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The boundaries of firms as information barriers

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When contracts are incomplete, the property-rights theory of firms suggests that ownership of physical assets provides better outside options, which in turn strengthen the owner's incentives to invest in the enterprise. This approach is less suitable for human capital firms such as management consulting that lack physical assets. This article develops an alternative theory for integration that sheds light on the boundaries of human capital firms. In particular, when a relationship between parties includes large potential externalities, reducing the outside option of each party will be beneficial. Integration provides this reduction by blurring the contribution of individual parties within the firm, and thus lowering their independent market valuation. Unlike some results in the property-rights literature, the results here are robust to variations in ex post bargaining solution.

1. Introduction

■ What difference does it make when firms merge? This question has been extensively studied in economics—from the traditional explanation that mergers can internalize externalities (such as pollution), to the modern property-rights theory, which interprets mergers as concentrations of ownership under certain parties and argues that ownership matters because when one party acquires the assets of another party the bargaining positions of both parties are affected, as is their willingness to make relationship-specific investment. In most of these theories, however, the firm is defined as a collection of physical assets, and human assets are often ignored. Consequently, they cannot help us to understand firms from a human perspective, which is particularly important in understanding human-capital intensive firms such as law, consulting, medicine, investment banking, advertising, and accounting firms, which are playing increasingly important roles in many countries.[1] This article provides a preliminary step to understanding why firms—defined as collections of human assets—merge or separate.

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[1] See Zingales (2000) for more discussion on this problem.

The main idea of the article is based on the observation that if several businesses are integrated as one firm, their individual identities become less observable to outsiders, compared to the case where they are separated as different firms. This observation is supported by the fact that financial data for different parts of a firm are usually proprietary and hence not available to the public (Rajan, Servaes, and Zingales, 2000). Furthermore, in order to "give shareholders a pure play" on some particular parts of their operations, many firms need to spin off these parts (Ross, Westerfield, and Jaffe, 2002).

Because of this information asymmetry across firm boundaries, outsiders may misattribute the value of some parts of a firm's operations to other parts. This kind of *identity mixing* is in line with Tadelis's (2002) idea of "separation of entity from identity." In some real-life situations, the mixing is an unintended consequence. For example, the misconduct of Arthur Andersen LLP in its auditing of Enron jeopardized Anderson's creditability regarding the rest of its customers (Doogar, Sougiannis, and Xie, 2003). Furthermore, a potential problem in Audi's 5000 model decreased the demand for Audi's 4000 and Quattro models (Sullivan, 1990). In other situations, firms deliberately mix the identities of different businesses under their control. For example, by naming the whole firm after a division that only accounts for less than 10% of overall sales, Sara Lee Corporation intentionally imposes the good image of its bakery division on the rest of the firm, including totally unrelated lines of business such as Electrolux vacuum cleaners and Coach leather goods (Fisher, 1986). In addition, it is hard to know who really invented Viagra because Pfizer always claims that hundreds of scientists are responsible for the development of the most renowned impotence drug.[2] In addition to mixing the identities of existing businesses, firms often mix the identities of their established businesses with those of their new ones, as in what the marketing literature refers to as "brand extension."[3] For example, Mattel's popular Barbie doll brand has been extended to many other products such as Barbie home furnishing and Barbie cosmetics (Kotler and Armstrong, 2004).

To model this identity-mixing role of firm boundaries, we define a firm as *a collection of human assets, the owners of which work so closely together that outsiders cannot clearly distinguish one from the other.* The results are as follows. Under Nash bargaining, when investment externalities are relatively great (small), integration increases (decreases) efficiency, and the relationship specificity—the discount of the joint surplus caused by breaking up the relationship—alleviates (aggravates) the hold-up problem. Under alternating-offer bargaining, the result that externalities favor integration is *not* reversed in general (in contrast to the case in property-rights theory). In addition, altering firm boundaries is more likely to matter if the businesses involved are more separated originally, or more diversified.

The result that investment externalities favor integration can shed light on IBM's recent acquisition of PricewaterhouseCoopers' consulting practice (henceforth PwC). What seems to be interesting in this deal is IBM's motivation to reinvent itself, a technology consultancy with fast-decreasing profit margins, as a business consultancy that usually enjoys high profit margins.[4] However, how can the integration create value for IBM and PwC? We argue that if integration entails a certain degree of identity mixing between IBM and PwC, then it can create value if the investment externalities between IBM and PwC are large (in a sense yet to be specified).

To understand the intuition, imagine that there is a project that requires a new strategy (to be developed by PwC) and a new information technology (to be developed by IBM). Conceivably, IBM's investment in developing the technology will be more effective if it is coordinated with PwC's strategy plan, and hence the investment is relationship specific. Thus, the standard hold-up argument implies that IBM will invest too little. Arguably, IBM's investment may have positive

[2] "Rush to Claim Viagra Mantle." *Courier Mail* (Queensland, Australia), July 17, 1998.

[3] For a formal model of brand extension, see Choi (1998).

[4] "IBM's Palmisano Sets His Course." *Business Week,* August 1, 2002.

externalities to the value of PwC's strategy, even if PwC does not use IBM's technology.[5] If acquired, the "new IBM" will be viewed as a mixture of the old IBM and PwC because the new firm's boundaries blur the individual identities of different business groups. Thus, the acquisition changes the market perception of IBM to be more of a business consultant and less of an IT developer. This blurring of identities will be beneficial if the old IBM investment has strong positive externalities on the value of PwC's strategy, and it is better if the market does not value them as a technology firm. As will be discussed latter, we argue that this is likely to be the case.

