THE ADVANTAGE OF AUCTION OVER CONTRACT IN MULTIPLE-STAGE INVESTMENT PROJECTS

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Abstract. Auction can yield a sale price that is an unbiased estimate of a sale-item’s true value. This is well known. An auction can have another, less widely discussed, result as well. Auctions can reduce the variance of sale price as compared with a contract for sale between seller and a single buyer. Ostensibly, where seller and buyer are assumed to be risk neutral, this reduction in variance may have no significance, and auction, with its attendant costs, may be inferior to contract. On closer analysis, however, where projects require multiple stages of investment, one by an entrepreneur and at least another by an outside financier, the reduction in variance made possible by an auction of the early stage can increase the expected value of the project as compared to the value from an ex ante contract that implicitly or explicitly ties the hands of a later investor. Though counterintuitive, the reason for this increased value, which can redound to the benefit of the entrepreneur, is that an early-stage auction can reduce the probability that the project will attract later-stage investment. That is, an auction can increase the expected return to an entrepreneur because the auction can increase the chance of failure. This observation has implications for the theory of efficient contracts and vertical integration.

I. INTRODUCTION

Imagine that a risk-neutral Entrepreneur has completed the first stage of a two-stage project. Assume that the entrepreneur must sell the project to someone else who will complete the second stage. Assume also that a risk-neutral potential Buyer of the project can invest $40 in the second stage, then expect revenues as follows: $0 with 25% probability, $100 with 50% probability, and $200 with 25% probability. Assume that Entrepreneur and Buyer can casually (i.e. costlessly) observe these potential payoffs.

Some simple analysis reveals that, given these assumptions, the expected value of the project is $60: i.e., .5($100) + .25($200) - $40 = $60.

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Consequently, Entrepreneur might convince Buyer to pay $60 for the project.\footnote{In fact, if Buyer were the only potential buyer, one would expect the contract price for sale to be somewhere between $0 and $60. The division of expected surplus would depend on the parties’ relative bargaining power. A price of $60 is chosen here for the sake of simplicity in illustration. As the remainder of this illustration and paper will demonstrate, if Buyer offers nothing unique to the project, Entrepreneur may expect more than $60 from a competition among potential buyers, and the assumption that Entrepreneur will garner $60 from a negotiated contract is thus conservative.} Entrepreneur may have another choice, however. Unless Buyer is the only potential buyer, Entrepreneur could auction the partially completed project. But why would Entrepreneur bother? Bidders in an auction incur entry and investigation costs and, as French & McCormick (1984) show, in equilibrium these costs are ultimately borne by the seller. For this reason, it can be in the seller’s interest to negotiate a sales contract with a single buyer rather than auction an item on the market of numerous potential buyers.\footnote{See French & McCormick (1984) at 431-32.} This observation yields a seemingly straightforward conclusion, that Entrepreneur should accept a $60 offer from Buyer rather than bother with an auction of a project with an expected value of $60. This is, for example, the conclusion reached by Hansmann & Kraakman (1992) in the context of a broader discussion (addressed below) on the potential for buyer strategic behavior in multiple-stage projects. If a buyer offers the true expected value of a project, a risk-neutral seller would be foolish to incur the cost of an auction only to expect the same sale price.

The assumed identity of auction and contract price, however, while seemingly straightforward, is not necessarily correct. In this illustration, the identity assumption fails to recognize that $60 is the value of the project \textit{given} the $40 second-stage investment. And it is a mistake to assume such investment. To be sure, the $40 expenditure is worthwhile if an investor is limited to the initially available background information. But an auction may improve the information available \textit{prior} to the second stage investment. Enhanced information can increase the expected value of the project and thus the expected return to the entrepreneur. This extra value, moreover, counterintuitively derives from the increased likelihood that no buyer will appear and that the seller will thus earn no return.

The key move here, and the primary contribution of this paper, is the application of a “convergence theorem” to a multiple-stage investment decision. The convergence theorem holds that under plausible conditions in a sealed-bid tender auction, as the number of bidders increases, the winning bid will converge in probability to the value of the object at auction. Milgrom (1979). Application of this theorem to multiple-stage investment reveals that the auction of an early stage may yield no buyer, a zero sales
price, and demise of the project where such outcome is efficient. A sales contract based on background information alone would more often result in a positive sale price and profit for the entrepreneur, but would be suboptimal. Thus, where a risk-neutral entrepreneur earns all rents from a project, the entrepreneur may prefer the lower probability, but higher expected return, of an auction.

