and technological choice and type matches that maximize the total surplus, and individual rationality can then be satisfied with lump-sum transfers.

ment and the efforts of a firm's risk-neutral members. Two agency problems have to be solved: one internal due to a moral hazard problem in effort provision, and one external due to an asymmetry of information about the output of the firm between its members and outside lenders. Each problem can be solved at no extra cost if there is enough wealth in the firm: the moral hazard problem can be solved if agents can post a large enough incentive bond, and the costly state verification problem is absent if the firm can be self-financed. Otherwise a costly monitoring (of effort) or auditing (of output) technology needs to be used.

This leads to two possible internal organizational forms: the *M*-firm uses the monitoring (of effort) technology and the *I*-firm does not. These forms represent the extremes of a trade-off between monitoring costs and team free-rider problems. There is an additional, equally important, trade-off between the size of surplus generated and the flexibility to distribute it. The *M*-firm tends to have more flexibility, although it may yield a smaller surplus (for incentive compatibility, shares in the *I*-firm must exceed the smallest feasible share in the *M*-firm, but the *M*-firm uses extra resources in order to monitor). Sometimes the two trade-offs come into conflict, and the resolution may be technically inefficient in the sense that monitoring of effort is used while the firm could afford not to use it. Hence, an organizational form may serve as an instrument for wealthy agents to earn high returns to wealth, even if it is not an efficient means of providing incentives.

Whether this kind of outcome can arise depends jointly on the efficiency of the financial market and the distribution of wealth. When the external verification problem is absent (if the cost of auditing output is small) the map from wealth levels to equilibrium utility levels is invariant to the distribution. Moreover, in this case, every equilibrium allocation is equivalent to one in which firms share the surplus equally among their members and consist of agents with equal wealth. Of course, distribution may affect the aggregate surplus created by the economy. Nevertheless, this effect of the distribution is purely compositional.

With a severe enough financial market imperfection (when the cost of auditing is large), distribution matters in an important way, both for the allocation of surpluses in firms and for the types of firms that emerge. We show that *M*-firms which are technically inefficient may arise under certain conditions. In an example, when wealth is distributed unequally,

all firms are technically inefficient M -firms.² When wealth is distributed more equally, all firms are (technically efficient) I -firms. The equilibrium map from wealth to surplus and firm type is no longer invariant: distribution matters.

Our model's structure is similar to those of club theory: a firm is simply a coalition of agents assembled to engage in production. The ways in which they generate and distribute surplus must adhere not only to technological constraints, as in the standard club-theoretic framework, but also must satisfy incentive compatibility constraints. We set up this model in the next section. In Section 3 we define the feasible allocations for coalitions and establish the existence and Pareto optimality of an equilibrium. In that section we find the wealth effects manifesting themselves in two distinct ways pertinent to the trade-offs between the two types of firms. Section 4 begins with a numerical example which illustrates most of the main points of our approach and then presents some more general characterization results. We conclude in Section 5.

2 The Economy

2.1 Preferences and Demographics

The economy lasts one period and has a single storable consumption good which may also be used as capital. There is a large number of agents (indexed by the unit interval with Lebesgue measure; denote this set A) with identical preferences defined over income and effort. All agents have one unit of indivisible effort and one unit of indivisible time, but differ in their wealth endowment: $\omega(a)$ is the wealth of agent a ; $\omega : A \rightarrow \Omega \subset \mathbb{R}_+$ is Lebesgue measurable. We assume that there are finitely many wealth levels, that is, $\Omega = \{\omega_0, \dots, \omega_L\}$ where ω_i is increasing in i . Let h^i denote the measure of agents with wealth ω_i , $H(\omega)$ the measure of agents with wealth less than ω . Agents have identical risk-neutral preferences which may be summarized by the von Neumann-Morgenstern expected utility $E\{y - e\}$, where $y \geq 0$ is the realized lifetime income and $e \in \{0, 1\}$ is the effort level chosen. Observe that the source of wealth effects in this model is the lower bound on

²It is not the use of the monitoring technology per se that is technically inefficient. For instance, if the economy consists of poor agents, M -firms could form and be technically efficient because the agents could not afford to post the incentive bond.

income which simultaneously imposes a lower bound on an agent's utility.

2.2 Technology

Agents' economic activity surrounds four technologies. First, there is a perfectly divisible safe asset which earns an exogenous gross return $r > 0$. By arbitrage, this return is also earned by lenders of capital (one could also think of our economy as small and open, with r the world gross interest rate). Second, a fixed cost of K_I must be incurred before production; once sunk, this capital cannot be recovered. This project succeeds, yielding R , with a probability π_n (n is the number of agents expending effort on the project), and fails, yielding 0, with probability $1 - \pi_n$. We make the following assumptions about the function π :

Assumption 1 $\pi_n < 1$ is nondecreasing in n with $\pi_0 = 0$.

Assumption 2 $\exists \tilde{n} : \pi_n - \pi_{n-1}$ is increasing for $n \leq \tilde{n}$ and nonincreasing for $n \geq \tilde{n}$.

These assumptions give the expected output function $\pi_n R$ the standard sigmoid shape; since there is a region of increasing returns, firms will typically consist of two or more agents.

Productive effort is not directly observable without the use of the third technology. If in addition to K_I , the firm makes a fixed capital investment of $K_M - K_I$, then not only is it possible to produce, but also to verify its members' effort; think of $K_M - K_I$ as the cost of a factory building inside of which it is easy to monitor the project's participants. In order to ensure that projects can be viably operated with the monitoring technology (and *a fortiori* without it), we make

Assumption 3 $\exists n : \pi_n R - K_M r - n > 0$.

Finally, the fourth technology permits verification of the outcome of the project by an "outside" party (i.e., someone other than the agents undertaking the project). It costs γ to audit the output and learn whether the project succeeded; this information becomes public knowledge.

2.3 Information

Information is held symmetrically except as noted above. Specifically:

Assumption 4 *The output is common knowledge to the members of a firm, but is unobserved by nonmembers.*

Assumption 5 *The parties to a contract with an agent can observe all other contracts he may have signed.*

Assumption 6 *Wealth can be costlessly verified.*

The first assumption gives rise to the costly state verification problem. The other two allow us to ignore adverse selection; only moral hazard (in its hidden-action and hidden-information forms) plays a role in this paper.

2.4 Occupations and Organizations

Given the technological and information assumptions (including those on the indivisibility of time and effort), there are three things an agent can do in this economy. First, he may invest all of his wealth in the safe asset (or lend to other agents — these activities yield the same return) and expend no effort or time. This option is called *subsistence*, and it yields income $\omega(a)r$ to agent a . Often, no one chooses subsistence in equilibrium, but it always provides a lower bound on utility for the other occupations.

If he does not choose subsistence, an agent becomes a member of a firm, spending his unit of time on a project, and investing part or all of his wealth there (any remainder can be invested in the safe asset); a firm is simply the set of agents who spend their time on a given project. Since his time is indivisible, an agent can belong to at most one firm. We call a firm with a capital investment of K_k , $k = I, M$, a k -firm. Typically a firm's members will be *workers*, expending their effort on the project. However, because a member has an information advantage over an outsider, there may be situations in which some members are brought in merely for their capital and are not expected to work; we call the agents who select this third occupation *silent partners*.

3 Feasibility and Equilibrium

The timing structure of our model is illustrated in Figure 1. It is quite standard for models of contracting and organization except for the presence of a competitive matching stage in which the firms form.

[Figure 1 about here]

The “competitive” equilibrium concept we use is a variant of the f -core (or “finite core,” which is just like the standard core for continuum economies except that only finite coalitions are allowed to block), due to Kaneko-Wooders [16] and [17] (see also Hammond et al. [9] and Wooders [30]), and related to the “social coalitional equilibrium” of Ichiishi [15] as well as the classical theory of clubs [27]. Applications of core-like concepts to private information economies include Boyd and Prescott [6] and Boyd et al. [7].

The set of agents partitions itself into finite coalitions, each of which achieves something feasible for itself (to be defined below, but basically this comes down to producing output and distributing it among the members and the lenders according to incentive compatible sharing rules and financial contracts) and such that no other (finite) coalition could form which would give each of its members a payoff higher than what they are getting in their current coalitions. We interpret the coalitions as firms or enterprises. Lenders are not part of explicit coalitions, and could be thought of either as being outside the economy, or as costlessly operating intermediaries who accept the safe asset investments of the economy’s agents as deposits.

3.1 Contracts and feasibility

Before defining our equilibrium concept formally, we must specify what is meant by a feasible contract for a firm. Let F be a (finite) set of agents. A *contract* for F is $c = (K_k, p, x, \bar{e})$, where K_k , $k = I, M$, is the capital investment; p is the probability of audit, i.e., the probability that a lender employs the output verification technology following a report of failure by the borrowing firm; $\bar{e} : F \rightarrow \{0, 1\}$ defines the effort levels that the agents are expected to exert, $x : F \rightarrow \mathfrak{R}_+$ defines the income of the agents when the project succeeds and when each agent exerts the effort $\bar{e}(a)$.³ We now define the set of feasible

³We prove in our working paper [22] that there is no need to consider more complex contracts.

contracts.