In the related literature, property-rights theory pioneered by Grossman and Hart (1986) and Hart and Moore (1990) (henceforth GHM) is one of the most prominent theories of firms. One of its main messages is that when contracts are incomplete, the ownership of physical assets matters because it can change the marginal returns of investments through outside options, and hence change the incentives of the businesses to make relationship-specific investments.[6] As argued previously, this physical-asset perspective loses sight of the human aspects of firms.

Human-capital-intensive firms are also a major concern of Levin and Tadelis (2002), who build a theory of partnerships but do not focus on the boundaries of firms. This article also differs from theirs in that they define partnership as an institution that redistributes *profits* among partners, whereas we define the firm as an institution that redistributes *outside options* (*identities*) among members of the firm. The idea that blurring identity can enhance investment incentives also appears in a very different model of Morrison and Wilhelm (2004), who justify partnership as a way to encourage intergenerational transfer of human capital (mentoring). Our model is also related to some of the recent studies on reputation (for example, Tadelis, 1999), which also entertain the idea that identity can be detached from entity, although their definitions of outside identities—names—are rather different from ours—outside options. Moreover, the idea that garbling information can improve efficiency can also be found in the literature on career concerns (for example, Dewatripont, Jewitt, and Tirole, 1999). Finally, investments with externalities have been studied under different names by different authors, such as the "cooperative investment" of Che and Hausch (1999). Again, very few of these studies focus on the boundaries of firms, which is the main topic of this article.

The remainder of this article is organized as follows. The basic setup is presented in Section 2. The model is then analyzed with Nash bargaining in Section 3, and alternating-offer bargaining in Section 4. Section 5 concludes the article.

2. The basic setup

■ There are two business entities indexed by i, where $i \in \{A, B\}$. There is a project that requires the "collaboration" of these two businesses, which means combining their human assets and finishing the project (but does not mean "integration," as explained later). Denote as $a \in \mathbf{R}^+$ and $b \in \mathbf{R}^+$ the respective investments that A and B make in developing their human assets. Additionally, denote the joint investment space of the two businesses as $S = \mathbf{R}^+ \times \mathbf{R}^+$. Furthermore, denote the real values of A's and B's human assets as $F(a, b)$ and $G(a, b)$, respectively. Assume that the private marginal cost of the investment is unity for both A and B, and the total value of the project is $F(a, b) + G(a, b)$. The following assumption is critical to the results.

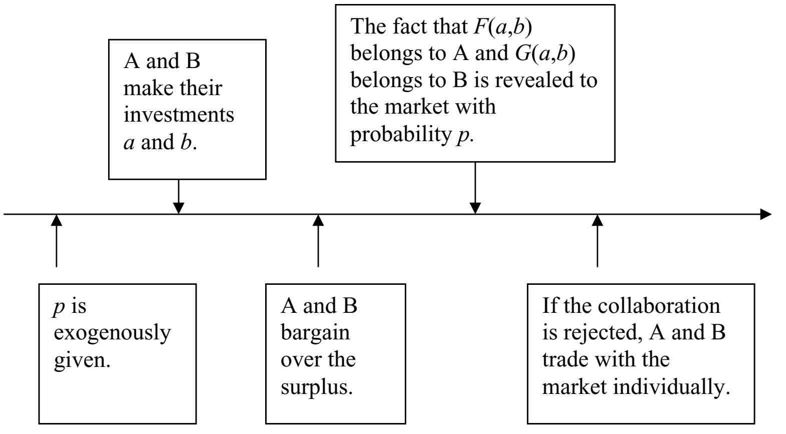
Assumptions. $F(\cdot)$ and $G(\cdot)$ are weakly increasing in their arguments and satisfy the single-crossing property, $F_{ab} \geq 0$ and $G_{ab} \geq 0$.

[5] For example, IBM's investment in designing a test-run system might identify potential problems in the strategy so that PwC can correct them. To the extent that the correction avoids problems that may arise even if the strategy is implemented with a system provided by a firm other than IBM, IBM's investment has a positive spillover to the value of the strategy inside and outside of the relationship with PwC.

[6] Under the Nash bargaining structure of GHM, ownership enhances a manager's investment incentives. In contrast, under the alternating-offer bargaining structure of Chiu (1998) and de Meza and Lockwood (1998), ownership hinders a manager's investment incentives.

FIGURE 1

THE TIMELINE



The conditions in the assumption are the same as in Che and Hausch (1999) and consistent with Hart and Moore (1990).

With the setting above, a pair of investments $(\bar{a}, \bar{b})$ is first best if it satisfies

$$(\bar{a}, \bar{b}) \in \arg\max F + G - a - b.$$

If A and B agree to collaborate, then a return that is equal to $F(a, b) + G(a, b)$ will be paid jointly to them. However, if either of them rejects the collaboration, then the project will fail and generate no value. In this case, A and B can independently capitalize their human assets in an outside market. Denote as $f(a, b)$ and $g(a, b)$ the real values of A's and B's human assets in the market. Assume that $f = F/\gamma$ and $g = G/\gamma$, where $\gamma > 1$, so the values of human assets will be discounted if A and B do not collaborate, which reflects the idea that the investments of A and B are relationship specific.

Regarding the information structure, we follow GHM by assuming that the *levels* of F, f, G, g, a, and, b are observable but not verifiable to A, B, and the market. Departing from GHM, we assume that before A and B bargain to split the joint surplus, the fact that F belongs to A and G belongs to B is private information of A and B and hence cannot be observed by the market.[7] The boundaries of the firm are modelled by a probability p that this fact is revealed to the market after the bargaining. The parameter p thus represents the weakness of the information barriers. The asymmetric information regarding the identities of A and B before the bargaining and the revelation of identities after the bargaining is the main difference between this article and GHM in terms of information structure. The following is the timeline of the investment game (see Figure 1).

For simplicity, assume that the prior belief of the market is that the following two possibilities are equally likely.