Part II of this paper elaborates on this application of convergence theorem to multiple-stage investment. Part III positions such application in a model of multiple-stage investment where buyer misbehavior is feared. Part IV discusses more general implications of the convergence theorem for multiple-stage investment, including possibly broad implications for the integration of production. Part V offers a brief conclusion.

II. CONVERGENCE AND AUCTION OF AN EARLY-STAGE PROJECT

The value of convergence in an early-stage auction can be demonstrated with a simple model followed by application of the model’s results to the two-stage project described in the introduction. More formal descriptions are left to more technical literature.

A. A Simple Model and Basic Results

Entrepreneur contemplates a two-stage project, the first stage of which she can complete at no cost. It is commonly known that even upon completion of the first-stage, the project has no value unless an investment is made. If after completion of the first stage, an investment of $I$ is made, then the project has a commonly known expected common value of $\bar{V} > I$, but there will be significant variance in the distribution of the value, $V$, given $I$. At the time of first-stage completion, the actual, common value of the project, given an investment of $I$, will be either $V_a$ or $V_b$, where $V_a < I < V_b$. Let $p$ be the probability that $V = V_a$ so that $\bar{V} = pV_a + (1 - p)V_b$.

Although $V$ is not directly observable (or verifiable), any potential purchaser can update her information about the project if she draws a signal, $s$. Let $s$ take the form of an estimate of $V$ and let $c$ be the cost of such signal. Let $V_a$ be the mean of the distribution of $s$ conditional on $V = V_a$ and let $V_b$ be the mean of the distribution of $s$ conditional on $V = V_b$. A signal is not observable (or verifiable) to anyone other than the person who spends $c$ and thus draws the signal. No one can draw more than one independent signal. (The last assumption and its implications are discussed in Part III below).

The Entrepreneur has three options on how to proceed: (i) do nothing and earn nothing; (ii) before anyone has an opportunity to draw a signal, $s$, negotiate for the sale of the project with an individual purchaser who will invest $I$ in the project; or (iii) sell the project through a first-price, sealed-
bid auction,\textsuperscript{3} any participant in which will spend $c$ to bid, and the winner of which will invest $I$ in the project.

If transaction costs of one-on-one negotiation are low enough, Entrepreneur would prefer option (ii), negotiation, to option (i), scrapping the project, because, transactions cost aside, negotiation would yield Entrepreneur a positive return of $\bar{V} - I$ or some portion thereof (depending on Entrepreneur’s bargaining power). There are circumstances, however, in which Entrepreneur would prefer option (iii), the auction, even where Entrepreneur would have all the bargaining power, where the auction costs—$\sum c$ over all bidders—would be borne by Entrepreneur, and where such costs would exceed the transactions cost of negotiation.

Observe that a bidder in a contested auction will not only draw an estimate based on her private signal but will also adjust her estimate conditional on her private signal being the highest drawn among all bidders.\textsuperscript{4} According to Milgrom’s convergence theorem,\textsuperscript{5} as the number of bidders approaches infinite, the variance of the sale price at a common-value auction approaches zero, and the probability that the sale price will be almost precisely the item’s true value approaches one.

In this model, convergence implies that the bidder who draws the highest signal, $s$, will, at the limit, precisely adjust her value estimate based on that signal such that where $V = V_a$ there will be no bid (because $V_a < I$) and where $V = V_b$ the winning bid will be $V_b - I$. Consequently, if $c = 0$ and the number of bidders were arbitrarily large, Entrepreneur would expect to receive from an auction $(1 - p)(V_b - I) > \bar{V} - I$.

In any real-world setting, $c > 0$ and there will not be infinite bidders in equilibrium. But the insight here is that by saving up to $p(I - V_a)$, an auction may be both in Entrepreneur’s interest and socially optimal.

As a formal matter, this result is not assured for every distribution of value estimates. The necessary (and sufficient) conditions are shown in Milgrom (1979). Suffice it to say here that there is an important set of distributions for which the convergence theorem holds. In Milgrom’s words,

\textsuperscript{3} In this paper, any reference to an auction is intended as a reference to a first-price, sealed-bid auction under the conditions described by Milgrom (1979). This assumption does not detract from the generality of the fundamental analysis.


\textsuperscript{5} See Milgrom (1979); see also Grossman (1981).
convergence implies “the identity of price and value for large tender auctions with appropriate information structures.” The result is that “private information [becomes] aggregated in the equilibrium price.” And as shown here, such aggregation can redound to the benefit of an entrepreneur who requires investment in a multi-stage project.