3.1.1 Finance

Our model of the financial market closely resembles the standard one in the costly state verification literature (see [28], [5], [3], [25]). The supply side of the financial market is competitive with free entry (we treat it here as devoid of agency problems, although a natural extension would allow for active financial intermediation as a separate occupation, as in Diamond [8] or Boyd and Prescott [6]). The firm F puts up its members' wealth $\omega_F \equiv \sum_F \omega(a)$ as collateral, receives a loan K_k , and then carries out its production activities.⁴ Once the outcome of the project becomes known to the firm's members, they report it to the lender. If they report success, each agent in the firm obtains his share $x(a)$.

Since the firm typically has an incentive to report failure even if it succeeds (reporting success when there is failure is assumed infeasible), the lender will need to conduct random audits to insure truthful reporting. The state contingent transfers to the agents must therefore satisfy a truth-telling constraint; in addition they must insure the lender with a nonnegative expected profit and be consistent with the nonnegativity of income:

$$\sum_F x(a) \geq (1 - p) R \tag{1}$$

$$\pi_n \sum_F x(a) + (1 - \pi_n) p\gamma \leq \pi_n R + (\omega_F - K_k) r \tag{2}$$

$$\forall a \in F : x(a) \geq 0 \tag{3}$$

We show in our working paper [22] that equilibrium financial contracts maximize the firm's expected income $\pi_n \sum_F x(a)$, subject to these constraints.⁵ The solution to this program

⁴Since it makes no difference whether the firm provides collateral $C < \omega_F$ and borrows $K_k - (\omega_F - C)$, we assume the collateral is ω_F and do not specify it in the contract. It is routine to show that agents have a weakly dominant strategy to invest all of their initial wealth in their firm: as long as $\omega_F < K_k$, it is better to reduce the size of the loan or increase the size of the collateral, than to invest in the safe asset.

⁵Note that this is a *result* of competition, rather than a behavioral assumption, as in the principal-agent framework. There, it is well known ([5], [3]) that nothing is lost by supposing that firms get a zero income in failure states. This fact as well as the maximization of firm's expected income are more delicate to establish in our model because it is not always straightforward — especially in the presence of silent partners — to distribute the gains from increasing a firm's income among all its members without distorting any of their

is

$$\pi_n \sum_F x(a) = \begin{cases} \pi_n R + (\omega_F - K_k) \tau, & \text{if } \omega_F \geq K_k \\ \pi_n R + (\omega_F - K_k) \alpha_n \tau, & \text{if } \omega_F < K_k \end{cases}, \quad (4)$$

where $\alpha_n \equiv \frac{\pi_n R}{\pi_n R - (1 - \pi_n) \gamma} > 1$ whenever $\frac{\pi_n R}{1 - \pi_n} > \gamma > 0$. (If $\pi_n R - (1 - \pi_n) \gamma \leq 0$, then external finance is infeasible, while if $\gamma = 0$, external and internal finance are equally costly.) Here we see the first wealth effect: as measured by the size of α_n , firms which need external finance face a higher marginal cost of capital and a higher marginal return to initial wealth than do firms which can finance internally.

3.1.2 Share

The share contract x distributes the proceeds of the project among the firm's members. In the M -firm, which uses the monitoring technology, the share contract is written contingent on the effort of members as well as on the firm's output. The I -firm contract can only be written contingent on the output of the enterprise.

***I*-firms** Here, of course, the *prima facie* problem is that of the free-rider: once the contract is signed, each member typically gains less than he expends, and so has no incentive to work at the level that maximizes the expected surplus (Alchian and Demsetz [1]; Holmström [13]). Under some conditions, though, *I*-firms can achieve the maximum surplus (Williams-Radner [29]; Legros-Matsushima [20]) and under others can approximate as closely as desired the maximum surplus (Legros [19], Legros-Matthews [21]). In the present model, in fact, an *I*-firm may be able to achieve the maximum surplus (an *M*-firm never does, since K_M units of capital are required to produce $\pi_n R$, while the *I*-firm uses only K_I).⁶

If an *I*-firm has n agents working, $\sum_F \bar{e}(a) = n$, and the share contract x must induce a game in effort levels in which \bar{e} is a Nash equilibrium. Hence, writing $\Delta \pi_n \equiv \pi_n - \pi_{n-1}$, the following incentive compatibility constraints are satisfied:

incentives to provide effort.

⁶As we have said, the observed organizational form will result from a trade-off among the costs of each, so whether we imagine *I*-firms to be fully efficient or only nearly so doesn't matter for the general point. In either case, efficiency doesn't determine the outcome.

$$\begin{aligned}\bar{e}(a) = 1 &\implies \pi_n x(a) - 1 \geq \pi_{n-1} x(a) \text{ or } \Delta\pi_n x(a) \geq 1 \\ \bar{e}(a) = 0 &\implies \Delta\pi_{n+1} x(a) \leq 1\end{aligned}\tag{5}$$

Using the fact that $x(a) \geq 0$ and adding up over all agents in the firm, (5) implies that $\sum_F x(a) \geq \frac{n}{\Delta\pi_n}$. Combining this with (4) and rearranging yields

$$\begin{aligned}\omega_F &\geq K_I + \frac{\pi_n}{\alpha_n r} \left(\frac{n}{\Delta\pi_n} - R \right), \quad \omega_F < K_I \\ \omega_F &\geq K_I + \frac{\pi_n}{r} \left(\frac{n}{\Delta\pi_n} - R \right), \quad \omega_F \geq K_I\end{aligned}\tag{6}$$

indicating that the firm requires a certain minimum wealth just to satisfy the incentive constraints. In effect the firm's members need to post incentive bonds; this is the second way that wealth effects manifest themselves, and is unique to the I -firm. For later use, let us denote the right hand side of equation (6) when $\omega_F < K_I$ by $\underline{\omega}(n, \gamma)$ and write $\underline{\omega}(n) = \omega(n, 0)$.

M -Firms In this case, effort levels are observable, and shares can be contingent on output and effort levels. By the principle of maximum punishment, the cheapest way to implement a profile of effort levels \bar{e} is by giving a share of zero to the agents who are detected shirking.⁷ It follows that the incentive compatibility conditions are simply

$$\begin{aligned}\bar{e}(a) = 1 &\implies \pi_n x(a) \geq 1 \\ \bar{e}(a) = 0 &\implies \pi_n x(a) \geq 0.\end{aligned}\tag{7}$$

At this point we can point out the principle difference in the restrictions on sharing rules between I -firms and M -firms. As we have said, an I -firm generates a greater surplus for a fixed n provided it can satisfy (5). But note that for any working member, (5) implies that the expected income is equal to $\pi_n x(a) \geq \frac{\pi_n}{\Delta\pi_n}$, which is strictly larger than the effort disutility of unity if $n \geq 2$. Note that the minimum wealth/income constraint is crucial here: without it, (5) could always be satisfied without making expected income larger than

⁷More precisely, let e be the observed vector of effort levels and let $x(a|e)$ be the income of agent a when the project succeeds and when the vector of observed effort levels is e . If $e = \bar{e}$ or if $e = 0$, let $x(a|e) = x(a)$. If $e \neq \bar{e}$ and if $e \neq 0$, let $G(e) = \{a \in F : e(a) \neq \bar{e}(a)\}$ be the set of agents who deviate from their contracted effort level and let $x(a|e) = 0$ if $a \in G(e)$ and $x(a|e) = x(a) + \sum_{G(e)} \frac{x(b)}{\#G(e)}$ if $a \in F \setminus G(e)$. (It is necessary to have $\sum_F x(a|e) = \sum_F x(a)$ for all e , including $e = 0$, in order to satisfy the truth-telling constraint.)

unity, simply by making the payoff when there is failure low enough. On the other hand, in an M -firm, the expected compensation may be as low as unity and still satisfy (7): indeed, if it is individually rational to join an M -firm, it is also incentive compatible.

It is this wedge between the minimum feasible compensations in each type of firm that creates the possibility that an agent may prefer to join the inefficient M -firm rather than the more efficient I -firm: the smaller wage bill in the M -firm may leave him more surplus, even after allowing for the expenditure on monitoring. Of course, whether this possibility can be realized in equilibrium, that is whether the M -firm compensation is indeed bid low enough, is precisely the general equilibrium question we need to answer.

For a finite set F , let $C(F)$ be the set of feasible contracts, i.e., contracts (K_k, p, x, \bar{e}) that satisfy conditions (1), (2), (3), (5), and (7). Observe that the principle departure from the usual notion of feasibility for principal-agent contracts is the absence of any participation constraint: as we have said, the individually rational utility levels are endogenous variables here. For $a \in F$ and $c = (K_k, p, x, \bar{e})$ where $\sum_a \bar{e}(a) = n$, we define the *surplus* of agent a who is party to contract c by

$$u(a|c) = \pi_n x(a) - \omega(a) r - \bar{e}(a),$$

that is, as the utility gain yielded by the contract over subsistence.

