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Organizational Design, Technology and the Boundaries of the Firm

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Focus (specialization) improves productivity but leads to more dependency and opens a door for holdup problems. We analyse how organizational design interacts with the allocation of ownership in minimizing the holdup problem. We identify a new cost of integration: inefficient organizational design in an integrated firm. We also show that the boundaries of the firm depend on technology.

Introduction

In the property rights theory of the firm, ownership is the only instrument used to minimize the holdup problems in specific human capital. In Grossman and Hart (1986) and Hart and Moore (1990), ownership gives power and power improves incentives, while with reputation effects (Baker *et al*. 2002; Halonen 2002) or applying a different bargaining model (Chiu 1998; De Meza and Lockwood 1998), ownership can demotivate.

The point of this paper is that, in addition to ownership, organizational design can affect the holdups. Specialization is a powerful force for increasing efficiency (e.g. in Adam Smith's pin factory). But specialization also leads to more dependency and opens a door for holdup problems. If the holdup problems are too great, it is better for the agents not to specialize. Multiskilling removes the holdup power of a specialized agent because other agents are able to perform the same task. That is the benefit of multiskilling. Multiskilling also makes the agents less productive for a given investment in human capital because they are unfocused.[1] This is the cost of multiskilling. Organizational design and ownership interact in interesting ways in our model, as illustrated in the following example.

Consider an IT firm with two programmers, 1 and 2. A typical project of developing a program consists of two tasks: algorithmic design (task A) and graphic design (task B). Programmer 1 can specialize in one task, say algorithmic design, and learn the skills to develop the algorithms that run the program. Alternatively, he can learn the skills to complete the whole project, algorithmic and graphic design, on his own.[2] We call this multiskilling. Suppose that it is efficient for each programmer to specialize in one task. Organizational design in this example is the choice between specialization and multiskilling.

Our interest is in how organizational design interacts with ownership. Suppose that programmer 1 owns the integrated firm where programmer 2 is his employee. Suppose that programmer 1 specializes in algorithms, and programmer 2 specializes in graphics. Specialization gives holdup power to programmer 2 because he is the only person who can design graphics and the project cannot be completed without him. Programmer 1 underinvests in algorithmic skills because programmer 2 expropriates part of the marginal value of his skills. Programmer 1 therefore implements multiskilling for his firm.[3] Multiskilling removes the holdup power of his employee because the owner is able to complete both parts of the project.[4] Therefore the owner has good incentives for investing in human capital. But now the programmers are unfocused and given investments are less valuable than with specialization.

Now consider a situation where there are two small firms (nonintegration): programmer 1 owns a firm that writes the algorithms for the program, and sells it to a firm owned by programmer 2. Programmer 2 completes the project with graphics, and sells it to the final customer. Under nonintegration the programmers naturally specialize in one task and task allocation is efficient. This is how organizational design and ownership interact: under integration an inefficient task allocation is chosen to improve the owner's bargaining position, while under nonintegration the programmers efficiently specialize.

If tasks A and B are highly complementary to the degree that the firm owned by programmer 2 is the only customer for programmer 1's firm, which in turn is the only supplier for programmer 2's firm, then nonintegration results in serious holdup problems. These holdup problems can be avoided if both tasks are performed in one integrated firm. This result is well known. What we add is that this economy comes at the cost of inefficient task allocation. The integrated firm is designed to give power to the owner rather than to employ the best[5] production methods.

We find that the optimal size of the firm depends on technology: the interplay between economies of scope or scale and returns to specialization. Therefore there is a clear link between the property rights theory and the classic technological view of the firm. We find that when the returns to specialization are significant, a fragmented ownership structure with two small firms is optimal. This creates a larger class of owning agents who have the right incentives for specialization, while under concentrated ownership structure the worker is not allowed to obtain the power that specialization gives him. On the other hand, when economies of scope or scale are much more important than returns to specialization, the optimal firm size is large. Separating very complementary assets would not give power to anyone, and the holdup problems would be very severe. Then it is better to concentrate ownership in one agent's hands. Having one large firm would provide the best incentives for human capital investments—even if it comes at a cost of inefficient task allocation, namely multiskilling. Accordingly, we have identified *a new cost of integration*: inefficient organizational design in an integrated firm. This result is interestingly robust to the alternative bargaining model.

We can also relate our result to the technological view of the firm (as discussed, for example, in Hart 1995, pp. 15–17) where the limit to the size of the firm in the presence of economies of scale is somewhat unsatisfactory. In our paper it is the inefficient organizational design chosen to deal with holdup problems that limits the size of the firm.

Our model builds on Hart and Moore (1990). An important determinant for the optimal ownership structure in their paper is the importance of an agent as a trading partner. Our point is that this determinant can be endogenous depending on the organizational design. Holmström and Milgrom (1994) analyse ownership and job design as complementary instruments motivating the workers, and focus on the interactions arising from the cost function. In their paper ownership gives the same returns whatever the job design, while the point of this paper is that job design affects the bargaining outcome within the firm.

Hart and Moore (2005) also analyse task allocation (coordination or specialization) in the theory of the firm. They focus on *ex post* efficiency, while this paper is on *ex ante* incentives.

Mitusch (2000) examines how organizational design (job independence or instructions) affects the holdup problem. He finds that under job independence, the worker increases his bargaining power by investing in reducing the firm's ability to produce without the worker. But worker's increased bargaining power is a good thing—unlike in our paper—because the same investment simultaneously improves the firm's productivity.

Also related is the literature where organizational design is chosen to protect the firm's invention or other valuable knowledge. In Porter Liebeskind (1996), specialization is a way to limit the power of employees—contrary to our paper. Without specialization, each employee knows every part of the project and is in a position to leak the knowledge for imitation elsewhere, while under specialization, each employee knows only part of the project, which protects the knowledge. Rajan and Zingales (2001) show that flat hierarchy can protect invention. This is because an employee who steals the invention cannot survive in competition with the firm unless he leaves with enough subordinates, which he does not have in a flat hierarchy. Also, in Rebitzer and Taylor (2007), organizational structure is used to deal with expropriation. They show that up-or-out promotion contests arise to prevent grabbing clients and leaving in law firms.

The main result of this paper is that specialization causes power problems in integrated firms which can be avoided by multiskilling. Multiskilling is the *ability* to perform a number of tasks. It can result from multitasking (performing various tasks simultaneously) or rotation (performing various tasks sequentially). In our static model, multitasking is equivalent to rotation. Eliminating holdup problems is not the only motivation for multiskilling. Multiskilling improves the firm's ability to deal with change (Koike 1984; Aoki 1986) and improves workers' incentives for technical change (Carmichael and MacLeod 1993). There can be learning spillovers between tasks arising from either intertask learning (Lindbeck and Snower 2000) or knowledge transfer between workers (Lazear 1998, pp. 328–30). Multiskilling increases the flexibility of the firm (Lazear 1998, p. 445). Workers may have a preference for a variety of tasks (Cosgel and Miceli 1999). Job rotation can also be used to extract employee information (Ortega 2001; Arya and Mittendorf 2004). To our knowledge, the power reduction motive for multiskilling is novel.