B. An Illustration of Entrepreneur’s Gain

Application of the convergence theorem, thus explained, to multiple-stage projects becomes a simple matter. Return to the illustration from the first part of this paper. A risk-neutral Entrepreneur has completed the first stage of a two-stage project. Assume that the entrepreneur must sell the project to someone else who will complete the second stage. Assume also that a risk-neutral potential Buyer of the project can invest $40 in the second stage, then expect revenues as follows: $0 with 25% probability, $100 with 50% probability, and $200 with 25% probability. Assume that Entrepreneur and Buyer can casually (i.e. costlessly) observe these potential payoffs. Should Entrepreneur sell the project to Buyer for $60, the most Buyer would pay for the project given the background information alone? The answer is no, assuming the applicability of the convergence theorem, unless the transaction costs of a multiple-bidder auction are prohibitively high.

Entrepreneur can benefit from an auction because an increase in the number of bidders may, at the limit, allow the bidders to be certain that the winning bid precisely reflects the project’s revenues. In this example, under the convergence theorem, with an infinite number of bidders there would be a 25% chance that the winning bid will be $0 and that no one would invest $40 in the second stage. Thus, the expected sale price for the project would be .5($60) + .25($160) = $70. (Note that the actual sale price, if there is a sale, will be either $60 or $160, not $70. But this is of no interest to a risk-neutral entrepreneur ex ante because for either of these better outcomes the $40 investment will be required.) Unless bidding costs, borne by the seller in equilibrium, are at least $10, then, Entrepreneur would do better with an auction than with a negotiated sale to Buyer.

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6 Id. at 687.
7 Id. at 688.
8 That is, .5($100) + .25($200) - $40.
10 Of course the bidding costs for a literally infinite number of bidders would be infinite, and even as the number of bidders approached infinite, the variance of the winning bid around the project’s value would never quite reach zero. This example is merely illustrative.
Note that any gain from auction is available notwithstanding that the background information was correct. The above calculations derive from rather than refute the initially available probability distribution. The auction simply updates the background predictions through the aggregation of private information. That is, collectively, though not independently, the bidders know which event from the probability distribution has occurred and collectively transfer that information in the form of bids. As a result, the seller does not bear the cost of wasted investment in a bad-state outcome. Here that means Entrepreneur need not compensate an ultimate buyer from a good-state outcome for the expected loss of a $40 investment, a loss that will occur one fourth of the time based on initial probability estimates. Thus, it is not a coincidence that the expected $70 sale price at auction in this illustration is both $10 more than the $60 maximum price of a negotiated sale and equal to the avoided $10 expected loss—i.e. .25($40)—from investment on initial information alone (or even from information supplemented by Buyer alone, as opposed to the market as a whole).

In essence, for a multi-stage project, convergence allows the seller of an early stage to cut off the losing side of a payoff distribution. The result is a lower probability of a positive return than reliance on initial probabilities would yield, but a higher overall expected return. Any paradox is merely apparent, and vanishes even ostensibly once one recognizes that the seller would ultimately bear the net loss of inefficient second-stage investment.

This insight has implications for a number of analyses. The discussion immediately below, on hands typing, introduces a somewhat more complicated setting than the one illustrated above, a setting where strategic behavior of the parties is considered. The discussion is designed to shed additional light on the observations made above and, in the process, to describe limitations on the conclusions that can be drawn from those observations. Following that discourse is a brief commentary on convergence and vertical integration.

III. HANDS TYING

Consider another multiple-stage project in which after an entrepreneur expends effort a potential investor receives a noisy signal about early-stage quality. Assume, again, as may often be realistic for such a project, that neither the entrepreneur’s effort nor the investor’s signal is observable or

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11 Based on initial probability, and without better information, the second-stage investment is efficient because it has an expected value of $60, compared to no investment and no return.

12 The parenthetical in the text is explained more fully in the next part of this paper.
thus contractible. The question arises whether the entrepreneur should contract for investment prior to completion of the early stage, a “hands-tying” contract, or wait until potential investors receive the signal from early-stage production. The introduction of convergence theorem to this problem militates against hands tying and in favor of an early-stage, post-production auction. This is the case even though the investor subject to a hands-tying contract might investigate the merits of further production prior to investment.

A. The Role of Signals

The case for auctions over hands tying is made in two parts, the first a seemingly step back, the second two steps forward. First, the potentially destructive role of a signal is examined in a model that includes an entrepreneur and a single potential investor. Second, the potentially productive role of signals is examined when additional potential investors are introduced.