3.2 Equilibrium

Defining equilibrium in this economy follows the standard club-theoretic approach: having specified what is feasible for any (finite) group of agents, we need only specify what groups will form. Since we have a continuum of agents, it is possible to find one-to-one maps from arbitrarily small sets of positive measure onto sets of large measure: we therefore must restrict ourselves to partitions which satisfy a measure-consistency criterion.⁸ Call a partition of A into finite sets *measure-consistent* if for all positive integers m and for all

⁸For instance, let N be a fixed number and suppose that $\Omega = \{0, \omega\}$, where ω is large enough to cover the capital requirement of a project. Suppose that all agents in $\left[0, \frac{1}{2N+1}\right]$ have wealth ω (are rich) and that the other agents have wealth 0 (are poor). A reasonable candidate for equilibrium is that half of the poor agents join firms each of which has one rich and N poor agents, while the remaining poor are idle. Without measure consistency, however, it would be possible to have *every* poor agent join a firm with that same organization, i.e., one rich and N poor.

$i, j = 1, \dots, m$, the set of all i^{th} members of size- m elements of the partition has the same measure as the set of all j^{th} members of those elements (see Kaneko-Wooders [17]).⁹

We now provide our definition of equilibrium.

Definition 1 *An equilibrium (\mathcal{P}^*, c^*) is a minimal measure-consistent partition \mathcal{P}^* of A into finite sets and a function c^* on \mathcal{P}^* such that*

- (i) *For almost every $F \in \mathcal{P}^*$, $c^*(F) \in C(F)$,*
- (ii) *For all finite $T \subseteq A$ and $c \in C(T)$, there exists $a \in T$ such that $u(a|c) \leq u(a|c^*(F))$.*

The second condition (ii) is the core stability condition — deviating coalitions must make all of their members strictly better off in order to upset a putative allocation. Notice that this definition follows Kaneko-Wooders in ruling out the possibility of blocking by infinite coalitions (feasibility is not even defined for them). In the present context, we feel this restriction is justified. Recall that a continuum economy is simply an approximation to a large finite economy. It can be shown that there is a uniform finite upper bound \hat{n} on the size of “effective” blocking coalitions — if in a finite economy any coalition of size larger than \hat{n} blocks a putative allocation, there is a subcoalition no larger than \hat{n} which also blocks.¹⁰ This upper bound is independent of the size of the finite economy and thus applies as well to the continuum economy taken as the limit of some sequence of finite

⁹We also place a further restriction on the equilibrium partition, namely that it satisfy “minimality.” By this we mean that no element of the partition can be broken into subsets, each of which feasibly achieves the same surplus for all its members as in the original coalition. For instance, two separate projects are not considered to belong to the same firm. For our purposes, there is no loss of generality in adding this restriction.

¹⁰The formal proof is somewhat involved and is omitted. But the intuitive argument is simple enough. The production technology implies that there is an upper bound \bar{N} on the number of working agents in the firm (by increasing the number of working agents beyond that number, the total surplus in the firm decreases and the incentive problem becomes more severe). The only problem is finding a bound on the number of agents who are not expected to work. It turns out that there is a finite bound $\bar{\omega}$ on the total amount of wealth that a firm ever needs; above this level, it gains nothing for its members that they could not achieve by investing in the safe asset or borrowing from the financial market. Thus any non-working agents who add wealth over $\bar{\omega}$ or who add zero wealth do not contribute to the total surplus. Let ω^0 be the minimum positive wealth (which exists by finiteness of Ω). Thus \hat{n} can be chosen equal to be any integer exceeding $\bar{N} + \frac{\bar{\omega}}{\omega^0}$.

economies. The same kind of argument shows that membership in all equilibrium firms will be uniformly bounded by \hat{n} .

The proof of existence is a straightforward application of the results in the literature on the f -core and is in the Appendix. Moreover, since from what we have just said, the grand coalition cannot achieve any allocation that is not achieved by a collection of finite coalitions, we also obtain Pareto optimality of the equilibrium allocation (optimality is, of course, of the constrained sort, by (1), (2), (3), (5), (7), and Assumptions 4-6).

Proposition 2 *An equilibrium exists and is constrained Pareto optimal.*

We emphasize the Pareto optimality of the equilibrium, since the allocation typically will not satisfy other common efficiency notions such as surplus maximization or technical efficiency. A firm is *technically inefficient* if it is possible to produce the same output by using less input; it is *surplus inefficient* if there is a feasible way for it to generate more surplus. In our context, the output of a firm is the expected probability of success, and a technically inefficient firm could generate more surplus by *reorganization*: M -firms can be technically inefficient if the firm can be organized as an I -firm with the same number of agents working. Surplus inefficiency is the more familiar concept of inefficiency encountered in principal-agent models. It occurs, of course, whenever technical inefficiency does, but may also arise if, for instance, a firm operates with a number of working members other than the one which maximizes the surplus.

Since failures of technical and surplus efficiency are typically more evident than failures of Pareto optimality, they are often the focus of policy or popular discussion about possibilities for reorganization in corporations, health care, or the former Soviet Union. Nontransferabilities such as the wealth effects studied here give rise to conflicts between surplus or technical efficiency and Pareto optimality and help to explain why apparently desirable reorganizations often face considerable resistance.

4 Some Characterizations

We are now in a position to study how organization is determined in equilibrium. We will proceed first by studying a simple numerical example, and then will give some more general results.

4.1 An Example

Consider an economy in which $\pi_0 = 0$, $\pi_1 = 0.1$, $\pi_2 = 0.6$, $\pi_n = 0.8$, for $n \geq 3$. Let $R = 15$, $r = 1$, $K_I = 1$, $K_M = 2$. Finally, suppose there are just three wealth levels, namely 0, 2, and 4 with corresponding fractions of the population h^0 , h^1 , and h^2 . Any single-person firm generates negative surplus, and average surplus is maximized at $n = 2$ for both I -firms and M -firms. The first-best allocation therefore consists entirely of two-agent I -firms.

The first best is achieved when $\gamma = 0$. To see this, note that in this case $\underline{\omega}(2)$ is negative, so that even agents with wealth zero (call them “poor”) can satisfy (5) if they try to form I_2 -firms (refer to an n -person k -firm as k_n -firm). Any allocation which did not give almost every agent at least one half of the I_2 -firm surplus would be blocked by pairs of agents forming their own I -firms. Thus, all agents will choose to enter into this kind of contract, regardless of the distribution of wealth. Finally, the matching of types (i.e., wealth levels) within firms is indeterminate in this case, since everyone gets the same surplus no matter who is in the firm they join; in particular the surplus and firm type allocation is always the same as the one which arises when every firm contains agents of a single wealth level.

Things are rather different when γ is sufficiently large, however (say > 45). In this case, both types of firms, at any size, are either infeasible or generate negative surplus when composed entirely of poor agents. Thus, every firm will have to have at least one agent with positive wealth. Each firm will then have enough capital to satisfy the aggregate I firm incentive compatibility constraint. Since every firm would then be fully financed internally, there would be no role for silent partners.

We shall be interested in how the organization of firms varies with the distribution. Agents with wealth 2 and 4 (the “rich”) behave identically from the point of view of firm membership, so the parameter of interest for examining the effect of distribution on organization is h^0 .¹¹

We begin by asking under what conditions a rich agent will prefer to join each of the possible firm types and sizes. Observe first that he will always (weakly) prefer to have poor agents in his firm rather than other rich agents. Indeed, poor agents can never get more surplus than rich agents in equilibrium, since the rich agents could then break off and form

¹¹We chose an example with three rather than two wealth levels in order to allow variations in distributions with common means — organization then truly varies with the way wealth is distributed.

their own firms. Denote the equilibrium M -firm compensation going to a poor agent by w (this is independent of the size of the firm), and the corresponding compensation in an I_n -firm by v_n . The rich agent will choose the organization and size of firm which give him the highest residual incomes, that is he will compare $\max_n \{ \pi_n R - K_I r - (n-1)v_n \}$ and $\max_n \{ \pi_n R - K_M r - (n-1)w \}$. It is easy to show that only M_3 -firms and I_2 -firms can arise in equilibrium.¹² In an M_3 -firm, the total expected income is $\pi_3 R - K_M r = 10$ and in an I_2 -firm it is $\pi_2 R - K_I r = 8$.

Suppose first that the poor are relatively scarce ($h^0 < 1/2$). Then even if each rich agent matches with only one poor agent, there will be leftover rich agents to keep bidding up their (I_2 -firm) compensation until it reaches 4. It follows that all firms are I_2 -firms in which everyone receives a compensation of 4; some are composed of one rich agent and one poor one; the remainder consist of two rich ones. Each of these firms is efficient in both the technical sense and the surplus-maximizing sense, and indeed the economy performs at its first-best level.

On the other hand, if there are many poor ($h^0 > 2/3$), then even if every rich agent matches with two poor, there are still unmatched poor. Thus w must be bid down to its minimum value of unity. This yields an income of 8 to the rich agent in an M_3 -firm, which he prefers to the maximum of 6.8 that he can obtain in an I_2 -firm. Some of the poor will remain in subsistence, although they are indifferent between that status and working for a wage of 1.