In this paper we assume that specialization is efficient so that we get an interesting trade-off: multiskilling is inefficient but improves power problems. The above literature, however, suggests that multiskilling can be the efficient organizational design. In such a situation our result shows that there is an additional benefit from multiskilling: in addition to, for example, inducing learning spillovers between the tasks, multiskilling reduces power problems.

But of course there is a limit to multiskilling, and that is what this paper is about. We find that in an integrated firm job design is too broad. The two tasks of our model could consist of sub-tasks among which multiskilling is efficient. Therefore benefits of multiskilling are not necessarily absent from our model. But the combination of the two tasks—literally being able to complete every stage of production—is too broad, and therefore specialization is efficient.

The rest of the paper is organized as follows. In Section I we relate our work to the literature on the theory of the firm. Section II introduces our model of ownership and organizational design. Section III analyses the incentives for organizational design and investments in human capital under various ownership structures, while Section IV derives the optimal ownership structure. The next three sections show that our assumptions about symmetric task allocation (Section V), contractible organizational design (Section VI) and Nash bargaining (Section VII) are not critical. Section VIII discusses the empirical implications of the paper. Section IX concludes.

I. Related Literature

Marglin vs Williamson

Adam Smith compares two production modes in pinmaking: specialization and separate crafting of each individual pin. He concludes that there are significant returns to specialization. This has been interpreted as a rationale for the rise of capitalist firm. Marglin (1974) points out that there is a third production mode where each worker proceeds from task to task, first drawing out enough wire for thousands of pins, then straightening it, etc. He proposes that this is as efficient as specialization of each worker in one task since time will not be lost in constantly switching between tasks (and he does not acknowledge the other reasons for returns to specialization). Marglin interprets this as a nonhierarchical organization of production. Since according to him the capitalist and nonhierarchical organizations are equally efficient, specialization 'was introduced so that the capitalist got himself a larger share of the pie at the expense of the worker'—not for efficiency reasons.

However, these alternative production modes could be implemented under various ownership structures. Clearly, the separate crafting of each individual pin is inefficient. Marglin's third production mode is in fact a description of multiskilling. Then there is a choice between specialization and multiskilling. Specialization does not imply a capitalist mode but could be (and indeed in our model is) implemented in the entrepreneurial mode (nonintegration) where each worker is a boss of his own. According to Marglin, multiskilling would be chosen in nonhierarchical organizations and specialization in capitalist firms. Our model gives exactly the opposite prediction. However, our model is consistent with Marglin in that the capitalist organization (integration) is designed to give a larger share of the pie to the capitalist (choice of multiskilling to weaken workers' bargaining power)—but in the same time the capitalist firm arises only when it is efficient.

Williamson (1985, Chapter 9) takes the opposite view to Marglin and proposes that capitalist authority relation is the most efficient mode. His federated entrepreneurial mode is like our nonintegration, and his capitalist authority relation is like our integration. Specialization is assumed to occur for both modes, and there is no discussion of the power that the specialized workers obtain in the capitalist mode.

The point of this paper is that organizational design is endogenous. Specialization does not imply a capitalist firm, and multiskilling does not imply a nonhierarchical firm.

It should be noted that we have a rather special definition of specialization. Under specialization, only one agent knows how to perform a particular task and therefore gains power. Specialization often refers to dividing a task into smaller tasks which can be performed by several agents. In such a situation there is competition between agents and specialization does not give much power to a single agent (though as a group they have power). The stylized fact is that this type of specialization occurs in large capitalist firms as per Marglin and Williamson. Our analysis applies when specialization is limited by the extent of the market (small firms where it is not feasible for many workers to specialize in the same task).

Grocers and employees

Alchian and Demsetz (1972) raised the question of why an employee would accept his employer's authority any more than a grocer would listen to a consumer. The worst sanction in both cases is firing. The property rights theory shows that the difference is that the grocer walks away with his asset, while an employee leaves without any assets. This difference gives the employer leverage (Hart 1995, p. 58).

In this paper there is a further difference. An employee can be fired also *ex ante* if he does not accept the task allocation, while a grocer can only be fired *ex post*. A customer can either buy from the grocer or not, but he does not have a say about the organizational design in the grocery, while an employer has authority in task allocation, although he cannot tell the employee how hard to work on a given task. Therefore the employee accepts a task allocation that does not violate his individual rationality constraint (like Simon's (1951) area of acceptance). This idea is related to Holmström's (1999) view of the firm as an island economy where the CEO has the power to define the rules of the game.

Access

Finally, we relate our paper to Rajan and Zingales (1998). Rajan and Zingales (RZ) introduced the idea that regulating access to critical resources can have important incentive effects. In RZ, an entrepreneur E owns the asset but does not invest in human capital. There are two tasks, and the question is whether a single manager should perform both tasks or E should hire two managers each specializing in one task. Let us take their case of complementary investments, which is similar to this model. If E grants access to a single manager, the manager has to share the value of his investment with E and he receives half of the marginal value of his investment. If E grants access to two managers (specializing in different tasks), the bargaining is between three agents and each manager receives less than half of the marginal value. Incentives are worse than when access is granted to a single manager. RZ's solution to the power problems created when two managers specialize in different tasks is that a single manager should perform both tasks and therefore access is granted only to a single manager.

RZ is closely related, but our emphasis is on the *owner's* incentives. In RZ the owner does not have an investment and this question does not arise. The owner of the integrated firm always has access to both assets he owns, but what is important is that he may not have the skills to operate both of them. Under specialization the owner can operate only one asset, which gives holdup power to the employee who has specialized in operating the other asset, while multiskilling removes the holdup power of the employee as the owner has the skills to operate both assets. Furthermore, in this paper ownership is endogenous while in RZ ownership is fixed to E.

II. The Model

We analyse a setup where there are two agents, 1 and 2, and two assets, a_1 and a_2. *Ex ante* the agents learn to operate the assets. Under *specialization* agent i learns to use only a_i, while under *multiskilling* each agent learns to use both assets. We denote the level of investment in human capital of agents 1 and 2 by I_1 and I_2, respectively; $I_i \in [0, \overline{I}]$, $i = 1, 2$, where $\overline{I} > 0$. Organizational design determines whether this is an investment to learn to use both assets or only one.

Our model builds on Hart and Moore (1990). We simplify their setting by having two agents and two assets, and endogenize organizational design in their framework.[6]

The cost of the investment is $c(I_i)$ and is assumed to have the following standard properties.

Assumption 1. $c(0) = 0$. c is twice differentiable. $c'(I_i) > 0$ and $c''(I_i) > 0$ for $I_i \in (0, \bar{I})$, with $\lim_{I_i \to 0} c'(I_i) = 0$ and $\lim_{I_i \to \bar{I}} c'(I_i) = \infty$.

Ex post production and trade occur. The value of production depends on which agent(s) are involved and on which assets they are using. The value of production depends also on organizational design and on the human capital of the included agents. Under multiskilling a coalition S of agents with a set of assets A and given investments $I = (I_1, I_2)$ can generate a value $v(S, A|I)$, while under specialization a value $V(S, A; \alpha|I)$ can be obtained, where $\alpha \geqslant 1$. The parameter α is a measure of the returns to specialization: how much higher value the specialized agents can generate for given investments.