1. One-on-One Negotiation

An entrepreneur possesses unique skills but lacks funds to complete a project that requires two stages. Investors bring no particular expertise to the project, but can provide the funds needed for the second stage. Imagine, for example, that in the first stage of a novel’s production an author writes a manuscript while in the second stage a publisher invests in printing and promotion. How should an entrepreneur organize such a project? This is the question addressed by Hansmann & Kraakman (1992). (The model that follows is derived from that article, with alterations noted and explained.)

The value of the project’s outcome, \( v \), given the required investment, \( I \), can be either good, \( v_g \), or a bad, \( v_b \). These values are such that \( v_b < I < v_g \). The entrepreneur can expend either no effort, in which case the project will have a certain value of \( v_b \), or a fixed amount of effort, \( e \), in which case there is a probability, \( q \), that the outcome will be good and the probability \( (1 - q) \) that the outcome will be bad, where \( 0 < q < 1 \).

Although effort is not observable, prior to second-stage investment the investor receives a noisy signal, \( s \), which indicates whether the project will succeed or fail. There are two possible values for \( s \), a signal of a good outcome, \( s_g \), and a signal of a bad outcome, \( s_b \). If the project will have a good outcome, the signal will be \( s_g \) with a probability of \( r \) and a value of \( s_b \) with a probability of \( (1 - r) \). For simplicity it is assumed that the reliability of a good signal is the same as the reliability of a bad signal. That is, if the project will have a bad outcome, the signal will be \( s_b \) with a probability of \( r \) and a value of \( s_g \) with a probability of \( (1 - r) \). Thus, probability \( (s = s_g | v = v_g) = r \) = probability \( (s = s_b | v = v_b) = r \), where \( .5 \leq r \leq 1 \). At the limits, the signal contains no information when \( r = .5 \) and perfect information when \( r = 1 \). If the investor has an opportunity to reject the project after receiving a signal,
and does so, $v = 0$. All of the preceding is known by both the entrepreneur and the investor, each of whom is assumed to be risk neutral.

Although it will not always be that the entrepreneur should expend effort, the hands-tying problem is interesting only where such expenditure is efficient. Assuming that the entrepreneur should expend $e$, there are (from society’s perspective) two plausibly efficient courses for further investment. The first course is for the investor always to invest, in which case the expected value of the project is:

$$qv_g + (1 - q)vb - I - e. \quad (1)$$

The second course is for the investor to invest but only after observing $s_g$, in which case the expected value of the project is:

$$qr(v_g - I) + (1 - q)(1 - r)(vb - I) - e. \quad (2)$$

It is, therefore, efficient to condition second-stage investment on a positive signal where Expression (2) is greater than Expression (1), that is where:

$$-(1 - q)r(v_b - I) > q(1 - r)(v_g - I). \quad (3)$$

The left-hand side of Expression (3) is the loss avoided by relying on a correct signal. The right-hand side is the loss incurred by relying on an incorrect signal. The smaller $q$, the greater $r$, the smaller $v_g$, and the smaller $v_b$, the more likely that it will be efficient to condition investment on $s$.

The interesting case here is the one in which Expression (3) is not satisfied. In this case, it is inefficient for an investor to rely on $s$. Yet given the option, a self-interested investor might so rely. To see this, consider what the entrepreneur’s and investor’s contract would look like if the parties agreed to ignore $s$ because the loss avoided from relying on the signal would be smaller than the loss incurred. Assume that the entrepreneur would attempt to capture the surplus from contract here, as it is the entrepreneur—e.g., an author—who brings a unique opportunity to the project, while the investor—e.g., a publisher—provides capital alone. (For now ignore the mechanism through which the entrepreneur might capture such surplus.)

Thus, to attract funds without sacrifice of the entrepreneur’s unique opportunity, the entrepreneur would offer an investor:

$$D = ((I - vb)/q) + vb; \quad (4)$$

where the investor would receive this amount out of $v_g$ in a good outcome and would receive $vb$ in a bad outcome. This would lead the investor to expect:

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13 The entrepreneur’s market power is discussed in the next subpart of this paper.