- $F(a, b)$ belongs to A and $G(a, b)$ belongs to B (the truth).
- $F(a, b)$ belongs to B and $G(a, b)$ belongs to A.

This implies that, with probability p, the truth is revealed so that the market pays $f(a, b)$ and $g(a, b)$ for the human assets of A and B, respectively, whereas with probability $1 - p$, the truth is withheld and the market pays the expected values of A's and B's human assets, at an equal

[7] Given this assumption, there is no need to specify whether the market can observe who makes investment a and who makes investment b because what matters is the market's perception about F, f, G, and g.

value of $\frac{1}{2}[f(a,b)+g(a,b)]$.[8] This, in turn, implies that the *expected* payoffs for rejecting the collaboration are $\frac{1+p}{2}f+\frac{1-p}{2}g$ for A and $\frac{1-p}{2}f+\frac{1+p}{2}g$ for B. These two values are referred to as the *effective* outside option for A and B, to be distinguished from their respective *real* outside options, $f(a,b)$ and $g(a,b)$.

For ease of reference, denote $O(p)$ as an organizational structure with parameters p. To reflect the idea that as A and B become more integrated, their individual identities become less clearly observed by the market, integration is defined relatively as follows.

Definition. $O(p)$ is more integrated (less separated) than $O(p')$ if $p < p'$.

According to this definition, when $p = 1$, A and B are completely separated in the sense that the information barriers vanish and the market observes the true identities of A and B clearly, whereas when $p = 0$, A and B are completely integrated in the sense that the information barriers are the strongest and the true identities are never revealed. Note that integration and collaboration mean different things: the former is a special type of organizational structure and the latter is a task that needs to be accomplished under any given organizational structure (not necessarily integration). In fact, A and B can collaborate under a totally separated organizational structure. As indicated by the timeline, A and B know that it is efficient for them to collaborate, but they need to bargain over the joint return $F(a,b)+G(a,b)$ *after* they invest. This introduces a well-known hold-up problem, which will be analyzed in the following two sections under two leading bargaining structures in the literature: *Nash bargaining* and *alternating-offer bargaining*.

3. Nash bargaining

■ Assume that A and B bargain over the total surplus, $F(a,b)+G(a,b)$, in a 50-50 Nash bargaining game with the effective outside options defined previously. Given organizational structure $O(p)$, A's payoff is

$$u_A(a,b) \equiv \frac{1+p}{2}f+\frac{1-p}{2}g+\frac{1}{2}[F+G-f-g]-a, \tag{1}$$

and B's payoff is

$$u_B(a,b) \equiv \frac{1-p}{2}f+\frac{1+p}{2}g+\frac{1}{2}[F+G-f-g]-b. \tag{2}$$

In the standard GHM models, there is always underinvestment because investments are relationship specific and contracts are incomplete. The following result shows that this is also the case in this model.

Lemma 1. With 50-50 Nash bargaining, the equilibrium investments of A and B under any organizational structure $O(p)$ are lower than the respective first-best investments $\bar{a}$ and $\bar{b}$.

Proof. See Appendix A.

□ **Externalities revisited.** In reality, externalities certainly play important roles in mergers—the word "synergy" has been one of the most popular buzzwords used in justifying mergers. From the standard physical-asset perspective, the idea that integration can internalize externalities is well known. However, if a firm is viewed as a group of people instead of physical assets, it is not clear why integration can internalize externalities, because the problem is always a multi-person game, before or after the integration.

In our model, the externalities of investments (in addition to relationship specificity) also play a central role in justifying integration. The main result that investment externalities favor integration is presented in Proposition 1.

[8] Implicitly, we assume that the market is competitive so A and B will capture the full *perceived* value of their human assets.

Proposition 1. With 50-50 Nash bargaining, the joint profit is increasing (decreasing) in p—the degree of separation—if investment externalities are relatively small (large) in the sense that the investments of both businesses have a smaller (larger) effect on the other than on themselves, that is, $F_a \geq G_a$ and $G_b \geq F_b (F_a \leq G_a$ and $G_b \leq F_b)$ for all a and b.

Proof. Similar to the proof of Lemma 1, $(N, S, \{u_i^p : i \in N\})$, where $u_i^p = u_i$ as defined in (1) and (2), is a collection of *supermodular games* that are parameterized by p in [0, 1]. This implies that A's and B's equilibrium investment levels are increasing in p if $F_a \geq G_a$ and $G_b \geq F_b$ because

$$\frac{\partial u_A^p}{\partial a \partial p} = \frac{1}{2\gamma}(F_a - G_a) \geq 0 \text{ and } \frac{\partial u_B^p}{\partial b \partial p} = \frac{1}{2\gamma}(G_b - F_b) \geq 0, \tag{3}$$

for all a and b, which implies that $u_A^p(a, b)$ has increasing difference in (a, p) and $u_B^p(a, b)$ has increasing difference in (b, p). The result follows because given that there is always underinvestment, an organizational structure that can induce higher investments from both businesses must be more efficient. The argument for the case of $F_a \leq G_a$ and $G_b \leq F_b$ is symmetric. *Q.E.D.*

The intuition of the proof can be illustrated as follows. As p increases, A's effective outside option will depend more on F and less on G. When $F_a \geq G_a$, this will lead to an increase in the marginal return of a (as equation (3) indicates) and hence encourage A's investment, especially if a simplifying assumption that $\partial^2 u_A/\partial a^2 < 0$ is added. Similarly, increase in p will also encourage B's investment when $G_b \geq F_b$. In addition, the increases in a and b will reinforce each other under the assumption that $F_{ab} \geq 0$ and $G_{ab} \geq 0$. In sum, when $F_a \geq G_a$ and $G_b \geq F_b$, increasing p will encourage A and B to invest and hence increase the joint profit.