In what follows we simplify notation by not explicitly writing the investments in the value functions: $v(S, A|I) \equiv v(S, A)$ and $V(S, A; \alpha|I) \equiv V(S, A; \alpha)$. We make the following assumptions about the value function under specialization.

Assumption 2. $V(S,A; \alpha) = v(S,A)$ if and only if $\alpha = 1$ for all $S \neq \varnothing$ and $A \neq \varnothing$. $\partial V(S, A; \alpha)/\partial\alpha > 0$.

In other words, when there are no returns to specialization, given investments generate the same value under both multiskilling and specialization. Furthermore, the value of production under specialization is increasing in the returns to specialization.

We further make the following assumptions about the marginal values of investments. We adopt the notation

$$\frac{\partial}{\partial I_i} v(S, A) \equiv v^i(S, A) \quad \text{and} \quad \frac{\partial}{\partial I_i} V(S, A; \alpha) \equiv V^i(S, A; \alpha).$$

$A \backslash a_i$ denotes a set of assets that does not include a_i.

Assumption 3. Under specialization, $V^i(S, A\backslash a_i; \alpha) = 0$ and $V^i(i, \{a_1, a_2\}; \alpha) = V^i(i, \{a_i\}; \alpha)$.

Assumption 4. Under multiskilling, $v^i(S, \varnothing) = 0$ and $v^i(i, \{a_1, a_2\}) = v^i(12, \{a_1, a_2\})$.

Assumption 5. $V(i, \varnothing; \alpha) = v(i, \varnothing)$.

We assume that the investments are asset-specific, that is, the skills have no value unless the agent is in the same coalition with the relevant asset(s). This explains the first part of Assumptions 3 and 4, and Assumption 5. Assumption 3 further says that when the agents specialize, the marginal value of agent i's investment without the contribution of agent j is the same whether the coalition has asset a_j or not. Agent i's skills are geared to operating asset a_i only, and therefore a_j does not enhance the value of his skills at the margin. In other words, specialization makes agent j indispensable to a_j, while according to Assumption 4, under multiskilling the marginal value of agent i's investment is not enhanced by agent j joining the coalition. Agent i knows how to operate both assets and therefore agent j is not important at the margin. In other words, multiskilling makes the agents dispensable.

Additionally, we make the following assumptions as in Hart and Moore (1990). The assumptions are for simplicity written only for $v(S, A)$, but $V(S, A; \alpha)$ is assumed to have the same properties.

Assumption 6. $v(S,A) \geqslant 0$ and $v(\varnothing, A) = 0$. $v(S, A)$ is twice differentiable in I. $v^i(S,A) \geqslant 0$ for $I_i \in (0, \overline{I})$. $v(S, A)$ is concave in I.

Assumption 7. $v^i(S,A|I) = 0$ if $i \notin S$.

Assumption 8. $\dfrac{\partial}{\partial I_j} v^i(S,A|I) \geqslant 0$ for $j \neq i$.

Assumption 9. For all subsets $S' \subseteq S$, $A' \subseteq A$, $v(S,A) \geqslant v(S',A') + v(S \backslash S', A \backslash A')$.

Assumption 10. For all subsets $S' \subseteq S$, $A' \subseteq A$, $v^i(S,A) \geqslant v^i(S',A')$.

Assumption 6 gives the standard properties for the value function (increasing and concave), taking into account that agent i's investment does not affect the value of *all* coalitions. Assumption 7 follows on from this and states that agent i's investment increases the value of only those coalitions of which he is a member. According to Assumption 8, the agents' investments are (weakly) complementary. Assumption 9 ensures that it is *ex post* efficient for the agents to produce together with both assets. According to Assumption 10, the marginal value of investment is nondecreasing in the number of agents and assets in the coalition.

We make one final assumption.

Assumption 11. $v(12, \{a_1, a_2\}|I_1 = I', I_2 = I'') = v(12, \{a_1, a_2\}|I_1 = I'', I_2 = I')$, $v(1, \{a_1, a_2\}|I_1 = I') = v(2, \{a_1, a_2\}|I_2 = I')$, $v(1, \{a_1\}|I_1 = I') = v(2, \{a_2\}|I_2 = I')$.

Assumption 11 says that the investments enter symmetrically in the value functions. Since also the cost functions are symmetric, the agents are identical.

Contracts

We assume that *ex ante* contracts can only be written on the ownership structure and organizational design. (Section VI shows that our results are robust to noncontractible organizational design.) Investment in human capital is too complex to be described in a contract. It is assumed to be observable for the agents but not verifiable in courts. Furthermore, contracts on trade can only be written *ex post*.

The *ex ante* contract determines the ownership structure and organizational design. The assets can be either *nonintegrated* (1 owns a_1 and 2 owns a_2) or *integrated* (one agent owns both assets). The agents either *specialize* in operating one asset or learn to operate both assets (*multiskilling*).[7] The agents have symmetric information, and therefore suitable transfer payments *ex ante* guarantee that a joint surplus maximizing ownership structure and organizational design are chosen.

The timing of the model is illustrated in Figure 1. *Ex ante*, the agents write a contract on the ownership structure and organizational design. Then the agents choose their investments in human capital noncooperatively. *Ex post*, production occurs and spot contracts on trade are negotiated. We assume that the agents divide the gains from trade according to Nash bargaining.

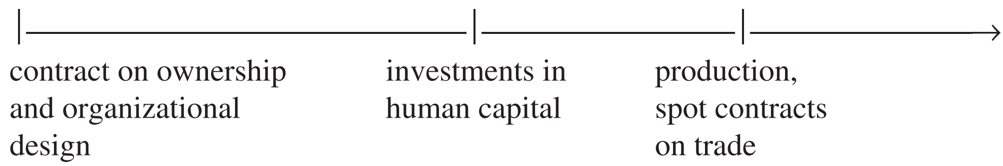

FIGURE 1. Timeline.

First best

The first best is for each agent to specialize in one task and to choose the level of investment in human capital according to

$$(1) \qquad V^i(12, \{a_1, a_2\}; \alpha) = c'(I_i^*), \quad i = 1, 2.$$

Because investments are not contractible they will be chosen noncooperatively and typically first best does not obtain. Our aim is to find an ownership structure and organizational design that give second best incentives for human capital investments.