14 This expression is a standard representation of a debt contract where the debtor has limited liability.
\[ qD + (1 - q)v_b = I. \]  
(5)

The entrepreneur, in turn, would expect:
\[ q(v_g - D) - e. \]  
(6)

Substituting the right hand side of Expression (4) for \( D \) in Expression (6), and rearranging terms, yields Expression (1), the social return to the project without reliance on any signal. That is, if the investor is compensated according to Expression (5), the entrepreneur will, by design, garner the entire surplus from contract and, if such surplus exists, will have an incentive to expend effort.\(^{15}\) (This contract structure is a deviation from the model presented by Hansmann and Kraakman, but follows their observation that in fact, though not in their model, the entrepreneur, and not the investor, likely will be the source of rents.\(^{16}\))

The contract described would be efficient if the investor were to ignore the signal at the time of investment. But it is not an equilibrium position for the investor to contribute \( I \) in exchange for a promise of \( D \) despite a signal of \( s_b \). To see this, let \( p_b \) be the probability of a good outcome given \( s_b \), and note that:
\[ p_b = \frac{q(1-r)}{(q(1-r) + (1-q)r)}. \]  
(7)

Where \( r = .5 \), it is the case that \( p_b = q \), as can be understood intuitively by observing that when \( r = .5 \), the signal contains no information and the probability of success is, as it must be, the same as before the signal. Where \( r > .5 \), however, that is where the signal has any content, \( p_b < q \). In the extreme, where \( r = 1 \), \( p_b = 0 \) and there is no chance of success given \( s_b \). Thus, if an investor were to accept in exchange for \( I \) an entrepreneur’s obligation to pay \( D \) calculated by reference to Expression (4), substituting \( p_b \) for \( q \) in Expression (5), the investor would expect:
\[ p_b D + (1 - p_b)v_b < I. \]  
(8)

The intuition here is simple. Where an investor’s return depends at least in part on the success of a project, a payment obligation designed to leave the investor with a zero expected profit for financing any, or the average, project will leave the investor with an expected loss for financing a project that the investor knows is less than ordinarily likely to succeed. Thus, given the choice of whether to invest in exchange for the entrepreneur’s obligation

\(^{15}\) In a richer model effort, here the discrete amount \( e \), would instead be a continuous function so that the entrepreneur’s equilibrium expenditure would in fact be suboptimal, though perhaps only slightly so. In any case, relaxation of the simplifying assumption here does not detract from the generality of the essential observations about this model.

\(^{16}\) Hansmann & Kraakman (1992) at 633 n. 3.
of $D$, an investor will reject a project after observing $s_b$ even though, by hypothesis, efficiency requires the pursuit of all projects regardless of $s$.

The investor, moreover, would gain rents from the project if the entrepreneur allowed the investor to finance only those projects that generated a signal of $s_g$. To see this, let $p_g$ be the probability of a good outcome given $s_g$, and note that:

$$p_g = \frac{qr}{qr + (1-q)(1-r)}.$$

(9)

This expression, like Expression (7), equates the probability of success with $q$ when $r = .5$ and the signal thus contains nothing but noise. In this expression, however, as $r$ approaches 1 so does the relevant probability of success. That is, as a good signal becomes perfect the chances of success become certain. Where $r > .5$, therefore, $p_g > q$. Thus, if an investor were to accept in exchange for $I$ an entrepreneur’s obligation to pay $D$ calculated by reference to Expression (4), substituting $p_g$ for $q$ in Expression (5), the investor would expect:

$$p_g D + (1-p_g)v_b > I.$$

(10)

There would be another alternative, were $s$ contractible. If obligations could be conditioned on $s$, the entrepreneur could, in advance of first-stage production, contract to pay the investor $D_b$ given $s_b$ and $D_g$ given $s_g$, where:

$$D_b = (\frac{(I-v_b)}{p_b} + v_b);$$

(11)

and where:

$$D_g = (\frac{(I-v_b)}{p_g} + v_b).$$

(12)

Note that Expressions (11) and (12) are derived from Expression (4), with the applicable probability of success substituted for $q$. Such a contract would allow the investor to collect from the entrepreneur exactly enough in the event of a good outcome to compensate for the investor’s loss in the event of a bad outcome. This tradeoff would be the equivalent of an entrepreneur’s effective personal guaranty of the obligation $D = I$ (such guaranteed obligation itself not plausible here given the assumption that the entrepreneur has no assets other than the unique opportunity of the project to be financed).