IBM's acquisition of PwC is generally considered to be "a win-win deal" by investors. This can be explained by the proposition because it is likely that investment externalities are relatively large between IBM and PwC and hence it is more efficient to integrate. The argument to support this claim is as follows. On the one hand, IBM's effort in establishing the right technology is likely to be crucial in the success of PwC's strategy because "companies realize their decision about information technology . . . has a profound effect on revenue, profit, and their future direction."[9] Given that the profit margin of strategy is much higher than that of technology, it is quite likely that IBM's investment actually has a larger effect on PwC than on itself in terms of *market value*.[10] On the other hand, PwC's effort in modifying its strategy to avoid difficult technology issues may not be very useful for PwC itself, but may generate great cost savings on IBM's side. In fact, it is reported that "the networked computer has put technology at the heart of strategy, and vice versa."[11] Hence, investment externalities between IBM and PwC are likely to be relatively large.

In general, the condition that favors integration, such as when the investment of one business has a larger effect on the other business than on itself, can be satisfied in many situations, especially when the effect refers to the change of value of human assets, such as knowledge, which is well known for massive externalities in its production process (Foray, 2000). This can be the case whenever the investing business cannot capture the economic value of the investment as effectively as the other business. As in the case of IBM and PwC, it could be that the investing business operates in a more competitive industry and hence has lower profit margins than the other business. Alternatively, it could be that the investing business does not have a marketing strategy that is as aggressive as that of the other. For example, Microsoft, through its Windows operating system, obviously capitalizes more on the idea of the "graphical user interface" than Apple, who popularized it. In fact, many firms in high-tech (human-capital-intensive) industries succeed by "stealing" other firms' ideas (Rajan and Zingales, 2001).

[9] "Commentary: HP's Consulting Bet: Why Investors Are Anxious." *Business Week,* September 25, 2000.

[10] According to *The Deal* (June 7, 2004), "if IBM stays with their original services direction, they'd be able to deliver only a progressively decreasing impact to an organization. . . . But if you help a customer automate manual processes, the savings you can squeeze out of it are larger."

[11] "Goodbye, Monday." *The Economist,* August 1, 2002.

Proposition 1 gives sufficient conditions under which increasing or decreasing the degree of separation can improve efficiency. Although it is meant to be a comparative-static result on the organizational parameter p, it also helps to find a more efficient organizational structure, starting at an arbitrary one. For example, if $F_a > G_a$ and $G_b > F_b$ for all a and b, then full separation ($p = 1$) is the most efficient. Conversely, if $F_a < G_a$ and $G_b < F_b$ for all a and b, then full integration ($p = 0$) is the most efficient. In general, it is quite likely that the most efficient organizational structure entails an intermediate degree of separation ($p \in (0, 1)$). Numerical examples for some of these cases are provided in Appendix B.

Note that Proposition 1 incorporates asymmetric cases under which inducing investment from one of the businesses is not important (for example, when $F_b = G_b = 0$). In such cases, only one direction of investment externalities is important (for example, the condition that $G_b \geq F_b$ or $G_b \leq F_b$ is trivially satisfied when $F_b = G_b = 0$).

Proposition 1 raises a question about the role of externalities: do externalities entail a cost (as in conventional wisdom) that needs to be alleviated, or a benefit that can be augmented, by choosing the right organizational structure? To examine this question, consider two investment games indexed by $e \in \{e', e''\}$ where $e' < e''$, with identical first-best investments. Denote the real values of A's and B's human assets under game e as F^e and G^e, respectively. Say that investment externalities are larger in game e' than in game e'' if

$$\begin{aligned} F_a^{e'} < F_a^{e''} \quad &\text{and} \quad F_b^{e''} < F_b^{e'} \\ G_b^{e'} < G_b^{e''} \quad &\text{and} \quad G_a^{e''} < G_a^{e'}, \end{aligned}$$

for all a and b.

Proposition 2. The total surplus under game e' is lower than that under game e'' if investment externalities are larger in game e' than in game e''.

Proof. For each game e, denote A's and B's payoffs (defined in (1) and (2)) as u_A^e and u_B^e. The investment games e' and e'' compose a collection of *supermodular games* $(N, S, \{u_i^e : i \in N\})$ parameterized by e in $\{e', e''\}$ for the same reason as in the previous proofs. In addition, the fact that

$$\frac{\partial u_A^{e'}}{\partial a} = \frac{1 + p/\gamma}{2} F_a^{e'} - \frac{1 - p/\gamma}{2} G_a^{e'} - 1 < \frac{\partial u_A^{e''}}{\partial a} = \frac{1 + p/\gamma}{2} F_a^{e''} - \frac{1 - p/\gamma}{2} G_a^{e''} - 1$$

implies that $u_A^e(a, b)$ has increasing difference in (a, e) because $e' < e''$. Similarly, $u_B^e(a, b)$ has increasing difference in (b, e). It follows (again, by Theorem 4.2.2 of Topkis, 1998) that the equilibrium investment for game e is increasing in e, and hence the result. *Q.E.D.*

□ **The role of relationship specificity.** The more relationship specific the investments are, the less valuable A's and B's investments are outside their relationship. In property-rights theory, this always hurts investment incentives. Proposition 3 examines the same intuition under the current model.

Proposition 3. With 50-50 Nash bargaining, the joint profit is decreasing (increasing) in γ—the *real* relationship specificity of investments—if investment externalities are relatively small (large) in the sense that the investments of both businesses have a smaller (larger) impact on the other than on themselves, that is, $F_a \geq G_a$ and $G_b \geq F_b (F_a \leq G_a$ and $G_b \leq F_b)$ for all a and b.