Technology

Technology is one of the driving forces behind our results. We now work out some basic properties of the value functions with respect to the technology. In our model the assets can be either vertically or horizontally related, and to ease the discussion we define a concept of *joint economies* to describe economies of either scale or scope. When there are no joint economies (constant returns to scale or no economies of scope), we have:[8]

$$(2) \qquad v(12, \{a_1, a_2\}) = v(1, \{a_1\}) + v(2, \{a_2\}).$$

Equation (2) implies that the marginal value of investment is the same whether the assets are used together or separately:

$$(3) \qquad v^i(12, \{a_1, a_2\}) = v^i(i, \{a_i\}), \quad i = 1, 2.$$

With extreme joint economies the assets are useless separately,

$$(4) \qquad v(1, \{a_1\}) + v(2, \{a_2\}) = 0,$$

and therefore the marginal value of investment is zero with only one asset:

$$(5) \qquad v^i(i, \{a_i\}) = 0, \quad i = 1, 2.$$

For the intermediate case of some joint economies we have

$$(6) \qquad v(12, \{a_1, a_2\}) > v(1, \{a_1\}) + v(2, \{a_2\}) > 0.$$

We assume that in this case also the marginal value of investment is intermediate:

$$(7) \qquad v^i(12, \{a_1, a_2\}) > v^i(i, \{a_i\}) > 0, \quad i = 1, 2.$$

We introduce a parameter μ to measure the joint economies, $\mu \in [0, 1]$. $\mu = 0$ denotes extreme joint economies so that $v^i(i, \{a_i\}) = 0$, while $\mu = 1$ stands for no joint economies and $v^i(i, \{a_i\}) = v^i(12, \{a_1, a_2\})$. For the intermediate case, $0 < v^i(i, \{a_i\}) < v^i(12, \{a_1, a_2\})$, we have $0 < \mu < 1$. The higher the degree of joint economies, the lower is μ. The degree of joint economies is one of the driving forces in our model.

III. Organizational Design and Choice of Investments

We start by analysing how the incentives to invest depend on the organizational design and the ownership structure. This allows us to determine whether specialization or multiskilling will be chosen under a given ownership structure. Section IV follows by examining the optimal ownership structure.

Integration

Suppose that agent 1 owns both assets. What are the agents' incentives to invest under specialization and multiskilling? When we know the answer to this question we can determine whether specialization or multiskilling will be chosen under integration.

We start the analysis from *specialization*, i.e. agent i learns to operate only asset a_i, $i = 1, 2$. The default payoffs are important in determining the bargaining outcome. In this case agent 1's default payoff is $V(1, \{a_1, a_2\}; \alpha)$, the value she can generate with the assets she owns but without the contribution of agent 2, while agent 2's default payoff is $V(2, \varnothing; \alpha)$—if the agents split, agent 2 does not have access to the assets since he does not own them. The bargaining results in the following payoffs, P_1 and P_2, to the agents:

$$P_1 = \frac{1}{2}[V(12, \{a_1, a_2\}; \alpha) + V(1, \{a_1, a_2\}; \alpha) - V(2, \varnothing; \alpha)] - c(I_1), \tag{8}$$

$$P_2 = \frac{1}{2}[V(12, \{a_1, a_2\}; \alpha) - V(1, \{a_1, a_2\}; \alpha) + V(2, \varnothing; \alpha)] - c(I_2). \tag{9}$$

Each agent chooses investment noncooperatively, foreseeing the outcome of *ex post* bargaining. Accordingly, agent 1's incentives are given by the following first-order condition:

$$\frac{1}{2}V^1(12, \{a_1, a_2\}; \alpha) + \frac{1}{2}V^1(1, \{a_1, a_2\}; \alpha) - c'(I_1) = 0. \tag{10}$$

Under specialization the second asset does not enhance the marginal value of agent 1's investment since she does not know how to operate it (Assumption 3) and (10) is equivalent to

$$\frac{1}{2}V^1(12, \{a_1, a_2\}; \alpha) + \frac{1}{2}V^1(1, \{a_1\}; \alpha) - c'(I_1) = 0. \tag{11}$$

Agent 2's incentives are given by

$$\frac{1}{2}V^2(12, \{a_1, a_2\}; \alpha) - c'(I_2) = 0. \tag{12}$$

Each agent foresees that part of the surplus he generates by his investment is expropriated in *ex post* bargaining while he pays the full cost of investment. Therefore underinvestment (holdup) typically arises. Agent 2 receives only half of the marginal return on his investment and therefore underinvests significantly. Agent 1's incentives depend on the degree of joint economies. When joint economies are very strong so that $V^1(1, \{a_1\}; \alpha) = 0$, ownership does not improve incentives at all since specialization gives so much power to the worker. Ownership of the second asset does not increase the value of the owner's skills since she cannot operate the second asset. Ownership of the first asset does not enhance agent 1's incentives either since in this case one asset is useless without the other, while when there are no joint economies,

($V^1(1,\{a_1\};\alpha) = V^1(12,\{a_1,a_2\};\alpha)$), the owner receives the full marginal return on her investment and therefore chooses first best investment. When the productivity of asset a_1 is independent of a_2, the worker has no power over the owner's skills. Therefore the weaker the joint economies, the better are the owner's incentives because the worker's holdup power is decreased.

We then analyse *multiskilling*, i.e. each agent learns to operate both assets. The payoffs are given by equations (8) and (9) by setting $\alpha = 1$, and the owner's incentives for investing are[9]

$$\frac{1}{2}v^1(12,\{a_1,a_2\}) + \frac{1}{2}v^1(1,\{a_1,a_2\}) - c'(I_1) = 0. \tag{13}$$

Since agent 1 has the skills to operate both assets, agent 2 is dispensable (Assumption 4) and (13) is equivalent to

$$v^1(12,\{a_1,a_2\}) - c'(I_1) = 0, \tag{14}$$

and the worker's incentives are

$$\frac{1}{2}v^2(12,\{a_1,a_2\}) - c'(I_2) = 0. \tag{15}$$

The owner can operate both assets and therefore the marginal value of her investment does not depend on whether or not the worker is in the same coalition. The owner has all the power and chooses efficient investment *given multiskilling*, the inefficient task allocation. The worker has to share the value of his investment fifty–fifty with the owner to gain access to the assets whatever the task allocation, and therefore faces a significant holdup.

Above we have analysed the incentives to invest in specific human capital for a given task allocation. Moving one step backward, we now examine optimal *organizational design*.

The benefit of specialization is that given investments have higher value. The cost of specialization is that it gives power to the worker and he can hold up the owner. The owner's incentives are accordingly diluted. The stronger the joint economies, the more power the worker obtains. This is because one asset is more dependent on the other and only the worker knows how to operate the second asset. This trade-off determines the choice of task allocation under integration.

Proposition 1. There exists $\hat{\alpha}$ such that under integration, specialization is chosen if and only if $\alpha \geqslant \hat{\alpha}$. The greater the degree of joint economies, the higher is $\hat{\alpha}$.

Proof. The agents contract on the joint surplus maximizing task allocation. Denote the joint surplus under integration and specialization by $J^{I,S}$, and with multiskilling by $J^{I,M}$.

Under specialization, $\partial I_i/\partial\alpha > 0$ for $i = 1, 2$ (equations (11) and (12)) and $\lim_{\alpha\to\infty} I_i = \bar{I}$ by Assumption 1. Therefore the investment costs are finite and $\lim_{\alpha\to\infty} J^{I,S} = \infty$. Clearly, $J^{I,S} > J^{I,M}$ in the limit.

If $\alpha = 1$, there is no benefit to specialization, only the cost of lower incentives for the owner, equations (11) and (14) (and there is no cost either if there are no joint economies). Therefore $J^{I,S} \leqslant J^{I,M}$ for $\alpha = 1$.