Note that each of these M_3 -firms is technically inefficient since it would be feasible to reorganize them as I_3 -firms, thereby producing the same expected output with less input: each firm already has enough wealth to satisfy (6) and therefore could find a contract paying each member at least $\frac{\pi_3}{\Delta\pi_3} = 4$. The reason this does not happen in equilibrium is that the poor agents' outside opportunities are limited by the imperfect capital market, so that rich agents are better off paying them the low M_3 -firm compensation brought about

¹²A rich agent can always collect 4 by splitting the proceeds of an I_2 -firm formed with another rich agent. Since $\frac{\pi_3}{\Delta\pi_3} = 4$, an I_3 -firm can never yield him more than 3 (the maximum residual income to the rich agent is $11 - 2\frac{\pi_3}{\Delta\pi_3}$), and so will not appear in equilibrium. We can also rule out the M_2 -firm as an equilibrium organization. To see this, note that the M_2 -firm would be preferable to the M_3 -firm only if $w \geq 3$. But w cannot exceed 3 because that yields the rich agent less than 4. If $w = 3$, $w > \frac{\pi_2}{\Delta\pi_2} = 1.2$, and a rich agent would prefer to get 5 by reorganizing as an I_2 -firm.

by the relative abundance of poor.

Of course these firms are also too large compared to their first-best size: net output would be larger if every two M_3 -firms were replaced by three M_2 -firms (or I_2 -firms). This outcome would entail that more capital flow from the rich to the poor via the financial market; but the imperfection prevents this from happening.

For $1/2 < h^0 < 2/3$, equilibrium requires that rich agents be indifferent between the two types of firm, as must poor agents: $w = v_2$ and $8 - v_2 = 10 - 2w$ together imply that $w = 2$. The fraction μ of M_3 -firms is determined by the requirement that the demand for the poor equal the supply:

$$2\mu[1 - h^0] + \mu[1 - h^0] = h^0.$$

The graphs of μ along with the incomes accruing to rich and poor agents are shown in Figure 2(a) and (b). Note that the income distribution becomes more equal when the wealth distribution does. Figure 2(c) shows what firm types prevail in different parts of the distribution space, and in particular that economies with different organizational structures may have the same mean wealth.

[Figure 2 about here]

Besides illustrating how the internal organization of the firm depends on the external economy (that is, on the efficiency of the financial market and the distribution of initial endowments), this example also underscores how the *function* of the firm may also vary with these factors. Specifically, it is fair to say that the contractual form selected when $h^0 < 1/2$ is indeed the one which optimally provides incentives. But in the case $h^0 > 2/3$, a rent-seeking function of the organization predominates: incentives could be provided more cheaply by organizing as I_3 -firms, but rich agents would earn less surplus that way. In cases like these, policies such as the taxation of high incomes or the imposition of minimum wages may cause firms to reorganize, possibly with a gain in social surplus.¹³ Note however

¹³In this instance, a 100% tax on total income greater than 6 would cause all of the M_3 -firms to be reorganized as I_3 -firms, which would increase the total surplus by $1 - h^0$. Imposing a minimum wage of 2 would turn all enterprises into I_2 -firms, although this would not raise total social surplus: capital could still not flow to enough people to increase the number of firms sufficiently to compensate for the decreased output of existing firms.

that the equilibrium is (constrained) Pareto optimal. This illustrates the tension between surplus or technical efficiency and Pareto optimality brought about by wealth effects.

4.2 The Roles of the Financial Market and the Wealth Distribution

We proceed now to a more general consideration of the properties of equilibrium organizations. We divide our discussion to two cases corresponding to different assumptions about the efficiency of the financial market.

4.2.1 The case $\gamma = 0$

Our economies are parametrized by (Ω, H) and γ and r . For a fixed γ , we refer to a (Ω, H) -economy and when $\Omega = \{\omega\}$ is a singleton, we call the resulting economy a ω -economy.

When $\gamma = 0$, the characterization of equilibria of ω -economies is quite simple. First, note that all agents provide effort in equilibrium firms since it is not cheaper to borrow from within the firm than from the capital market. By equal treatment,¹⁴ it follows that the agents will form firms that maximize the average surplus.

Let $V_k(n) \equiv \pi_n R - K_k r - n$ be the total surplus in a k -firm with n working members. Let $n(\omega)$ denote the size of an I -firm that maximizes the average surplus subject to the constraint that the agents have enough wealth to satisfy incentive compatibility:

$$n(\omega) = \begin{cases} \arg \max \left\{ \frac{V_I(n)}{n} \mid n\omega \geq \underline{\omega}(n) \right\} & , \text{ if } \arg \max \neq \emptyset \\ 0 & , \text{ otherwise.} \end{cases}$$

Let N_M be the size of an M -firm that maximizes average surplus $\frac{V_M(n)}{n}$.¹⁵

Then in equilibrium, almost every agent receives a surplus of

$$u^e(\omega) = \max \left\{ \frac{V_I(n(\omega))}{n(\omega)}, \frac{V_M(N_M)}{N_M}, 0 \right\} \quad (8)$$

with almost every equilibrium firm of the type for which $u^e(\omega)$ is defined.

¹⁴See Lemma 1 in our working paper [22] for a proof that agents of the same wealth *who are in the same type of firm* have the same equilibrium utility.

¹⁵It is straightforward to show that $n(\omega)$ and N_M are uniquely determined.

The map defined by (8) represents the minimum surplus that an agent with initial wealth ω can obtain in any (Ω, H) -economy where $\omega \in \Omega$. Indeed, if there is a positive measure of agents of wealth ω who do not obtain $u^e(\omega)$ in the equilibrium of the (Ω, H) -economy, they could behave as in the ω -economy and obtain that surplus. One might think that when the economy consists of heterogenous types, the agents with larger wealth could obtain a higher surplus than $u^e(\omega)$ by forming firms with agents with lower wealth. This intuition is incorrect when $\gamma = 0$, and it is a remarkable fact that any equilibrium of a (Ω, H) -economy perfectly replicates the equilibria of the individual ω -economies, for $\omega \in \Omega$.

Proposition 3 *If $\gamma = 0$, then for any (Ω, H) , any equilibrium (\mathcal{P}^*, c^*) , and almost every agent a , $u(a|c^*) = u^e(\omega(a))$. Moreover, almost every agent a belongs to the same type of firm as in the $\omega(a)$ -economy equilibrium.*

Proof. Suppose that in an equilibrium of a (Ω, H) -economy, there is a positive measure of M -firms with n working members. Then, $V_M(n) \geq 0$ and moreover, each agent in the M -firm obtains at least the surplus given by (8). Therefore for each agent a in the firm, forming an M -firm in the $\omega(a)$ -economy is optimal. Hence, by definition of N_M , equilibrium M -firms must be of size N_M , and each agent gets the average surplus $\frac{V_M(N_M)}{N_M}$.

Consider now the case in which there is a positive measure of I_n -firms. We claim that for almost every I_n -firm and each a in the firm, $n\omega(a) \geq \underline{\omega}(n)$, i.e., that the I_n -firm leads to a positive surplus in the $\omega(a)$ -economy. Suppose instead that for some agent a in the I_n -firm, $n\omega(a) < \underline{\omega}(n)$. By definition of $\underline{\omega}(n)$, this is equivalent to

$$\frac{\pi_n}{\Delta\pi_n} - \omega(a)r - 1 > \frac{V_I(n)}{n}. \quad (9)$$

Note that the left hand side is the minimum surplus a can obtain in an I_n -firm while remaining incentive compatible. Let b be an agent in a 's firm for whom $n\omega(b) > \underline{\omega}(n)$ (such an agent must exist, since by hypothesis, the firm's wealth is at least $\underline{\omega}(n)$). Then (9) implies that there exists such an agent b whose surplus is strictly less than the average surplus $\frac{V_I(n)}{n}$. But now we have a contradiction, since n agents with wealth $\omega(b)$ could obtain a greater surplus by forming an I_n -firm on their own.

We conclude that each agent a in an I_n -firm can afford this type of firm in the $\omega(a)$ -economy, i.e., $n\omega(a) \geq \underline{\omega}(n)$. It follows that in almost all I_n -firms, the surplus is equally shared. But then, (8) implies that in an I_n -firm, $n = n(\omega(a))$. ■

The intuition for the result is the following. If agents with large wealth form an I -firm with agents who could not afford that type of firm when they are restricted to match together, the richer agents have to subsidize the incentive compensation of the poorer agents: the poorer agents cannot post the incentive bond since otherwise they would be able to create the firm on their own. Hence, in any equilibrium of any (Ω, H) -economy, there is (weak) *segregation*:¹⁶ agents who are matched together are those who have the same $u^e(\omega)$; often, this entails that agents matched together have the same wealth. In general, richer agents form I -firms and poorer agents form M -firms or are idle.

Clearly, in a ω -economy the total equilibrium surplus is maximized (which implies that each firm maximizes the total surplus of its members and is therefore technically efficient). In (Ω, H) -economies, equilibrium firms are still maximizing the surplus of their members but the equilibrium might fail to maximize the total surplus because of inefficiencies in matching.