Proof. $(N, S, \{u_i^\gamma : i \in N\})$ is a collection of *supermodular games* parameterized by γ, where $u_i^\gamma = u_i(a, b)$, as defined in (1) and (2). Both A's and B's equilibrium investment levels are increasing in γ if $F_a \leq G_a$ and $G_b \leq F_b$ because then

$$\frac{\partial u_A^\gamma}{\partial a \partial \gamma} = \frac{p}{2\gamma^2}(G_a - F_a) \geq 0 \quad \text{and} \quad \frac{\partial u_B^\gamma}{\partial b \partial \gamma} = \frac{p}{2\gamma^2}(F_b - G_b) \geq 0,$$

for all a and b. The argument for the case of $F_a \geq G_a$ and $G_b \geq F_b$ is symmetric. *Q.E.D.*

Proposition 3 points out a distinction between the current and the property-rights-theory definitions of the firm. In the current model, the marginal benefits for A and B can be rewritten, respectively, as $\frac{1}{2}(F_a + G_a) + \frac{p}{2\gamma}(F_a - G_a)$ and $\frac{1}{2}(F_b + G_b) + \frac{p}{2\gamma}(G_b - F_b)$. Note that the real relationship specificity (γ) affects investment incentives through the second terms of the two expressions. For the investment of each business, the role of γ in the corresponding term is to discount a tradeoff (which has an effect when $p > 0$) between the investment's marginal product on the investor's human assets (F_a or G_b) and on the human assets of the other business (F_b or G_a). As discussed after Proposition 1, the tradeoffs are caused by the revelation of the true identities. If the tradeoffs entail *gains* in both businesses' effective outside options (in the case that $F_a \geq G_a$ and $G_b \geq F_b$ so the differences are positive), then a higher γ implies lower gains and hence *lower* investment incentives. If the tradeoffs entail *losses* in the effective outside options of both businesses (in the case that $F_a \leq G_a$ and $G_b \leq F_b$ so the differences are negative), then a higher γ implies lower losses and hence *higher* investment incentives. In contrast, a parameter that corresponds to γ in property-rights theory will simply serve to discount the own outside option of each business (which is always positive), and hence increasing γ always hampers investment incentives.

Proposition 3 seems to challenge the received wisdom that relationship specificity always discourages investment. However, the correct relationship specificity in this model should be measured by the level of effective outside options ($\frac{1+p}{2}f + \frac{1-p}{2}g$ for A and $\frac{1-p}{2}f + \frac{1+p}{2}g$ for B), instead of the real outside options (f for A and g for B). The point of the proposition is that a *decrease* in the relationship specificity measured by the real outside options may imply an *increase* in the relationship specificity measured by effective outside options, which always discourages investment.

4. Alternating-offer bargaining

■ It is well known that the results of an incomplete-contract model such as the current one are very sensitive to the underlying bargaining protocol assumed. For example, Chiu (1998) and de Meza and Lockwood (1998) show that one of the main implications of GHM derived under Nash bargaining—ownership always enhances investment incentives—is generally overturned under alternating-offer bargaining. In the current model, however, the main result that externalities favor integration is relatively more robust in the sense that it holds under alternating-offer bargaining for nontrivial ranges of parameter values. This robustness is due to the existence of investment externalities and identity mixing, as discussed in details later in this section. In addition to serving as a robust check, this section also contains some results that predict the relevance of altering firm boundaries based on the original degree of separation (Proposition 5) and the diversity of the businesses involved (Proposition 6). As the important distinction between the real and effective outside options has already been stressed and only the latter will be used for discussion in this section, we will refer to A's and B's effective outside options ($\frac{1-p}{2}f + \frac{1+p}{2}g$ and $\frac{1+p}{2}f + \frac{1-p}{2}g$, respectively) simply as their *outside options* throughout this section.

Consider any organizational structure $O(p)$, where $p \in [0, 1]$. Under alternating-offer bargaining, A's and B's outside options will not matter unless one of them binds. Following de Meza and Lockwood (1998), the space of feasible investments can be partitioned into the following three regions:

$$R_0(p) = \left\{a, b \left| \frac{1}{2}[F + G] \geq \max\left\{\frac{1+p}{2}f + \frac{1-p}{2}g, \frac{1-p}{2}f + \frac{1+p}{2}g\right\}\right.\right\},$$

$$R_A(p) = \left\{a, b \left| \frac{1+p}{2}f + \frac{1-p}{2}g > \frac{1}{2}[F + G] \geq \frac{1-p}{2}f + \frac{1+p}{2}g\right.\right\}, \text{ and}$$

$$R_B(p) = \left\{a, b \left| \frac{1-p}{2}f + \frac{1+p}{2}g > \frac{1}{2}[F + G] \geq \frac{1+p}{2}f + \frac{1-p}{2}g\right.\right\}.$$

If $(a, b) \in R_0(p)$, neither A's nor B's outside option binds; if $(a, b) \in R_A(p)$, A's outside option binds but B's does not; if $(a, b) \in R_B(p)$, B's outside option binds but A's does not.[12] With this partition, A's and B's payoffs can be written, respectively, as

$$-a + \begin{cases} \frac{1}{2}[F+G] & \text{if} \quad (a,b) \in R_0(p) \\ \frac{1+p}{2} f + \frac{1-p}{2} g & \text{if} \quad (a,b) \in R_A(p) \\ F+G-\left(\frac{1-p}{2} f + \frac{1+p}{2} g\right) & \text{if} \quad (a,b) \in R_B(p) \end{cases}$$

and

$$-b + \begin{cases} \frac{1}{2}[F+G] & \text{if} \quad (a,b) \in R_0(p) \\ F+G-\left(\frac{1+p}{2} f + \frac{1-p}{2} g\right) & \text{if} \quad (a,b) \in R_A(p) \\ \frac{1-p}{2} f + \frac{1+p}{2} g & \text{if} \quad (a,b) \in R_B(p) \end{cases} .$$

A Nash equilibrium is a pair of investments in which the investment of each business maximizes its payoff in the region that the pair belongs to, given the investment of the other business.