By continuity there exists an $\alpha = \hat{\alpha} \geqslant 1$ such that $J^{I,M} = J^{I,S}$. This proves the first part of Proposition 1. The critical value for α is defined by

$$J^{I,S}(\hat{\alpha}) = J^{I,M}. \tag{16}$$

When the joint economies become stronger (lower μ), $J^{I,S}$ decreases:

$$\begin{aligned}\frac{\partial J^{I,S}}{\partial \mu} &= \left[V^1(12,\{a_1,a_2\};\alpha) - c'(I_1)\right]\frac{\partial I_1}{\partial \mu} \\ &= \frac{1}{2}\left[V^1(12,\{a_1,a_2\};\alpha) - V^1(1,\{a_1\};\alpha)\right]\frac{\partial I_1}{\partial \mu} > 0.\end{aligned} \tag{17}$$

To increase $J^{I,S}$ so that (16) is satisfied requires a higher α. This proves the second part of Proposition 1. $\square$

When α is very large, the returns to specialization are significant. Even if specialization gives a lot of power to the worker, the value of specialized skills is so large that specialization will be chosen. When α is close to one, the returns to specialization are negligible. Specialization would only give power to the worker without any counteracting gain. Clearly the agents then choose multiskilling. This is the intuition for the first part of Proposition 1: specialization is chosen for high α.

The second part of Proposition 1 states that the weaker the joint economies, the smaller the returns to specialization have to be for specialization to be chosen. If there are no joint economies, specialization does not give any power to the worker. Since there is no cost, specialization is chosen for any α. When joint economies are very strong, specialization gives a lot of power to the worker. Returns to specialization have to be significant for specialization to pay.

Nonintegration

Now suppose that the assets are nonintegrated. What are the agents' incentives when they specialize?

Under nonintegration and specialization, agent's default payoff is $V(i,\{a_i\};\alpha)$, the value he can generate with the asset he owns. The agents' payoffs and the incentives to invest are

$$P_i = \frac{1}{2}\left[V(12,\{a_1,a_2\};\alpha) + V(i,\{a_i\};\alpha) - V(j,\{a_j\};\alpha)\right] - c(I_i), \tag{18}$$

$$\frac{1}{2}V^i(12,\{a_1,a_2\};\alpha) + \frac{1}{2}V^i(i,\{a_i\};\alpha) - c'(I_i) = 0, \quad i = 1,2. \tag{19}$$

The incentives depend on the degree of joint economies. When there are no joint economies $(V^i(i,\{a_i\};\alpha) = V^i(12,\{a_1,a_2\};\alpha))$ the agents have first best incentives, while with extreme joint economies $(V^i(i,\{a_i\};\alpha) = 0)$ the agents receive only half of the marginal return on their investment at the margin. The holdup problems are severe since the firms are very dependent on each other. This shows that under nonintegration and specialization the agents' incentives are the worse, the stronger the joint economies.

What remains to be analysed is multiskilling. By definition, multiskilling means that agent i learns to operate the asset she owns, a_i, and additionally acquires skills to operate

a_j owned by agent j. This sounds like a strange arrangement, and indeed in equilibrium it is never chosen. Multiskilling would not improve the agents' bargaining position. If the agents fail to reach an agreement, each agent has access only to the asset she owns and that value does not depend on whether she could operate the other asset. Therefore with multiskilling, equations (18) and (19) apply with α set equal to one.

Since there is no cost of specialization, it is clear that:

Proposition 2. Under nonintegration, the agents will specialize.

IV. Optimal Ownership Structure

In Section III we analysed organizational design and investments for a given ownership structure. We now examine the optimal ownership structure.

Let us start by analysing the ownership structures under specialization. Comparing equations (11), (12) and (19), we see that agent 1's incentives are the same in both structures, while agent 2's investment is greater under nonintegration. Therefore given specialization, nonintegration dominates. The second asset does not improve agent 1's incentives under integration since she cannot operate that asset, while allocating that asset to agent 2 (nonintegration) improves agent 2's incentives. Accordingly, the agents would never choose integration if they want to implement specialization.

We know from Propositions 1 and 2 that multiskilling is only ever chosen under integration. Above we have shown that given specialization, nonintegration dominates. Therefore when we choose the ownership structure and organizational design pair optimally, we only need to compare nonintegration with specialization and integration with multiskilling.

To make the comparison clear, we rewrite the incentives for human capital investments. Under integration and multiskilling, we have

$$(20)\qquad v^1(12,\{a_1,a_2\}) - c'(I_1) = 0,$$

$$(21)\qquad \frac{1}{2}v^2(12,\{a_1,a_2\}) - c'(I_2) = 0,$$

and under nonintegration and specialization, the incentives are

$$(22)\qquad \frac{1}{2}V^i(12,\{a_1,a_2\};\alpha) + \frac{1}{2}V^i(i,\{a_i\};\alpha) - c'(I_i) = 0, \quad i = 1,2.$$

The benefit of integration is that agent 1's holdup problem is removed. The cost of integration is that multiskilling will be chosen and agent 2 has worse incentives. We have identified *a new cost of integration*: inefficient organizational design. An integrated firm is designed to give power to the owner rather than to employ the best[10] production methods.

The optimal ownership structure depends on both α and μ. When there are no joint economies ($\mu = 1$ and $V^i(i,\{a_i\};\alpha) = V^i(12,\{a_1,a_2\};\alpha)$) first best obtains under nonintegration and therefore nonintegration is optimal for any α.

With extreme joint economies ($\mu = 0$ and $V^i(i,\{a_i\};\alpha) = 0$) the agents are very dependent on each other under nonintegration and the holdup problems are severe, while under integration the owner receives the full marginal return on her investment but given investments have a lower value under multiskilling. Then the optimal ownership structure depends on α.[11] When α is close to one, the returns to specialization are negligible—integration dominates because agent 1 has better incentives and agent 2 has no worse incentives—while when α is large there are significant returns to specialization and the ownership structure is chosen to implement efficient task allocation. Nonintegration is optimal even if it results in higher holdup for agent 1.[12]

Proposition 3 shows how the optimal ownership structure depends on the returns to specialization and on the degree of joint economies.

Proposition 3. There exists $\tilde{\alpha}$ such that the optimal ownership structure is

(i) integration (and multiskilling) if and only if $\alpha < \tilde{\alpha}$,
(ii) nonintegration (and specialization) if and only if $\alpha \geqslant \tilde{\alpha}$.

$\tilde{\alpha}$ is increasing in the degree of joint economies.

Proof. Denote the joint surplus under nonintegration and specialization by $J^{NI,S}$.

For $\alpha = 1$ and $\mu = 0$, $J^{I,M} > J^{NI,S}$. Agent 1 has higher incentives under integration ((20) *vs* (22)), and agent 2's incentives are the same ((21) *vs* (22)). For $\alpha = 1$ and $\mu = 1$, $J^{I,M} < J^{NI,S}$, since first best obtains under nonintegration, while under integration the worker is subject to a holdup. Since $J^{I,M}$ does not depend on μ and $\partial J^{NI,S}/\partial\mu > 0$ (from equation (22)), by continuity there exists a $\mu = \mu'$, where $0 < \mu' < 1$, for which $J^{I,M} = J^{NI,S}$ at $\alpha = 1$.