The problem with an ex ante conditional contract is that $s$ is assumed to be noncontractible. Given this assumption, the investor would have an incentive to claim $s_b$ regardless of the actual signal. The signal is also assumed to be nonobservable. The investor, therefore, also would have an incentive falsely to claim $s_b$ if the entrepreneur waited until the completion of

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17 Like Hansmann and Kraakman, I assume that reputational interests alone would not cure the investor’s moral hazard problem.
first-stage production before negotiation of a contract. In either case, the investor could use the private information in the signal to profit at the entrepreneur’s expense, either by accepting an obligation of $D$ and then cherry-picking projects with a signal of $s_g$ or by demanding an obligation greater than $D_g$ for such projects. As a result, where the expected surplus from a project is marginal—i.e. where Expression (2) is barely satisfied—an entrepreneur might forgo a socially valuable venture. In any case, the entrepreneur will earn a suboptimal return on her unique opportunity, which may have been the product of earlier investment—e.g., an author’s time spent in honing her skills. Thus, when a signal is unobservable and consequently noncontractible an obligation conditioned on $s$ is not part of a plausibly efficient contract.

What remains, then, between an entrepreneur and a single investor is a hands-tying contract. Such a contract is negotiated before completion of a project’s early stage and thus before an investor can receive a signal. In a hands-tying contract, the investor here would agree in advance to provide $I$ in exchange for an obligation of $D$ regardless of the signal generated by the project’s first stage. Even though effort is not observable, the entrepreneur has an incentive to expend $e$ because the entrepreneur’s payoff depends on the success of the project.\(^\text{18}\) Now the signal will be ignored and the entrepreneur will pursue all projects, as is efficient for the class of projects at question. So, for example, (based on their analogous model) Hansmann and Kraakman offer the efficiency of hands tying as a possible explanation—as an alternative to, say, entrepreneurial risk aversion—when an author contracts for the printing and promotion of her book before the manuscript is written.

2. **Multiple Potential Investors**

The analysis of the hands-tying problem to this point has rested on an assumption that the entrepreneur would negotiate with a single investor. Now relax that assumption. Imagine an entrepreneur with a unique opportunity that can be financed by any number of competitive investors, none of whom can offer a unique contribution.\(^\text{19}\) Given multiple potential investors, the entrepreneur can address any individual investor’s incentive to misrepresent $s_g$ as $s_b$. The entrepreneur can offer a completed early stage—e.g., a completed manuscript—to multiple potential investors. That is, the entrepreneur can auction the project to the highest bidder. Now any investor attempt to deceive the entrepreneur could be met with a higher bid by a self-

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\(^\text{18}\) See note 15.

\(^\text{19}\) As discussed below, the perfect lack of unique contribution by an investor is merely illustrative and not necessary for the conclusion that auctions can be beneficial.
interested competitive investor. This prospect can restore to the entrepreneur the project’s full surplus.

Hansmann & Kraakman (1992) recognize the potential of an auction to generate investment in all projects for which investment is efficient. They observe that “there does exist an efficient equilibrium in which investors and entrepreneurs contract after the entrepreneur expends effort.”\(^{20}\) But, they say, in “this equilibrium, entrepreneurs commonly submit their project to multiple investors before having it accepted and investors examine signals on more projects than they finance. Yet, in the end, all projects are undertaken on the same terms that would be agreed to if each entrepreneur were simply to enter into a hands-tying contract with an investor prior to developing his project.”\(^{21}\) After noting that investor scrutiny is costly, they conclude that “there is strong reason for contracting in advance of the entrepreneur’s effort. Otherwise, avoidable transaction costs will be incurred and some worthwhile projects might not be produced. Moreover, at least in this simple model, contracting in advance yields a first-best outcome and thus brings no counterbalancing inefficiencies.”\(^{22}\)

There is a questionable supposition that undergirds the Hansmann and Kraakman auction analysis. In their concededly “simple model” they treat \(r\) as fixed and assume that, in an auction, some investor will observe \(s_g\) for, and finance, any project submitted, \(q\) of which will succeed.\(^{23}\) Hansmann and Kraakman do not believe that investors will be deluded. Instead they assume that investors will be aware of the presumed fact that multiple submissions will lead some to observe \(s_g\) even while others observe \(s_b\). With some investor observing \(s_g\) regardless of that signal’s merit, Hansmann and Kraakman reason that all investors can safely finance based on that signal so long as they do not act on the belief that the project has any greater likelihood than \(q\) to succeed.\(^{24}\) In terms of the model in this paper, Hansmann and Kraakman would imagine that every entrepreneur would find an investor who would, in essence, ignore the signal from a project’s first stage and provide \(I\) in exchange for an obligation of \(D\).

\(^{20}\) Hansmann & Kraakman (1992) at 640.

\(^{21}\) Id. at 641

\(^{22}\) Id. at 641-42.

\(^{23}\) Id. at 640-42. Hansmann & Kraakman, id. at 645, recognize that a signal can include both a prediction of value and an indication of the signal’s own reliability. But they neither draw this observation from, nor apply it to, the auction context, and their conclusions on this point are inapposite here.