Similar to the model of de Meza and Lockwood, the equilibrium does not always exist and there could be multiple equilibria in this setting. However, both problems are circumvented by exploring the supermodularity of the model, which allows the comparison of extreme (greatest and least) equilibria. Recall also that the solution is further simplified by assuming that A and B will choose the equilibrium with the highest investment from both of them because it is Pareto preferred.

Although changing the bargaining protocol is expected to cause dramatic changes in the investment behavior, the underlying hold-up problem should always exist as long as contracts are incomplete and investments are relationship specific. By applying the same argument as in Lemma 1 to each region of $R_0(p)$, $R_A(p)$, and $R_B(p)$, this intuition can be verified and is stated as Lemma 2.

Lemma 2. With alternating-offer bargaining, A and B will always underinvest, in the sense that the equilibrium investment levels of A and B will be lower than their respective first-best levels of investment $\bar{a}$ and $\bar{b}$.

Because under alternating-offer bargaining, changing p may cause a discreet change in equilibrium investments when it causes the outside option of some business to change from binding to not binding, or vice versa, the comparative-static analysis will be carried out by comparing two arbitrary organizational structures, instead of examining a single structure as in Section 3. For this purpose, four possible cases need to be analyzed: Case 1: the outside option of the same business is binding under both structures; Case 2: the outside options of neither business are binding under both structures; Case 3: the outside option of one business is binding under one structure and the outside option of the other business is binding under the other structure; and Case 4: the outside option of one business is binding under one structure and the outside option of neither business is binding under the other structure. Lemma 3 provides sufficient conditions for comparing two structures $O(p)$ and $O(p')$ under each case.

Lemma 3. Consider any two different organizational structures $O(p)$ and $O(p')$, with an alternating-offer bargaining protocol.

Case 1. If A's or B's outside option is binding under both $O(p)$ and $O(p')$, then Proposition 1 holds.

[12] It is impossible for both A's and B's outside options to bind because that implies the sum of their outside options will be greater than the joint surplus, violating the assumption that $\gamma > 1$.

Case 2. If A's and B's outside options are not binding under either $O(p)$ or $O(p')$, then $O(p)$ and $O(p')$ are equally efficient.

Case 3. If A's outside option is binding under $O(p')$ and B's outside option is binding under $O(p)$, then $O(p')$ is more (respectively less) efficient if $\theta F_a \geq \lambda G_a$ and $\lambda G_b \geq \theta F_b$ (respectively $\theta F_a \leq \lambda G_a$ and $\lambda\ G_b \leq \theta F_b$) for all a and b, where $\lambda \equiv \frac{2\gamma-2+p'-p}{2\gamma}$ and $\theta \equiv \frac{2-2\gamma+p'-p}{2\gamma}$.

Case 4. (i) If A's outside option is binding under $O(p')$ and no one's outside option is binding under $O(p)$, then $O(p')$ is more (respectively less) efficient if $\theta'\ F_a \geq \lambda' G_a$ and $\lambda' G_b \geq \theta' F_b$ (respectively $\theta' F_a \leq \lambda' G_a$ and $\lambda' G_b \leq \theta' F_b$) for all a and b, where $\theta' \equiv \frac{(1+p')-\gamma}{2\gamma}$ and $\lambda' \equiv \frac{\gamma-(1-p')}{2\gamma}$. (ii) If B's outside option is binding under $O(p')$ and no one's outside option is binding under $O(p)$, then $O(p')$ is more (respectively less) efficient if $\lambda' F_a \geq \theta' G_a$ and $\theta' G_b \geq \lambda' F_b$ (respectively $\lambda' F_a \leq \theta' G_a$ and $\theta' G_b \leq \lambda' F_b$) for all a and b.

Proof. The strategy of the proof is to index the two investment games under $O(p)$ and $O(p')$ so that the game with higher marginal benefits of investment from A and B has a higher index, and hence the argument used in all the previous proofs can be applied. The details are omitted. *Q.E.D.*

The robustness of Proposition 1 under Case 1 is not surprising, because a similar robustness also exists in standard property-rights theory.[13] Case 2 is not interesting on its own, but will become useful in the later discussion of the relevance of firm boundaries. Under Cases 3 and 4, one will expect the reversion of the result to arise. It is clear that this expectation is true given some parameter values. What seems to be interesting is that there are nontrivial ranges of parameter values under which extensions of Proposition 1 hold. With the assumption that $p' > p$,[14] Proposition 4 provides a precise statement of these extensions.

Proposition 4. Suppose that θ, λ, θ', and λ', defined in Lemma 3, are all strictly positive. With alternating-offer bargaining, the joint profit increases (decreases) as the degree of separation increases from p to p' if investment externalities are relatively small (large) in the sense that

- $\theta F_a \geq \lambda G_a$ and $\lambda G_b \geq \theta F_b (\theta F_a \leq \lambda G_a$ and $\lambda G_b \leq \theta F_b)$ for all a and b under Case 3, or
- $\theta' F_a \geq \lambda' G_a$ and $\lambda' G_b \geq \theta' F_b (\theta' F_a \leq \lambda' G_a$ and $\lambda' G_b \leq \theta' F_b)$ for all a and b under Case 4(i), or
- $\lambda' F_a \geq \theta' G_a$ and $\theta' G_b \geq \lambda' F_b (\lambda' F_a \leq \theta' G_a$ and $\theta' G_b \leq \lambda' F_b)$ for all a and b under Case 4(i).