From equation (22) it is clear that $\lim_{\alpha\to\infty} J^{NI,S} = \infty$ and $\partial J^{I,M}/\partial\alpha = 0$.

Therefore for $\mu \geqslant \mu'$, $J^{NI,S} \geqslant J^{I,M}$ for all $\alpha \geqslant 1$.

For $\mu < \mu'$, $J^{NI,S} > J^{I,M}$ if and only if $\alpha > \tilde{\alpha}$. The critical value for α is defined by

$$J^{NI,S}(\tilde{\alpha}) = J^{I,M}. \tag{23}$$

When the joint economies become stronger (lower μ), $J^{NI,S}$ decreases. To increase $J^{NI,S}$ so that (23) is restored requires a higher α. This explains why $\partial\tilde{\alpha}/\partial\mu < 0$. □

The optimal ownership structure depends on the relative importance of the returns to specialization and the degree of joint economies. When the returns to specialization are significant, fragmented ownership structure with two small firms is optimal—this creates two owners who have the right incentives for specialization—while when the joint economies are much more important than the returns to specialization, it is optimal to have one large firm. Separating very complementary assets would not give power to anyone, and holdup problems would be severe under nonintegration. Bringing the assets under common ownership minimizes the holdup problems as in Hart and Moore (1990). Our contribution is to identify a new cost of integration: inefficient organizational design. The integrated firm adopts multiskilling so that the owner's holdup problem is minimized.

It is interesting to note that the returns to specialization are a property of human capital, while the joint economies relate to the physical capital. We can restate our results by saying that when the emphasis is on human capital, entrepreneurship emerges, while dominant physical capital properties lead to a large integrated firm.

V. Asymmetric Task Allocation

In the main model, task allocation is symmetric: either both agents specialize in one asset or both agents learn to operate both assets. The driving force of our results is how multiskilling removes the holdup problem for the *owner* of the integrated firm. Multiskilling does not improve the incentives of an employee since he is in any case dependent on the owner. Therefore if we allow for asymmetric task allocation in the two-agent model, it is optimal to choose multiskilling for the owner and specialization for the employee.[13] But in this section we show that multiskilling can reduce holdup problems even among employees when we have more than two agents.

Consider a three-agent setup. To simplify notation, suppose that there is only one asset, a, and agent 1 owns the asset. The Shapley value gives the following payoffs to the agents:

$$P_1 = \frac{1}{3}[v(123,a) - v(23,\varnothing)] + \frac{1}{6}[v(12,a) - v(2,\varnothing)] + \frac{1}{6}[v(13,a) - v(3,\varnothing)] + \frac{1}{3}v(1,a) - c(I_1), \tag{24}$$

$$P_i = \frac{1}{3}[v(123,a) - v(1j,a)] + \frac{1}{6}[v(1i,a) - v(1,a)] + \frac{1}{6}[v(23,\varnothing) - v(j,\varnothing)] + \frac{1}{3}v(i,\varnothing) - c(I_i), \quad i,j = 2,3, i \neq j. \tag{25}$$

Suppose that there are three tasks. If each agent specializes in one task, the incentives are

$$\frac{1}{3}v^1(123,a) + \frac{1}{6}v^1(12,a) + \frac{1}{6}v^1(13,a) + \frac{1}{3}v^1(1,a) = c'(I_1), \tag{26}$$

$$\frac{1}{3}v^i(123,a) + \frac{1}{6}v^i(1i,a) = c'(I_i), \quad i = 2,3, \tag{27}$$

while with multiskilling, equations (26) and (27) change to

$$v^1(123,a) = c'(I_1), \tag{28}$$

$$\frac{1}{2}v^i(123,a) = c'(I_i), \quad i = 2,3. \tag{29}$$

Multiskilling removes the holdup problem for the owner—just like in the main model. What is new is that multiskilling improves the workers' incentives too. Workers cannot hold up each other because they all have the same skills. Therefore multiskilling can reduce power problems not just for the owner but among the workers too. Asymmetric task allocation, accordingly, does not dominate full multiskilling under integration.

VI. Noncontractible Organizational Design

In the main model we have assumed that organizational design is contractible. Therefore the *ex ante* contract on ownership structure also determines the organizational design. In this section we show that our results are robust to this assumption. The driving force in our model is the noncontractible *human* capital.

Suppose that organizational design is noncontractible and the owner has the right to choose it.[14] The natural timing is after the contract on ownership has been written but before the investments in human capital are made. The owner chooses organizational design to maximize his own payoff, not the joint surplus. How does this affect our results? Proposition 3 states that integration and multiskilling maximize joint surplus if and only if $\alpha < \tilde{\alpha}$, while nonintegration and specialization are joint surplus maximizing for $\alpha \geqslant \tilde{\alpha}$. We know that specialization is always chosen under nonintegration. To find out whether Proposition 3 is robust to noncontractible organizational design, we examine if the owner of the integrated firm chooses multiskilling for $\alpha < \tilde{\alpha}$. We analyse this question in Figures 2 and 3. The solid line in each figure represents the critical boundary $\tilde{\alpha}(\mu)$. Below the solid line, integration and multiskilling maximize joint surplus, while above it nonintegration and specialization are joint surplus maximizing.

The owner of the integrated firm chooses multiskilling if and only if $P_1^{I,M} > P_1^{I,S}$. The two possibilities for this critical boundary are presented in Figures 2 and 3 as dashed lines.[15] Below the dashed line, the owner of the integrated firm chooses multiskilling. If the critical boundary lies above $\tilde{\alpha}$, as in Figure 2, then Proposition 3 does not change at all. The owner indeed chooses multiskilling for $\alpha < \tilde{\alpha}$. In the situation of Figure 3, in region A the owner of the integrated firm would choose specialization. Therefore the critical boundary between integration and nonintegration shifts and becomes the thick line. Although the critical boundary shifts, the basic trade-off is not changed: nonintegration emerges for high α and high μ.

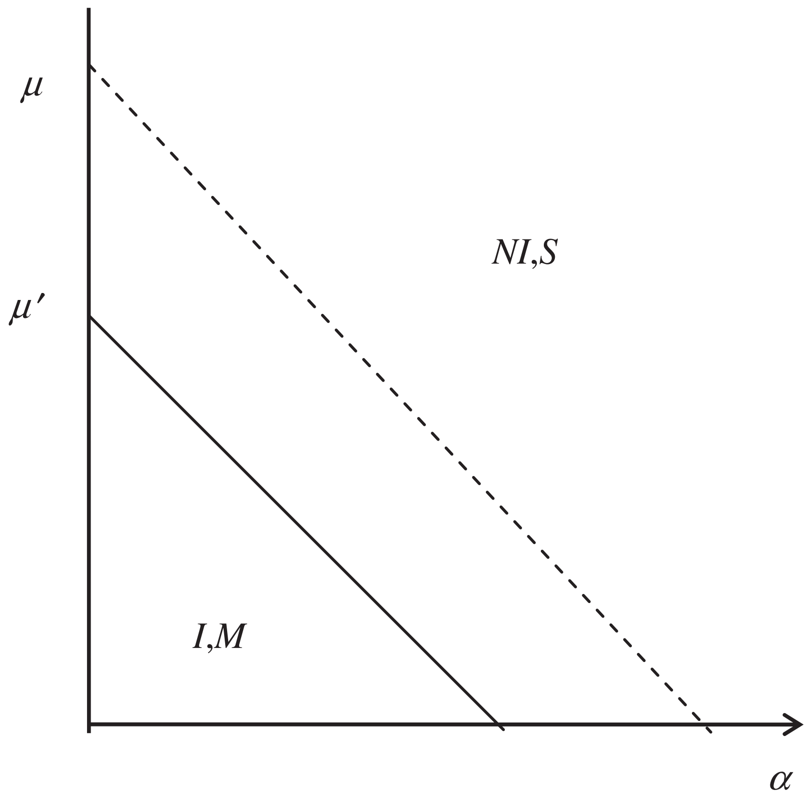

FIGURE 2. Critical boundary: case 1.