For instance, suppose that there are two atoms, one at 0 and the other at ω . Suppose that M -firms are not feasible, that ω is large enough for the equilibrium firms of the ω -economy to be I_n -firms and that agents use subsistence in the 0-economy. From Proposition 3, in the (Ω, H) economy, agents with wealth ω form I_n firms and agents with wealth 0 are in subsistence. If $(n-1)\omega > \underline{\omega}(n)$ it would be feasible for $(n-1)$ agents with wealth ω and an agent of wealth 0 to create a I_n firm. In equilibrium there are $\frac{h\omega}{n}$ I_n -firms while it would be feasible to have $\frac{h\omega}{n-1}$ firms of type I_n . Hence total surplus is not maximized in equilibrium. As we have argued above, the richer agents are unwilling to match with poor agents because poor agents can be made incentive compatible only if their compensation comes out of the wealth of the rich agents (something that the rich agents do not need to do when they match together since each of them is able to post a bond large enough for

¹⁶This result holds more broadly. For instance, weak segregation holds in a model in which the monitoring technology is imperfect, i.e., enables the verification of effort levels with probability q , where q takes values in $[0, 1]$ and where $K(q, n)$ is the capital cost necessary to use monitoring technology q with n working members. In [23] we provide the necessary and sufficient condition on the characteristic function that generate weak segregation for more general matching problems.

his own incentive compatibility).

When $\gamma = 0$, the only inefficiencies are in matching. Equilibrium firms maximize the total surplus of their members over the set of feasible contracts. What is striking is that this property is independent of the distribution: changing the distribution will not affect the equilibrium surplus of the agents nor the types of firms to which they belong (it may, of course, affect the total measure of firms of different types in the economy, but this effect is purely compositional). Hence when $\gamma = 0$, distribution does not matter: in order to understand the behavior of (Ω, H) -economies, it is enough to analyze the behavior of ω -economies.

4.2.2 The case $\gamma > 0$

As we have seen in the example of Section 4.1, when γ is positive, distribution does matter. The equilibrium map from individual wealth to surplus and firm type is not invariant with respect to the distribution. Moreover, equilibrium firms are technically inefficient for some distributions. The object of this section is to explain the emergence of heterogenous matching and of technically inefficient firms.

To understand why heterogeneous matches can occur when γ is large, first consider I -firms. Note that contrary to the case $\gamma = 0$ an I_n -firm can include agents who could not afford it if they had to be matched with agents of their own type. Indeed, if a cannot afford I_n in the $\omega(a)$ -economy, then $n\omega(a) < \underline{\omega}(n, \gamma)$, which is equivalent to $\frac{\pi_n}{\Delta\pi_n} - \omega(a)r - 1 > \frac{V}{n}$, where $V = \pi_n R - \alpha_n K_I r + (\alpha_n - 1)n\omega(a)r - 1$ is less than $V_I(n)$. Therefore, it is possible for a rich agent to form an I_n -firm with poor agents while getting more than the average surplus $\frac{V_I(n)}{n}$. Note that it must still be true that $n\omega(a) \geq \underline{\omega}(n)$, i.e., the poor agents would be able to form an I_n -firm if $\gamma = 0$. It is the wedge between what agents can do *once* they are matched with agents with sufficient wealth and what they *can* do if they are matched with agents of similar or lower wealth that provides the motive for heterogenous matching and rent seeking.

For M -firms, when γ is large enough, poor agents who form an M -firm obtain a positive surplus only if there is enough wealth inside the firm, i.e., only if there is a large number of silent partners. Therefore, if the cost of borrowing is large, poor agents who form an M -firm obtain a low average surplus. It is therefore possible for richer agents to attract

poor agents in M -firms, pay them a low compensation, and obtain for themselves a higher residual surplus than if they formed an I -firm and had to pay an incentive compensation.¹⁷

Because only M -firms can be technically inefficient in this model, and because M -firms experience only the financial market wealth effect, in order to derive a result in which equilibrium firms are technically inefficient, two basic conditions must be met. First, there must exist a nonnegligible set of agents who cannot generate a large surplus by forming an M -firm because they have little wealth and have to pay a large interest rate to the lender. Second, there must not be too much competition among the remaining agents to attract the first set. Here we develop conditions under which these two effects appear.

To simplify the analysis and to illustrate in a more dramatic fashion the role of the costly state verification problem, we consider economies in which the wealth effect due to the incentive problem would not be too severe if γ were small. We also assume that γ is large enough to prevent firms with zero wealth from attaining a positive surplus. Finally, we assume that there are positive masses of agents with wealth zero and with wealth greater than K_M .

Assumption 7 For all n such that $\pi_n R - K_I r - n > 0$, $\underline{\omega}(n) < 0$.

Assumption 8 $\forall n$, $\pi_n R - \alpha_n K_I r - n < 0$.

Assumption 9 $\omega_0 = 0$, $\omega_L > K_M$, $h^0 > 0$, $h^L > 0$.¹⁸

We first provide a necessary condition for equilibrium firms to be technically efficient. Consider an equilibrium (\mathcal{P}, c^*) and an agent a with wealth ω_L . From Assumptions 9 and 7, if a belongs to an M -firm, this firm is technically inefficient. Let

$$u^0 = \operatorname{ess\,inf}_{a \in A} u(a | c^*).$$

The surplus of a in an I -firm with n working members is

$$u(a | c^*) = \pi_n R - K_I r - \sum_{b \neq a} u(b | c^*) - n.$$

¹⁷When $\gamma = 0$, if rich agents can generate a positive surplus by creating an M -firm, all agents can also generate a positive surplus by creating an M -firm. Therefore, there is no possibility for a rich agent to claim more than the average surplus in any M -firm.

¹⁸Recall that ω_0 is the smallest wealth level in Ω , and ω_L the largest.

We show in our working paper [22] that in equilibrium the surplus $u(b|c^*)$ is nondecreasing in the wealth of the agent. Therefore, from Assumption 7 a weakly prefers to match with agents with minimal wealth $\omega_0 = 0$. Agents with zero wealth who work in an I_n -firm have a surplus at least equal to $\frac{\pi_n}{\Delta\pi_n} - 1$. To participate, they must obtain a surplus of at least u^0 . Hence, the largest surplus that a can obtain by forming an I_n -firm is

$$u_I = \pi_{n^*}R - K_I r - (n^* - 1) \frac{\pi_{n^*}}{\Delta\pi_{n^*}} - 1$$

where,

$$n^* = \arg \max_n \pi_n R - (n - 1) \max \left\{ u^0 + 1, \frac{\pi_n}{\Delta\pi_n} \right\}.$$

By definition of u^0 , and the fact that $u(b|c^*)$ is increasing in the wealth of b , there exists a positive measure of agents with zero wealth whose equilibrium surplus is u^0 . Agent a can form an M_n -firm with these agents and give them a compensation equal to $u^0 + 1$. It follows that the maximum surplus of a in an M -firm is

$$u_M = \pi_{N^*}R - K_M r - (N^* - 1) (u^0 + 1) - 1$$

where

$$N^* = \arg \max_n \pi_n R - (n - 1) (u^0 + 1).$$

If there are no inefficient firms, we must have $u_I \geq u_M$. Precisely, it is necessary that

$$u^0 \geq u^* = \frac{1}{N^* - 1} \left[(\pi_{N^*} - \pi_{n^*}) R - (K_M - K_I) r + (n^* - 1) \frac{\pi_{n^*}}{\Delta\pi_{n^*}} \right] - 1. \quad (10)$$

Because both n^* and N^* depend on u^0 , the right hand side of (10) is also a function of u^0 . This inequality is always satisfied if the right hand side is negative. Hence, we assume.

Assumption 10 $u^* > 0$ for all $u^0 \geq 0$.¹⁹

We are now able to derive conditions on the distribution of wealth for which (10) cannot hold. We first define a kind of “poverty line,” below which agents are too poor to earn significant surplus when matched with others who are below the line; the condition on the distribution then ensures that the poor so defined are plentiful.

¹⁹Typically, Assumption 10 is satisfied if $K_M - K_I$ is small enough. From Lemma 8 in the Appendix, $N^* \in [N_M, \bar{N}]$, where N_M maximizes the per-capita surplus in an M -firm that does not borrow and has no silent partner and \bar{N} maximizes the total surplus in a firm that does not borrow. Hence, $N_M = \arg \max_n \frac{\pi_n R - K_M r}{n}$ and $\bar{N} = \arg \max_n \pi_n R - n$. Since $\Delta\pi_n$ is decreasing in this region by Assumption 2, it follows that $n^* \leq N^*$, where the equality obtains when $u^0 = \frac{\pi_{N^*}}{\Delta\pi_{N^*}} - 1$.

Proposition 4 *Let $\omega^* = \min \left\{ \frac{K_I}{\bar{N}}, \frac{u^*}{(\alpha^* - 1)r} \right\}$. If*

$$H(\omega^*) > (\bar{N} - 1)(1 - H(\omega^*)) \quad (11)$$

there exists a positive measure of M -firms that are technically inefficient.

We have already outlined the argument of the proof; details are in the Appendix. We believe that condition (11) could be considerably weakened, though for moderate scales of production, the degree of inequality of the distribution that it requires may not be implausible, especially in some developing countries. For the example in Section 4.1, it can be checked that (11) is equivalent to $h^0 > 2/3$, while we know that it is only necessary that $h^0 > 1/2$ in order that inefficient M -firms exist.