As stated at the beginning of this section, the relative robustness of the result that investment externalities favor integration stems from two departures from the standard property-rights theory. The first is the possibility of identity mixing. In property-rights theory, ownership is complementary to investments and hence motivate investments under Nash bargaining, but demotivates investments under alternating-offer bargaining because it might cause the outside option of the acquiring business to bind, which, in turn, will necessarily cause a discrete drop in its marginal benefit of investment because investments are relationship specific. In the current model, identity mixing can also cause the outside option of a business to bind, but that does not necessarily imply that the marginal benefit of that business will drop even though investments are relationship specific. In some cases, it may actually *increase* the marginal benefits of both A and B. For example, in Lemma 3, changing $O(p)$ to $O(p')$ may cause A's outside option to bind, but that may increase the marginal benefits of investment for both A and B in Case 4(i) when $\frac{1}{2}(F_a + G_a) \leq \frac{1+p'}{2} f_a + \frac{1-p'}{2} g_a$ and $\frac{1}{2}(F_b + G_b) \leq F_b + G_b - (\frac{1+p'}{2} f_b + \frac{1-p'}{2} g_b)$.[15] This feature is specific to the current identity-mixing model.

[13] This is not the case that Chiu (1998) and de Meza and Lockwood (1998) focus on.

[14] Clearly, this assumption is without loss of generality. In fact, Case 3 can only happen under this assumption.

[15] Note that this condition is the same as $\theta' F_a \geq \lambda' G_a$ and $\lambda' G_b \geq \theta' F_b$ of the proposition.

The second departure is the introduction of investment externalities. Under alternating-offer bargaining, when the outside option of one business binds, the other business will hesitate to invest because, due to investment externalities, it will increase the former's outside option, which will decrease the latter's payoff because the latter is the residual claimant. This demotivating effect of *not having* a binding outside option relatively weakens the demotivating effect of *having* a binding outside option (due to relationship specificity), and hence weakens the reversion of the result across bargaining protocols. This intuition is also behind a recent study of de Meza and Lockwood (1998), who show that the result that ownership motivates investments under Nash bargaining will not generally be reversed under alternating-offer bargaining when there are investment externalities. Their paper, aligned with property-rights theory, differs from this article in the basic definition of the firm, as argued in the introduction.

□ **The relevance of firm boundaries.** One of the unique features that adopting alternating-offer bargaining brings to the model is to incorporate both cases in which the outside options matter and do not matter, as can be seen from Lemma 3. This provides a useful perspective to further explore the differences and similarities between the current definition of the firm and that of property-rights theory. To this end, two results that predict the relevance of firm boundaries are presented in this section, from the aspects of the degree of separation and the diversity of the businesses involved, respectively.

Proposition 5. Under alternating-offer bargaining, there is a cutoff point $\underline{p}$ such that organizational structures with degrees of separation smaller than $\underline{p} > 0$ are equally efficient, that is, $O(p')$ and $O(p)$ are equally efficient if $\max\{p', p\} \leq \underline{p}$.

Proof. Because $\frac{1+p}{2} f + \frac{1-p}{2} g = \frac{1-p}{2} f + \frac{1+p}{2} g = \frac{1}{2}(f+g) < \frac{1}{2}(F+G)$when $p = 0$ and both $\frac{1+p}{2} f + \frac{1-p}{2} g$ and $\frac{1-p}{2} f + \frac{1+p}{2} g$ are continuous in p, there is always a cutoff $\underline{p} > 0$ such that $(a, b) \in R_0(p)$ for all $\underline{p} > p$, and hence all $O(p)$ are equally efficient. *Q.E.D.*

Proposition 5 points out another distinctive feature of the model: integration *equalizes* the outside options of the two businesses. This is in contrast to the case of property-rights theory, in which integration means the concentration of ownership (on some particular parties) and hence increases the difference between the outside options of the different parties. This distinction leads to opposite predictions by the two different theories: integration beyond a certain level will become irrelevant with the current definition of firms, whereas separation beyond a certain level will become irrelevant with the definition of property-rights theory. As the current theory is more suitable for human-capital-intensive firms and property-rights theory is more suitable for physical-capital-intensive firms, the predictions yield the following empirical implication. When one group of businesses, for example, an industry, on average employs more integrated organizational structures than another, the performance of different businesses in the more integrated group should be more homogeneous (heterogeneous) if the groups are human-capital intensive (physical-capital intensive), given the assumption that the distributions of organizational structures of the two groups are otherwise comparable.

The relevance of firm boundaries can also be explored from another perspective—diversification. One easy way to parameterize diversification is to redefine $F(a, b)$ and $G(a, b)$ so that $F(a, b) = \alpha h(a, b)$ and $G(a, b) = \beta h(a, b)$, where $\alpha, \beta > 0$ and $h(a, b)$ satisfies $\frac{\partial h}{\partial a}, \frac{\partial h}{\partial b}, \frac{\partial h}{\partial ab} > 0$. With the parameters α and β, we can say that *the two businesses are more* (*less*) *diversified* if $|\alpha - \beta|$ increases (decreases) while $\alpha + \beta$ remains the same.

Proposition 6. Under alternating-offer bargaining, if the two businesses are not completely integrated ($p > 0$), the boundaries of the firms are more likely to matter if the human assets are more diversified.

Proof. Without loss of generality, assume that $\alpha > \beta$. Starting from any point (a, b) in $R_0(p)$, increase $\alpha - \beta$. The point will leave $R_0(p)$ and enter $R_A(p)$ when $\alpha - \beta$ is so large that

$(1-\frac{1}{\gamma})(\alpha+\beta) > \frac{p(\alpha-\beta)}{\gamma}$, and hence $\frac{1}{2}[F(a,b)+G(a,b)] > \frac{1+p}{2}f(a,b)+\frac{1-p}{2}g(a,b)$. This shows that $R_0(p)$, where the boundaries do not matter, will be overtaken by $R_A(p)$, where the boundaries matter, as $\alpha-\beta$ increases, and hence the result holds. *Q.E.D.*

The intuition is that (as long as there is some degree of separation between the two businesses) the more diversified the two businesses are, the more likely that the outside option of one of them will exceed half of the joint revenue, causing the outside option of that business to bind. In contrast to Proposition 5, the intuition of Proposition 6 has a counterpart in property-rights theory. Empirically, this intuition implies that if the distributions of organizational structures of two groups of businesses are the same but one group of businesses is more diversified than the other, then the performance of the businesses in the more diversified group should be more heterogeneous.