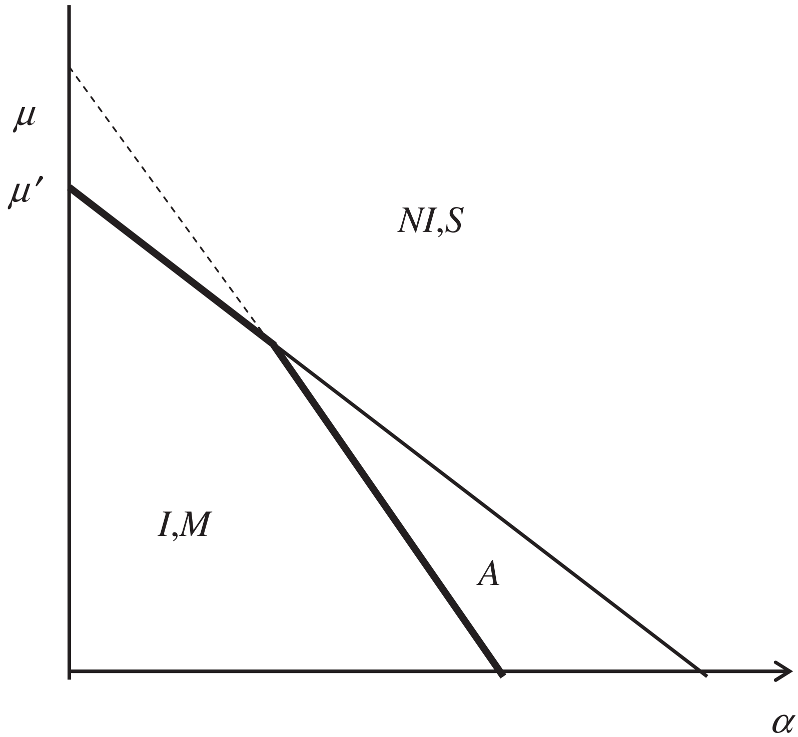

FIGURE 3. Critical boundary: case 2.

VII. Alternative Bargaining Model

We have applied Nash bargaining in our main model. The alternative bargaining model typically changes the results of the property rights theory (Chiu 1998 and De Meza; Lockwood 1998). In this section we apply the outside option principle in bargaining, and we find, surprisingly, that our main result is robust to the alternative bargaining model.

Under integration, the owner has a strong bargaining position and it is reasonable to assume that the outside option binds for the owner. Then the payoffs under integration and multiskilling are given by

$$P_1 = v(1, \{a_1, a_2\}) - c(I_1),$$

$$P_2 = v(12, \{a_1, a_2\}) - v(1, \{a_1, a_2\}) - c(I_2).$$

Since $v^i(1, \{a_1, a_2\}) = v^i(12, \{a_1, a_2\})$ under multiskilling, the resulting incentives for the agents are

$$v^i(12, \{a_1, a_2\}) = c'(I_i), \quad i = 1, 2.$$

As before, multiskilling improves the owner's bargaining position and he has efficient incentives given the task allocation. Now, additionally, the worker has efficient incentives because he receives the full marginal value of his investment when the owner's outside option binds.

Under nonintegration, the agents have relatively equal bargaining positions and we assume that outside options do not bind. Then the agents split the surplus fifty–fifty and the incentives under nonintegration and specialization are

$$\frac{1}{2}V^{i}(12,\{a_1,a_2\};\alpha)=c'(I_i),\quad i=1,2.$$

We can now see that our main result is robust to the alternative bargaining model. Under integration, there is no holdup problem but task allocation is inefficient, while under nonintegration, there is a holdup problem but given investments have higher value due to specialization. Therefore for high enough α, nonintegration and specialization are optimal, while for low α, integration and multiskilling are optimal—just like in Proposition 3. Inefficient task allocation therefore remains as the new cost of integration. The critical value for α is higher than in Proposition 3. This is because the surplus is higher under integration compared to our main model. Not only the owner but also the worker has efficient incentives. Furthermore, the surplus under nonintegration is lower than in the main model because the term $\frac{1}{2}V^{i}(i,\{a_i\};\alpha)$ is missing. Outside options do not affect the division of surplus when they are not binding. This also means that under outside option bargaining, the degree of joint economies does not play a role as it does not affect incentives under nonintegration.

VIII. Empirical Implications

The message of this paper is that there are costs to specialization in vertically integrated firms, arising from power problems. In our model this results in no specialization in integrated firms. But if we allowed specialization to be a continuous variable, then some specialization would occur in the integrated firm but less than in the nonintegrated firm. Taking into account that our setup applies to human-capital-intensive firms, we can formulate the following hypothesis: *ceteris paribus, there is less specialization in vertically integrated human-capital-intensive firms than in other vertically integrated firms*. In Tayloristic assembly lines, specialization is fine-tuned. The work is routine and the workers do not have holdup power. In such a setup, specialization does not cause power problems. Our setup applies to human-capital-intensive firms where workers have holdup power and specialization causes power problems. According to our results, there should be less specialization in such firms compared to firms where work is routine. There is some interesting empirical work on job design (e.g. Zoghi *et al.* 2005), but this question has not been addressed.

Our main Proposition 3 finds that vertical integration emerges for low returns to specialization, while nonintegration is the equilibrium structure for high returns to specialization. Returns to specialization increase with market size (Rosen 1983). Therefore the empirical prediction of Proposition 3 is that there are less vertically integrated firms in large markets. This is similar to Stigler's (1951) hypothesis. According to Stigler, vertical disintegration is the typical development in growing industries, vertical integration in declining industries. The rationale is, however, different. Stigler argues that in infant industries, firms are integrated because the level of production at any one stage is too small to support specialization. When demand grows, the firms spin off stages and buy inputs from new specialized suppliers, while in this paper specialization causes power problems in integrated firms, which is why there is less specialization in vertically integrated firms. When the market grows and, accordingly, the returns to specialization increase, nonintegration emerges so that specialization can be implemented. Empirical results about the relationship of vertical integration and market size are mixed (see Elberfeld 2002 for a recent summary).

IX. CONCLUSIONS

In this paper we endogenize organizational design in the property rights theory of Hart and Moore (1990). In our model with two agents and two assets, the agents can either specialize in operating one asset or learn to operate both assets (multiskilling). Specialization increases productivity but (depending on the ownership structure) also increases holdup problems because a specialized agent is indispensable. Our interest is in how organizational design interacts with ownership.