The restrictions on the distribution for which technically inefficient firms arise in equilibrium are not generally reducible to conditions on standard inequality measures, which depend too much on what is happening in the middle of the distribution. Rather, the right sort of conditions to look for are related to the relative size of the upper and lower tails of the distribution. One way to capture this is to consider the number of people below appropriately chosen “poverty lines” and “affluence lines,” defined not in the usual sense by consumption baskets, but instead in terms of the capital requirements for production. We develop this idea further in [23].

5 Discussion

Our approach to modelling firm formation enables us to endogenize participation constraints and provides a natural setting for studying the impact of interacting market imperfections on the organization of the firm. It also suggests that the nature and role of organizations is best understood when attention is paid to general equilibrium effects. We devote the remainder of this section to a discussion of robustness and extensions.

Financial Market While we use a costly state verification model, what matters most is that the cost of borrowing is decreasing in total wealth. Our results could therefore be obtained using other models of imperfect capital markets, such as those in Bernanke-Gertler [4], Kehoe-Levine [18], and Hart-Moore [12].

Furthermore, we suppose that the interest rate r is exogenous. Closing the economy and letting r depend on the supply and demand would require some modification of our definition of equilibrium (for instance to accommodate a capital market clearing condition). However, the substance of Proposition 3 does not depend on r , except that the relevant comparison economies are ω -economies in which the prevailing interest rate is the one that clears the market in the original economy. We note that the equilibrium values of r are bounded above by $\frac{\pi_{\tilde{N}}R-\tilde{N}}{K_I}$ (else no one would have any reason to demand capital) and below by unity (since the consumption good is storable). One can therefore always find parameter values such that Assumptions 7-10 and condition (11) are satisfied, so Proposition 3 will still be valid. Our argument for the Pareto optimality of equilibrium would have to be modified, however, because financial market clearing would now involve an infinite coalition of agents.

Size of firms When $\gamma = 0$, size maximizes the average surplus in the firm, but when γ is positive, there is a tendency for firms to employ above or below this level. For instance, if M -firms form and do not have to borrow, then from the point of view of maximizing economy-wide surplus, it would be best for them to operate at a scale (that is to say, with a number of workers) which maximizes per-capita surplus. Not surprisingly, in the presence of financial market imperfections, oversized firms need not break up into smaller ones because agents may not have cheap enough access to capital. We offer some results in this vein in the Appendix and in [22]. See also [2].

Lotteries As is well known, when there are indivisibilities or nonconvexities, individual agents (or small groups of them) may have incentives to engage in lotteries over initial wealth. Clearly, our model can accommodate lotteries. Since they would occur *before* the matching stage, allowing them would simply cause wealth to be redistributed before the match occurs. In that case all that we say in the paper applies without qualification to the *ex-post* distributions or to initial distributions which are “lottery-proof.”²⁰ A natural question is whether the qualitative message of our paper is still valid when lotteries are

²⁰Let $U_H(\omega)$ be the equilibrium surplus achieved by an agent with wealth ω when the distribution is H (this is defined for all ω , including those not in the support of H). Nonconcavities in this function generate incentives to participate in lotteries. Thus H is lottery proof if $U_H(\cdot)$ is equal to its concavification at all wealth levels in the support of H .

allowed. In particular, is it still true that firms can be technically inefficient when the costly state verification problem is sufficiently severe?

A sufficient condition for the result to go through is the existence of a lottery proof distribution satisfying the conditions of Proposition 4. We now argue that *all* of the distributions in the example in Section 4.1 are lottery proof. To see this, observe that agents with zero wealth cannot engage in any nontrivial fair lotteries, since negative payoffs are infeasible. It is not hard to establish that the marginal value of wealth is always nonnegative (surplus is nondecreasing in wealth — see our working paper [22]). Moreover, for agents with wealth at least 2, the marginal value of wealth is exactly zero, since for all distributions in the example, they receive the maximum surplus in equilibrium. The only way an agent in that range would have an incentive to participate in a fair lottery is if there were some wealth level ω in the interval $[0, 2]$ for which $U_H(\omega) > U_H(2)$; but this contradicts the fact that $U_H(\cdot)$ is nondecreasing.

Risk Aversion An important source of wealth effects that we have not considered here is risk aversion. As a referee has pointed out, Proposition 3 no longer holds if agents are risk averse. The reason is that with risk aversion, even if there is no costly state verification problem, rich agents might prefer to form *I*-firms with poor agents who could not form *I*-firms by themselves, because it is easier to provide incentives to poor agents than to rich agents. However, risk aversion introduces many complications that go beyond the scope of this paper. In any case, risk neutrality enables us to illustrate in a dramatic way the role of the financial market for the organization of production.

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A Existence of an Equilibrium

Here we sketch the proof of existence of an equilibrium for our economy. Let \mathcal{F} be the set of finite subsets of A . We will construct a characteristic function \widehat{U} which associates to each finite coalition F a subset of $\mathfrak{R}^{\#F}$. \widehat{U} will satisfy the properties of Theorem 1 of Kaneko-Wooders [17] and therefore the f -core of $(A, \mathcal{F}, \widehat{U})$ is non-empty. Existence of an equilibrium for our economy will follow.

Let $F \in \mathcal{F}$, $C(F)$ be the corresponding set of feasible contracts and

$$U(F) \equiv \left\{ u \in \mathfrak{R}^{\#F} \mid \exists c \in C(F) : u = (u(a|c))_{a \in F} \right\}$$

be the corresponding set of surplus vectors. From the definition of $C(F)$, it is clear that $U(F)$ is closed in $\mathfrak{R}^{\#F}$. Let $\widehat{U}(F) = U(F) - \mathfrak{R}_+^{\#F}$ be the comprehensive extension of $U(F)$. $\widehat{U}(F)$ is closed in $\mathfrak{R}^{\#F}$.

Let $A^i \equiv \{a \in A \mid \omega(a) = \omega_i\}$ be the set of agents with wealth ω^i , $i = 1, \dots, L$. $\{A^i\}$ is a finite partition of A .

We first establish that \widehat{U} is a characteristic function, that is, it satisfies the following:

- (i) $\widehat{U}(F)$ is a non-empty, closed subset of $\mathfrak{R}^{\#F}$. for all $F \in \mathcal{F}$.
- (ii) $\widehat{U}(F) \times \widehat{U}(G) \subseteq \widehat{U}(F \cup G)$, for all $F, G \in \mathcal{F}$, $F \cap G = \emptyset$.
- (iii) $\inf_{a \in A} \sup \widehat{U}(\{a\}) > -\infty$.
- (iv) $\forall F \in \mathcal{F}, u \in \widehat{U}(F), u' \in \mathfrak{R}^{\#F}, u' \leq u \implies u' \in \widehat{U}(F)$.
- (v) $\forall F \in \mathcal{F}, \widehat{U}(F) \setminus \cup_{a \in F} \left\{ \text{int} \left[\widehat{U}(\{a\}) \times \mathfrak{R}^{\#F-1} \right] \right\}$ is non-empty and bounded.

Conditions (i), (ii) and (iv) follow from the construction of \widehat{U} . We note that for any a in A , $\widehat{U}(\{a\}) = (-\infty, 0]$. This proves (iii) and establishes that $\widehat{U}(F) \setminus \cup_{a \in F} \left\{ \text{int} \left[\widehat{U}(\{a\}) \times \mathfrak{R}^{\#F-1} \right] \right\}$ is non-empty. By incentive compatibility, the minimum surplus of an agent in F is $-\omega(a)r$ (i.e., when a invests her wealth in the firm and is compensated only for her effort). Therefore, the maximum that an agent can obtain is $\pi_{\bar{N}}R - K_I r - \bar{N} + \omega_{F \setminus \{a\}} r$. Consequently, each $u \in \widehat{U}(F)$ is bounded above by the vector $\bar{u}^F = \left(\pi_{\bar{N}}R - K_I r - \bar{N} + \omega_{F \setminus \{a\}} r \right)_{a \in F}$. It follows that $\widehat{U}(F) \setminus \cup_{a \in F} \left\{ \text{int} \left[\widehat{U}(\{a\}) \times \mathfrak{R}^{\#F-1} \right] \right\}$ is bounded.

$(A, \mathcal{F}, \hat{U})$ is a game without side payments. Let Π be the set of measure-consistent partitions of A and for $\mathcal{P} \in \Pi$, let $F(a) \in \mathcal{P}$ the firm to which a belongs. Let $L(A, \mathfrak{R})$ be the set of measurable functions from A to \mathfrak{R} ; for $v \in L(A, \mathfrak{R})$ and $F \in \mathcal{F}$, v^F is the restriction of v to F . Define the following sets:

$$H(\mathcal{P}) \equiv \{v \in L(A, \mathfrak{R}) \mid v^{F(a)} \in \hat{U}(F(a)), \text{ a.e. } a \in A\}$$

$$H \equiv \cup_{\mathcal{P}} H(\mathcal{P})$$

$$H^* \equiv \{v \in L(A, \mathfrak{R}) \mid \exists \{v^k\} \subset H, v^k \rightarrow v\} \text{ where the convergence is in measure.}$$

If $v \in H^*$, then $F \in \mathcal{P}$ can improve upon v if for some $\hat{u} \in \hat{U}(F)$, $\hat{u}(a) > v(a)$ for each $a \in F$. $C_f(\hat{U})$, the f -core of $(A, \mathcal{F}, \hat{U})$, consists of those elements of H^* that cannot be improved upon by any finite coalition.