5. Conclusion

■ This article aims at providing a new theory for human-capital-intensive firms which cannot be explained by most of the existing theories that view firms as collections of physical assets. We define a firm as a collection of human assets, the owners of which work so closely that outsiders cannot distinguish them clearly. With this definition, we have shown that when investment externalities are relatively large (small), joint surplus is decreasing (increasing) in the degree of separation and increasing (decreasing) in the degree of relationship specificity, defined in a regular way. The latter result suggests that relationship specificity should be measured in effective terms to reflect its true meaning in the current context. In addition, the main message that investment externalities favor integration holds relatively robustly across the Nash and alternating-offer bargaining protocols. Finally, the article provides predictions about the relevance of altering firm boundaries based on the degree of separation of the original structure and the diversity of the businesses involved.

Admittedly, the firms defined here may look very different from firms defined legally in practice. For example, according to our definition of the firm, the divisions of a firm that issues individual financial reports for each division should be viewed as separated “firms”; in contrast, two firms with exclusive contracts can be seen as an integrated firm because they are not recognized by the market. Nevertheless, we believe that this definition captures one important, human aspect of firms. The model is very simple and hence easy to extend in future work. One promising possibility is to allow the businesses involved to influence the determination of firm boundaries.

Appendix A

■ Proof of Lemma 1: The first-best investment $(\bar{a}, \bar{b})$ can be represented as the equilibrium of an imaginary investment game in which A's payoff is $u_A^1(a,b) \equiv F+G-a$ and B's payoff is $u_B^1(a,b) \equiv F+G-b$. Index this game by $t=1$. In addition, index the actual game by $t=0$ and let $u_i^0(a,b)=u_i(a,b)$, where $i \in N$, as defined in (1) and (2). These two games compose a collection of *supermodular games* $(N, S, \{u_i^t : i \in N\})$ parameterized by t in $\{0,1\}$ because, most importantly, investments have *positive* externalities, which implies that $u_i^t(a,b)$ has increasing difference in (a,b) or equivalently $\frac{\partial^2 u_i^t}{\partial a \partial b} > 0$ for each i.[16] In addition, the fact that

$$\frac{\partial u_A^0}{\partial a} = \frac{1}{2}(F_a+G_a)+\frac{p}{2}f_a-\frac{p}{2}g_a-1 < \frac{\partial u_A^1}{\partial a} = F_a+G_a-1$$

(because $f=F/\gamma$, $g=G/\gamma$, and $\gamma>1$) implies that $u_A^t(a,b)$ has increasing difference in (a,t), and similarly $u_B^t(a,b)$ has increasing difference in (b,t). It follows (by Theorem 4.2.2 of Topkis) that the equilibrium investments for game t are increasing in t, and hence the result. *Q.E.D.*

[16] For supermodular games, it is also required that the joint strategy set S is a sublattice of $\mathbf{R}^2$ and $u_A^t(a,b)$ and $u_B^t(a,b)$ are supermodular in a and b, respectively. These two conditions are trivially satisfied given the current setup. For more details on supermodular games, see Topkis.

Appendix B

■ In this appendix, numerical examples for situations under which the most efficient organization is full separation ($p = 1$), full integration ($p = 0$), or "half integration" ($p = \frac{1}{2}$), are provided. Let $\gamma = 2$ and

$$F(a, b) = \sqrt{a} + \delta(a, b)\sqrt{b} + \sqrt{a}\sqrt{b} \text{ and } G(a, b) = \delta(a, b)\sqrt{a} + \sqrt{b} + \sqrt{a}\sqrt{b}.$$

Consider first the case that

$$\delta(a, b) = \frac{1}{2}.$$

In this case, the equilibrium entails $a = b = \left(\frac{1}{8}p + \frac{3}{4}\right)^2$, which shows that a and b are strictly increasing functions of p and hence it is optimal to set $p = 1$, which gives the highest level of investment $(a, b) = (\frac{49}{64}, \frac{49}{64})$, and hence the highest joint surplus.[17] By a symmetric argument, we can see that it will be optimal to set $p = 0$ if we consider the alternative case that

$$\delta(a, b) = 2.$$

Now let us consider a case in which a moderate degree of separation is optimal. Suppose now that

$$\delta(a, b) = \begin{cases} \dfrac{1}{2} & \text{if } a < k \text{ and } b < k \\ 2 & \text{if } a \geq k \text{ and } b \geq k \end{cases},$$

where $k = \frac{169}{256}$. One can understand this setting as investment externalities increase after investments pass the cutoff point k. In this case, the equilibrium investment a (or b) will always be lower than k (hence $\delta = \frac{1}{2}$) and an increasing function of p (that is $a = (\frac{1}{8}p + \frac{3}{4})^2$) when $p \in [0, \frac{1}{2})$, or higher than k (hence $\delta = \frac{1}{2}$) and an decreasing function of p (that is $a = (-\frac{1}{4}p + \frac{3}{2})^2$) when $p \in [\frac{1}{2}, 1]$. It is clear that the greatest investment ($a = b = \frac{121}{64}$) can be induced when $p = \frac{1}{2}$.

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[17] For simplicity, the setting is chosen so that the first-best levels of investment for A and B are actually ∞.

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