\(^{24}\) See id. at 640-42.
Hansmann and Kraakman overlook, however, the fact that the auction process itself can alter the reliability of the signal $r$. The discrete division of signals into $s_g$ and $s_b$, and the assignment of a reliability measure, $r$, to these signals, are artifacts of an illustration. More realistically, each potential investor would estimate an auctioned project’s value along a spectrum and adjust its estimate to account for the presence of other potential bidders as part of the auction process. As explained in the first part of this paper, the adjustment can cause the winning bid to “converge in probability” on an auctioned object’s true value.\(^\text{25}\)

Placed in context of the hands-tying model, convergence could generate something analogous to a winning bid that would be based on $s_g$ or $s_b$ but with an $r$ of 1 (in the limiting case). It follows that from a bid based on $s_g$, an entrepreneur would be able to attract $I$ for a promise of $D_g$ determined through application of Expressions (9) and (12). (As noted above, application of Expression (9) with $r = 1$ yields $p_g = 1$. Application of Expression (12), in turn, with $p_g = 1$ yields $D_g = I$.) Put simply, where a project is certain to succeed, the entrepreneur needn’t compensate the investor for the risk of failure.

To be sure, the entrepreneur will realize a signal of $s_g$ with a probability of only $q$. But the entrepreneur’s, and society’s, ex ante expected return from a project will be:

$$q(v_g - I) - e; \quad (13)$$

this is merely a special case of Expression (2), with $r = 1$. The savings over a hands-tying, forced investment regardless of $r$, shown by Expression (1), would be $(1 - q)(I - v_b)$. That is, the savings are from avoidance of the investment wasted when the project fails. Thus, convergence does in the hands-tying model exactly what it does in the simple illustration from this paper’s first part.\(^\text{26}\) After completion of an early production stage, convergence effectively cuts off the losing side of a payoff distribution.

The observation that convergence can increase $r$ and lead to a more efficient allocation of resources becomes intuitively clear once one notes that convergence, once again in Milgrom’s words, “results in private information being aggregated in the equilibrium price.”\(^\text{27}\) No one bidder may have a reliable estimate of a project’s true value, but collectively all bidders may know that value and the auction process may permit the value’s expression. This does not mean that hands tying is never efficient. Auctions

\(^{25}\) Milgrom (1979) at 679.

\(^{26}\) See the text accompanying notes 8 – 12.

\(^{27}\) Id. at 688. See also note 7.
have transaction costs, as Hansmann and Kraakman observe. And, to the extent such costs greatly exceed the costs of one-on-one contract negotiation, hands tying may be preferable. But transaction costs aside, where the convergence theorem holds, there are significant potential gains from auction over contract. These gains count against and thus limit the efficacy of hand-tying arrangements.

B. The Power of Auction

There remains the question of whether an auction is truly necessary for an entrepreneur to benefit from convergence. One might imagine that the entrepreneur could complete an early stage of production and maintain a reservation price of $D_g = I$ in negotiation with an individual investor. That investor could then take multiple draws of information about the project’s true worth, thus (in essence) increasing $r$ internally, accepting the entrepreneur’s offer if and only if the ultimate, blended signal is $s_g$. (Or in terms of the model presented in Part II, above, a single potential purchaser could learn whether the value of the project were $V_a$ or $V_b$.)

An initial response to this conjecture is that a negotiated contract with a single investor who individually enhances available information is essentially an alteration of the auction’s form, and likely an inefficient one. The agreement supposed would not be a hands-tying contract, as the deal would be struck after early-stage production. So this contract form, like an auction, incorporates the collection of information post early-stage production. But as a location for information gathering, as an alternative to the market, any single investor may be a poor site.

Again consider the example of an author who seeks printing and promotion services from a publisher. The manuscript is complete, but casual guesses about the book’s prospects are highly variable. A reduction in this variance requires multiple independent expert readers, each with the proper incentives to evaluate the manuscript properly. Each reader must, in effect, provide an accurate estimate of what she would pay for the manuscript were she forced to bid with her own funds. It might be difficult, and wasteful, for every publisher in the industry to employ and provide incentives for many separate agents who would thus review a manuscript before an offer were accepted or made. (Even if every publisher took this course, an auction might result anyway, as would be the case if no publisher could be sure that a manuscript had not previously been shopped to other publishers.)