Theorem 1 of Kaneko-Wooders [17] establishes the non-emptiness of the f -core of $(A, \mathcal{F}, \hat{U})$ when a simple condition, called *per-capita boundedness*, is satisfied. We shall need the following definitions.

Definition 5 $(A, \mathcal{F}, \hat{U})$ has the r -property with respect to $\{A^i\}_{i=1}^l$ if for any $F \in \mathcal{F}$, for any $i = 1, \dots, l$, and for any $a, b \in A^i$,

(i) if $a \notin F$, $b \notin F$, then $\hat{u} \in \hat{U}(F \cup \{a\}) \Leftrightarrow \exists \hat{u}' \in \hat{U}(F \cup \{b\})$ s.t.

$\hat{u}(d) = \hat{u}'(d)$, for all $d \in F$ and

$\hat{u}(a) = \hat{u}'(b)$;

(ii) if $a, b \in F$, $\hat{u} \in \hat{U}(F)$ then $\hat{u}' \in \hat{U}(F)$ where

$\hat{u}(d) = \hat{u}'(d)$, for all $d \in F \setminus \{a, b\}$ and

$\hat{u}(a) = \hat{u}'(b)$ and $\hat{u}(b) = \hat{u}'(a)$.

This condition says that any two agents of the same type are substitutes. It is clear that our $(A, \mathcal{F}, \hat{U})$ has the r -property.

Definition 6 For any $F \in \mathcal{F}$, a payoff vector \hat{u} has the equal treatment property if $\hat{u}(a) = \hat{u}(b)$ for all $a, b \in F \cap A^i$, all $i = 1, \dots, l$.

Definition 7 \hat{U} is per-capita bounded with respect to $\{A^i\}_{i=1}^l$ if there is a $\delta \in (0, 1)$ and a $Q \in \mathfrak{R}$ such that if $F \in \mathcal{F}$ is a coalition satisfying $(1 + \delta) h^i \geq \frac{\#(F \cap A^i)}{\#F} \geq (1 - \delta) h^i$ and if $\hat{u} \in \hat{U}(F)$ has the equal treatment property, then $\hat{u}(a) < Q$ for all $a \in F$.

We need to establish that \hat{U} is per-capita bounded with respect to $\{A^i\}$. We argued above that if $\hat{u} \in \hat{U}(F)$, then $u \leq \bar{u}^F$. Clearly, as more agents are added to a given F , $\bar{u}^F(a)$ increases. Per-capita boundedness requires that equal treatment payoff vectors feasible for F are uniformly bounded above, but only for those finite coalitions in which the relative proportions of types are close to the corresponding proportions in the whole economy.

Let $\delta = \frac{1}{2}$. For $F \in \mathcal{P}$, let $n^i = \#(A^i \cap F)$. We consider finite coalitions such that $\frac{3}{2}h^i \geq \frac{n^i}{\sum_{i=1}^I n^i} \geq \frac{h^i}{2}$, i.e., the proportion of types in F is δ -close to the proportion of types in A . Note that for all such F , $n^i > 0$ for each i .

Let $\hat{u} \in \hat{U}(F)$ have the equal treatment property. In order to find the maximum that an agent in $A^i \cap F$ can obtain, it is enough to find the maximum total surplus for agents in $A^i \cap F$ and divide by n^i . The maximum total payoff of the set of agents in $A^i \cap F$ is $\pi_{\bar{N}}R - K_I r - \bar{N} + \sum_{j \neq i} n^j \omega_j r$. From our assumption on the proportions of types in F , one can show that $\frac{n^j}{n^i} \leq 3\frac{h^j}{h^i}$. Therefore, if the payoff vector satisfies equal treatment, the maximum payoff to $a \in A^i \cap F$ is

$$Q^i = \frac{\pi_{\bar{N}}R - K_I r - \bar{N}}{n^i} + \sum_{j \neq i} \frac{3h^j}{h^i} \omega_j r$$

Choosing $Q = \max\{Q^i\}$ then ensures that \hat{U} satisfies per-capita boundedness.

Theorem 1 of Kaneko-Wooders [17] now tells us that there exists $\hat{v} \in \mathcal{C}_f(\hat{U})$. Thus there is $\mathcal{P} \in \Pi$ such that for almost all $a \in A$, $\hat{v}^{F(a)} \in \hat{U}(F(a))$. By definition of the comprehensive extension of $U(F(a))$, for almost all a , there exists $v^{F(a)} \in U(F(a))$ such that $v^{F(a)} \geq \hat{v}^{F(a)}$. Clearly, since \hat{v} cannot be improved upon, neither can v . Consequently, $v \in \mathcal{C}_f(U)$. Using the feasibility condition, for almost all a , there exists a contract $c^{F(a)}$ such that $v^{F(a)}(b) = u(b|c^{F(a)})$ for all $b \in F(a)$. This establishes the existence of an equilibrium for our economy. ■

B Size of Firms

When γ is positive, rich agents who belong to M -firms want to maximize their residual surplus; this creates a tendency for M -firms to be larger than the average surplus maximizing size N_M . As long as the M -firm does not need to borrow, the size of the firm is bounded

above by the surplus maximizing size \bar{N} . However, if the firm needs to borrow, it is possible for the M -firm to have more than \bar{N} working members, since a higher probability of success decreases the cost of borrowing.

While M -firms always employ more than the average surplus maximizing level, I -firms might employ less than that level. Indeed, since the incentive compensation is increasing in the number of working members, an agent who is able to give the minimum incentive compensation to other working members of the firm might prefer to limit the size of the firm below the average surplus maximizing level.

Lemma 8 1. *Let F be an M -firm.*

$$(i) \sum_F \bar{e}(a) \geq N_M$$

$$(ii) \omega_F \geq K_M \implies \sum_F \bar{e}(a) \leq \bar{N}$$

$$(iii) \omega_F < K_M \implies \sum_F \bar{e}(a) \leq N(\omega_F), \text{ where } N(\omega_F) \text{ maximizes}$$

$$\pi_n R - \alpha_n (K_M - \omega_F) r - \omega_F r - n;$$

$N(\omega_F)$ is decreasing with ω_F and is equal to \bar{N} at $\omega_F = K_M$.

2. *If F is a I firm and if $\omega_F \geq K_I$, $\sum_F \bar{e}(a) \leq \bar{N}$.*

Proof. 1. (i) Let $u^0 \equiv \text{essinf}\{u(a|c^*)\}$. By definition of N_M , for any $n < N_M$, $\frac{\pi_{N_M} R - K_M r}{N_M} > \frac{\pi_n R - K_M r}{n}$, which is equivalent to $\frac{\pi_{N_M} - \pi_n}{N_M - n} R > \frac{\pi_n R - K_M r}{n}$. Since F is an equilibrium firm, $n(u^0 + 1) \leq \pi_n R - K_M r$. Therefore, using the inequality above, $u^0 + 1 < \frac{\pi_{N_M} - \pi_n}{N_M - n} R$ which is equivalent to,

$$\pi_{N_M} R - K_M r - (N_M - n)(u^0 + 1) > \pi_n R - K_M r.$$

Let $G \supset F$ be such that $\#G \setminus F = N_M - n$ and $\forall a \in G \setminus F, u(a|c^*) = u^0$. If $\omega_F \geq K_M$, the previous inequality implies that there exists a contract in $C(G)$ that will lead to a strictly higher surplus for each agent in G than what they get in equilibrium (since the surplus is perfectly transferable among agents in an M -firm). This is a contradiction. If $\omega_F < K_M$, the previous inequality implies that

$$\begin{aligned} \pi_{N_M} R - \alpha_{N_M} K_M r + (\alpha_{N_M} - 1) \omega_G r - (N_M - n)(u^0 + 1) \\ > \pi_n R - \alpha_n K_M r + (\alpha_n - 1) \omega_F r \end{aligned}$$

since $\omega_G \geq \omega_F$ and $\alpha_{N_M} < \alpha_n$. Hence, here also there exists a feasible contract for G that makes all agents in G strictly better off than in equilibrium. Hence $\sum_F \bar{e}(a) \geq N_M$ as claimed.

(ii). By definition of \bar{N} , as long as $\omega_F \geq K_M$, the surplus is decreasing for $n \geq \bar{N}$. Because there is full transferability, M -firms that can be self-financed will not have more than \bar{N} agents working in equilibrium.

(iii) When $\omega_F < K_M$, there might be an incentive to expand the size of the number of working agents beyond \bar{N} because the cost of financing decreases with the number of working agents. The total surplus in such a firm is $\pi_n R - \alpha_n (K_M - \omega_F) r - \omega_F r - n$. This leads to the upper bound $N(\omega_F)$. It is immediate that this bound is decreasing in total wealth and is equal to \bar{N} when the wealth is K_M .