It is well known that strong joint economies make integration optimal. What we are adding is that it comes at the cost of inefficient organizational design. Under integration, the worker is not allowed to obtain the power that specialization gives him—multiskilling is adopted—while under nonintegration, each agent is a boss of his own and specialization does not cause power problems—the agents specialize. Therefore nonintegration is optimal when the returns to specialization are high (the cost of inefficient organizational design under integration is high) and the joint economies are weak (holdup problems arising from separating the assets are low), while integration arises when the returns to specialization are low (multiskilling is not very costly) and the joint economies are strong (nonintegration would lead to significant holdups).

Multiskilling implies that human capital is *less* specific in the integrated firm, while under nonintegration, asset specificity is greater due to specialization. Also, Ellman (2006) and Kvaloy (2007) predict a negative relationship between specificity and integration, and this is supported by empirical observations in Holmström and Roberts (1998).

There are dimensions to organizational design other than those analysed here. Their effect on power relationships inside and between the firms remains an open question.

Trust is important in relationships where dependency leads to vulnerability. In the future it will be interesting to explore how building and maintaining trust interacts with organizational design and ownership.

APPENDIX: CONSTRUCTING FIGURES 2 AND 3

The solid line in each of Figures 2 and 3 shows the critical boundary $\tilde{\alpha}(\mu)$ derived in Proposition 3. From the proof of the proposition we know that the critical boundary between integration with multiskilling and nonintegration with specialization cuts the vertical axis at μ', where $0<\mu'<1$, and that it is downward sloping.

The broken line in each figure is the critical boundary for the owner of the integrated firm when organizational design is noncontractible. Above it, the owner chooses specialization, and below it, he chooses multiskilling. Denote this critical boundary by $\alpha = \underline{\alpha}(\mu)$. We will first prove that $\underline{\alpha}'(\mu)<0$.

Total differentiation of the owner's payoff function with respect to α gives

$$\begin{aligned}\frac{\mathrm{d}P_1^{I,S}}{\mathrm{d}\alpha} &= \frac{\partial P_1^{I,S}}{\partial I_2}\frac{\partial I_2}{\partial \alpha} + \frac{\partial P_1^{I,S}}{\partial \alpha}\\ &= \frac{1}{2}V^2(12,\{a_1,a_2\};\alpha)\,\frac{\partial I_2}{\partial \alpha}\\ &\quad + \frac{1}{2}\left[\frac{\partial}{\partial \alpha}V(12,\{a_1,a_2\};\alpha) + \frac{\partial}{\partial \alpha}V(1,\{a_1,a_2\};\alpha)\right] > 0.\end{aligned}$$

$\partial I_2/\partial \alpha > 0$ from equation (12), and therefore the owner's payoff under specialization is increasing with α.

Then differentiate the owner's payoff with respect to μ:

$$\begin{aligned}\frac{\mathrm{d}P_1^{I,S}}{\mathrm{d}\mu} &= \frac{\partial P_1^{I,S}}{\partial I_2}\frac{\partial I_2}{\partial \mu} + \frac{\partial P_1^{I,S}}{\partial \mu} \\ &= \frac{\partial}{\partial \mu} V(1, \{a_1, a_2\}; \alpha) > 0.\end{aligned} \tag{30}$$

The worker's investment does not depend on the degree of joint economies (equation (12)). Therefore there is only the direct effect. The only term that is changed in the payoff function is $V(1, \{a_1, a_2\}; \alpha)$, because when agent 1 is on her own, the assets are separated in a sense since she only knows how to operate one asset. The higher the degree of joint economies (the lower μ), the lower agent 1's default payoff.

Since

$$\frac{\mathrm{d}P_1^{I,S}}{\mathrm{d}\alpha} > 0, \quad \frac{\mathrm{d}P_1^{I,S}}{\mathrm{d}\mu} > 0, \quad \frac{\mathrm{d}P_1^{I,M}}{\mathrm{d}\alpha} = 0, \quad \frac{\mathrm{d}P_1^{I,M}}{\mathrm{d}\mu} = 0,$$

$P_1^{I,S} = P_1^{I,M}$ maps a function $\alpha = \underline{\alpha}(\mu)$ such that $\underline{\alpha}'(\mu) < 0$.

We finally prove that $\underline{\alpha}(1) = 1$. Suppose that $\alpha = \mu = 1$. From equations (12) and (15), we see that agent 2's investment is the same with multiskilling or specialization. Equations (11) and (14) show that agent 1's investments are the same too. Since for $\alpha = 1$ the value functions are the same, the owner must be indifferent between specialization and multiskilling when $\alpha = \mu = 1$. Therefore this critical boundary cuts the vertical axis at $\mu = 1$, above μ'. Accordingly, the two possibilities for this critical boundary are presented in Figures 2 and 3.

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NOTES

1. Multiskilling can also be beneficial, for example due to learning spillovers, but in this paper we analyse a situation where specialization is first best and there is an interesting trade-off.
2. Note that the skills required to develop the program are to a large extent firm-specific. The programmers need to learn to work together so that the two parts of the program fit together. Even more importantly, programming requires a good knowledge of this particular firm's customers. About 50% of programming is understanding the application. For example, the firm could be developing a program to automate production of plastic. This requires understanding of the customer's technology and products and what can be difficult in the production process.
3. An alternative way to reduce the employee's holdup power under specialization is to hire another employee who would also specialize in task B. This would reduce the owner's holdup problem but would not eliminate it since the two employees can form a coalition and hold up the owner. We are analysing a relatively small firm where hiring an additional employee to provide internal competition is not feasible.
4. It is not necessary that he actually performs both tasks when the firm is working on a project, but the point is that he would be *able* to do that.
5. Absent holdup problems.
6. In Hart and Moore (1990), organizational design (the degree of indispensability of an agent) is exogenous.
7. In the main model we do not allow for one agent to specialize and the other agent to rotate. See Section V for discussion of asymmetric task allocation.
8. We discuss $v(S, A)$, but $V(S, A; \alpha)$ is assumed to have similar properties.
9. Remember that $V(S, A; \alpha) = v(S, A)$ if and only if $\alpha = 1$.
10. Absent power problems.
11. In Hart and Moore (1990), integration is optimal for $\mu = 0$. The result changes when organizational design is endogenous.
12. Note that agent 1's investment may be greater under nonintegration than under integration—even under integration, agent 1 is not subject to a holdup. With specialization, α affects the marginal value of

the investment, and if α is large enough, agent 1's investment will be greater under nonintegration than under integration. Agent 2's investment is always greater under nonintegration.

13. One interpretation is that the owner coordinates the specialized employees' work.
14. In other words, we assume that the owner keeps the formal and real authority over organizational design. Aghion and Tirole (1997) show that this is optimal when preferences are noncongruent, and in a sense Baker *et al.* (1999) confirm the result in a repeated setup. In our setup, preferences are noncongruent as each party prefers a task allocation that puts him in a powerful position (owner prefers rotation and employee specialization).
15. See the Appendix for how the figures were constructed.

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