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28 A more extensive discussion of auction costs can be found, for example, in French & McCormick (1984).
Despite the simplifying assumptions of the above illustrations and model, moreover, investors are not entirely fungible. Even where an entrepreneur possesses most or almost all of a project’s unique attributes, there may be some advantage in differentiation among investors, publishers for example. Thus, there may be some advantage in in-house readers who understand not only the interests common to all publishers bidding on a manuscript but the specialized interests of their own houses as well. In a richer model, a publisher’s bid for a manuscript would take into account both general and idiosyncratic values, and any account of the latter would interfere with the independent judgments on which convergence relies. Separate but nuanced perspectives are easier to maintain among independent investors, each in competition with the others. The beauty of an auction is its ability to aggregate isolated bits of information, even bits that are isolated with good reason. Compare Grossman (1981), which demonstrates a rational expectations equilibrium that gives consumers the same allocation as if each consumer has access to all of the economy’s information.

An auction can serve another purpose as well. The discussion in the above illustrations and model has simply assumed that, absent investor deception over a received signal, the entrepreneur would garner all rents from a project because the entrepreneur possesses all unique attributes. Even as qualified in the prior paragraph, it remains true that for many projects, such as book publication, the entrepreneur rather than the investor will be the predominant source of economic rents. Thus, overall efficiency requires that the entrepreneur rather than the investor acquire the predominant share of those rents. It remains to be demonstrated, however, how the entrepreneur as source of such rents captures them in a project for which the entrepreneur must attract outside investment. One-one-one negotiation is not typically a mechanism that assigns surplus to one party or the other. Rather that surplus would likely be divided in the negotiation process.29 An auction, which can aggregate information, also provides for competition among fungible resources and thus allows the proper allocation of rents to the possessor (and perhaps earlier investor in) unique resources.

IV. **Vertical Integration**

The convergence theorem has broad implications for multiple-stage projects. The illustrations and hands-tying model discussed above form a mere subset of applications. Consider more generally, the role of convergence in the question of whether production should be integrated. To be sure, this question will not always be a close one. For example, an automobile manufacturer would have little doubt about the wisdom of placing a car body on a completed chassis and engine assembly. In this example, the prospect is

29 See note 1.
vanishingly small that the later-stage investment would be wasted given the early-stage production. In this example, moreover, the appropriate level of second-stage investment may vary little with the ultimate value of the completed car. So, given the added transaction cost, perhaps no manufacturer would auction chassis assemblies to car body producers,\textsuperscript{30} even if an auction could reveal more accurately the value of the cars. There is, however, no theoretical reason to believe that the unthinking completion of projects would ordinarily be efficient.

There may be situations in which early-stage production is sensible even where the efficacy of later stage investment is uncertain. In addition to book publication, discussed above, multiple-stage investments—frequently financed by venture capital—in technology and other intellectual property come to mind. For such projects, the value of later-stage investment may importantly depend on the expected value of the project after early-stage production. In the hands-tying model above, late-stage investment was all or nothing. In more realistic settings, however, different levels of later stage investment are possible, and usefully vary with the value of the project at the time such investment is required. A novelist’s manuscript, for example, might be accepted for publication but justify only minimal marketing efforts. The book-publishing example, moreover, is not the only one plausible. For another, imagine that a small firm develops a potentially valuable medication. The new drug may justify much or little further expenditure in clinical trials and marketing depending on the market potential. It could thus be beneficial for the producer accurately to assess value after the early-stage production and before late-stage investment. As demonstrated above, an auction may be an efficient means of such assessment. If so, and if such assessment is valuable, one might expect that the pharmaceutical industry would not always integrate the creation of products with their further development.

More goes into a production integration decision than mid-production valuation, of course. But all else equal, the greater the variability of early-stage value and the greater the range of potentially valuable later-stage investment, the more important mid-production valuation, and the more likely a mid-project auction would be efficient as opposed to production integration. This is a testable hypothesis, at least in theory. I offer the hypothesis here and leave the test itself to later work.

V. Conclusion

The application of the convergence theorem to multiple-stage investment projects demonstrates an opportunity to increase the expected value of

\textsuperscript{30} This may not be, or may not always have been, so. The example is merely illustrative.
such projects through a reduction of uncertainty. Consequently, an early-stage auction may be preferable to a negotiated contract for late-stage investment, including the extended contract form of vertical integration, even where the transaction costs of the former exceed those of the latter. This conclusion may seem odd at first, as reduction of uncertainty is ordinarily seen as valuable only where risk aversion plays a role. On closer examination, however, the reduction of uncertainty here, through an auction’s aggregation of private information, can substantially enhance the allocation of resources.
References.