2. If F is an I -firm and $\omega_F \geq K_I$, $\sum_F \bar{e}(a) \leq \bar{N}$ since by increasing n beyond this level not only does the total surplus decrease but also the incentive problem becomes more severe. This is the only prediction that we can make for I -firms. ■

C Proof of Proposition 4

Suppose by way of contradiction that there are no technically inefficient firms, i.e., that $u^0 \geq u^*$. A contradiction is obtained by using the following three observations.

Observation 1: *Agents with wealth less than $\frac{u^*}{(\alpha^*-1)r}$, where $\alpha^* = \max_{n: \pi_n \geq \frac{\gamma}{R+\gamma}} \alpha_n$ cannot be silent partners in any type of firm.*

Suppose by way of contradiction that an agent with wealth $\omega < \frac{u^*}{(\alpha^*-1)r}$ is a silent partner in a firm with n working members. Whether the firm is a I firm or a M firm, the surplus to a silent partner must be bounded by the difference in total surpluses that the other agents in the firm can attain with and without the silent partner. Therefore, the maximum surplus of a silent partner is $(\alpha_n - 1)\omega r$. Since by assumption $u(b|c^*) \geq u^0 \geq u^*$, agents with wealth less than $\frac{u^*}{(\alpha^*-1)r}$ cannot be silent members.

Observation 2: *Suppose that an agent of wealth ω_i forms a firm with $n - 1$ agents of wealth less than $\omega^* = \min \left\{ \frac{K_I}{N}, \frac{u^*}{(\alpha^*-1)r} \right\}$. Then the firm does not borrow.*

We show in Lemma 4 of [22] that there is no loss in supposing that in any type of firm, the silent partners have the least wealth invested in the firm. From Observation

1, the firm has no silent partner. The surplus of the agent with wealth ω_i is bounded above by $\pi_n R - \alpha_n K r + (\alpha_n - 1)(\omega_F - \omega_i)r - (n - 1)(u^0 + 1) - 1$. From Assumption 8 $\pi_n R - \alpha_n K r - n < 0$. Since $\omega_F - \omega_i \leq (n - 1)\omega^*$ and $\alpha_n \leq \alpha^*$, $(\alpha_n - 1)(\omega_F - \omega_i)r - (n - 1)u^0 \leq (n - 1)[(\alpha^* - 1)\omega^* - u^0] < 0$. Hence, the surplus of the agent with wealth ω_i is negative, which is a contradiction.

Observation 3: *Suppose that an agent of wealth ω_i forms a firm with $n - 1$ agents of wealth less than $\omega^* = \min\left\{\frac{K_I}{\bar{N}}, \frac{u^*}{(\alpha^* - 1)r}\right\}$. Then $n \leq \bar{N}$.*

Follows from Observations 1, 2 and the fact that firms that do not borrow have less than \bar{N} working members.

From Observation 3, an agent of wealth ω_i wants to be matched with at most $\bar{N} - 1$ agents of wealth less than ω^* . From the assumption on H , there exists a set of positive measure of agents with wealth less than ω^* who are not matched with agents of wealth greater than ω^* . From Observation 1, and $\omega^* < \frac{K_I}{r}$, a firm consisting of agents of wealth less than ω^* must borrow. But Observation 2 leads a contradiction. Hence $u^0 < u^*$ and agents with wealth ω_L form technically inefficient M firms.

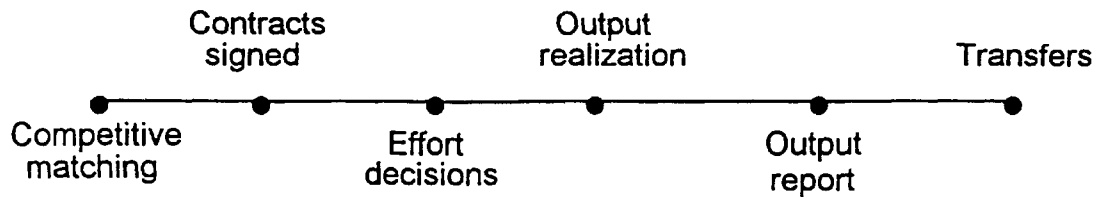


Figure 1

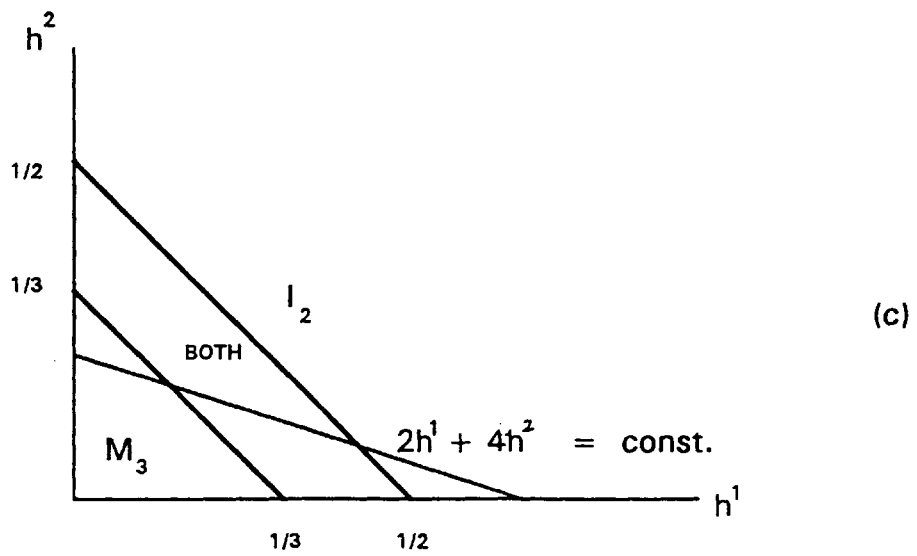
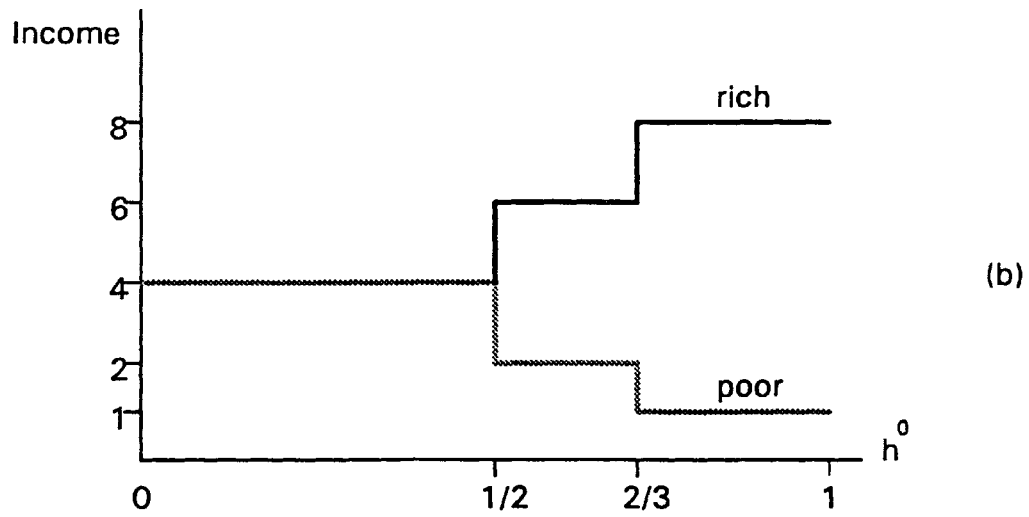
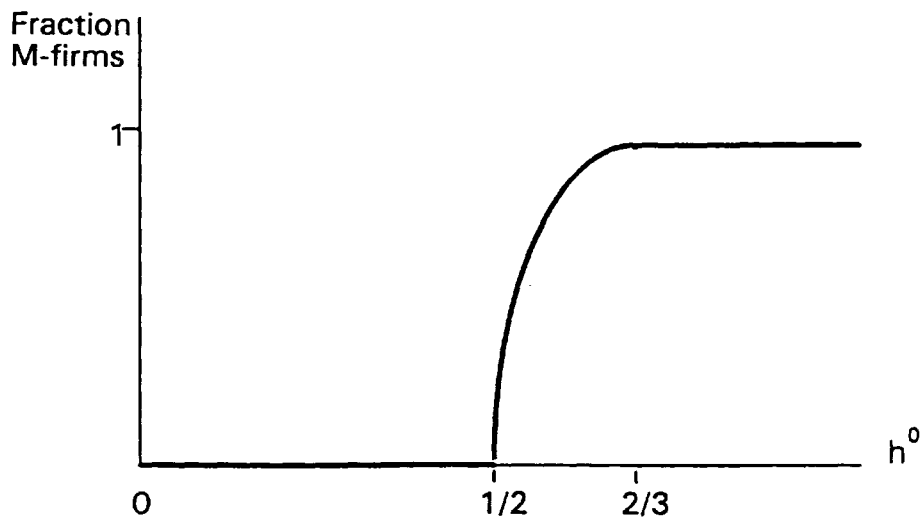


Figure 2

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