

VENDOR SCREENING IN INFORMATION TECHNOLOGY CONTRACTING WITH A PILOT PROJECT

Eli M. Snir ♦
Southern Methodist University, Cox School
esnir@mail.cox.smu.edu
Phone: (214) 768-1082

Lorin M. Hitt *
University of Pennsylvania, Wharton School
lhitt@wharton.upenn.edu
Phone: (215) 898-7730

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- ♦ 374 Crow, Cox School of Business, Southern Methodist University, 6212 Bishop Blvd.
Dallas, Texas 75275-0333 Fax: (214) 768-4099
- * 1300 Steinberg Hall-Dietrich Hall, The Wharton School, University of Pennsylvania, 3620
Locust Walk, Philadelphia, PA 19104. Fax: (215) 898-3664

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ABSTRACT

The growth in the information technology (IT) services market and the increasing tendency of firms to outsource some or all of their IT functions necessitate better mechanisms for selecting IT vendors. For most projects, there are a multitude of potential vendors that differ in quality and other aspects that are difficult to assess at the time of contracting. In addition, many projects have outcomes that are difficult to measure or verify by outside parties – as a result, strategies that require observability of outcome, such as incentive contracting, only provide limited benefits in vendor selection and in some cases can be ineffective or counterproductive. This paper presents an alternative mechanism for selecting high quality vendors using a two-stage contract. In the first stage, the client engages a vendor for a pilot project and observes the outcome. Using this observation, the client makes a decision on whether to continue the project to the second stage or terminate the project on pre-specified terms. By setting compensation for the pilot sufficiently low, and establishing a threshold performance level for continuation, the client can offer a contract that is only attractive to high quality vendors. Using game theoretic analysis we find that this contract performs better for the client than random selection among seemingly equally qualified vendors. This mechanism is useful in settings where vendor quality is uncertain, and especially in situations where a pilot project is undertaken for other reasons (such as demonstrating technical feasibility), where the benefits of this contracting mechanism can be realized at little incremental cost.

Keywords: Information Economics, Contracts, Incentives, Agency Theory, Outsourcing of IS, IS Project Risk Management

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1. Introduction

The past decade has seen an explosion in information technology (IT) outsourcing for building basic computer applications, systems maintenance and support, routine process automation, and even strategic systems. Estimates place the market size at \$350 billion by 2002, up from \$140 billion in 1997 (King [19]). The Yankee Group claims that of the 1,000 largest publicly traded companies in the US, nearly 40% contract for significant IT functions (Harris [13]). In the past, companies purchased off-the-shelf software or tailored vendors' applications to their own needs. Today outsourcing contains a continuum of activities from purchasing "shrink-wrapped" applications through complete divestiture of the entire IT function. As the range of possibilities has expanded, the market has shown a trend toward longer-term and increasingly complex outsourcing deals (DiRomualdo and Gurbaxani [8]; Grover, Cheon and Teng [11]). Many companies have found that purchasing IT components or services from external contractors allows them to enjoy the benefits of specialization and lower costs, while redeploying internal staff on projects that must be developed in house (Stedman [36]).¹

The increased reliance on large and complicated outsourcing arrangements places ever-increasing demands on the vendor selection process. The Gartner Group argues that vendor incompetence and other outsourcing errors will lead to a doubling of failed projects by 2003, from 5% to 10% of outsourced initiatives (Bartram [2]). For all except the largest IT projects, there are hundreds of possible vendors, only a small subset of whom have the capabilities to deliver a given system on time and within specifications. Because IT is an intangible product that may be heavily customized for each company, it may be very difficult to assess accurately vendor quality during the bidding process. Equally important, it is difficult to assess vendor performance objectively, even after project completion, reducing or eliminating the benefits of using standard performance-based incentive contracts. This may explain the high failure and

¹ These may be systems that embed the sources of a firm's competitive advantage and therefore cannot be safely outsourced, or represent systems where it is necessary for internal staff to gain expertise.

renegotiation rates even in carefully crafted incentive contracts for IT services.² Even for situations where many aspects of performance can be measured, either during the project through service level agreements, or after project completion through post-project audits, not all aspects of project outcome may be measurable to a degree where an outside party can certify compliance. Thus, we may be able to improve IT contracting by designing mechanisms that rely on *observability* of outcome, rather than the stronger standard of *verifiability* required for third-party enforcement of incentive contracts.

The difficulty of identifying vendor capability before contracting creates an environment where vendors have incentives to misrepresent their capabilities. For example, when clients use competitive bidding to choose vendors, low cost, low quality vendors often tender viable bids, claiming that they have the ability to provide high quality services. This results in the classic “lemons problem” (Akerlof [1]) – only low quality firms will aggressively bid and win contracts, leading clients to refrain from outsourcing altogether, even when substantial gains are possible.

The vendor selection problem with non-verifiable outcome is important in practice and has received attention in the academic literature on IT outsourcing (see Moad [28]; Rothfeder [32]; and Lacity and Hirschheim [21]), but there has been little discussion of how to avoid or address it without eliminating the outsourcing option altogether. This contrasts with the study of agency problems (“shirking” or moral hazard) when outcomes are verifiable – these issues have been extensively discussed in the IT outsourcing literature (Gurbaxani and Whang [12]; Grover, Cheon and Teng [11]; Lacity, Willcocks, and Feeny [22]; DiRomualdo and Gurbaxani [8]) and typical remedies are well understood (see the seminal paper by Grossman and Hart [9]).

The vendor selection problem is a special case of a general class of problems of *adverse selection* and the subclass of *screening* problems that has been studied extensively in economics (see e.g., Rogerson [31]; or McAfee and McMillan [26]). The general insight in screening models is that firms can improve their contracting outcomes by offering a contract that is only desirable to high quality vendors and unprofitable for low quality vendors. Where possible, these contracts overcome the problem that vendor quality is privately known by the vendor.

² The Gartner Group estimates that the difficulties of measuring IT benefits will lead by 2003 to disputes in 20% of incentive-based contracts, where the contract stipulated measurable performance levels, with a third of these requiring intervention by courts (Bartram [2]). Renegotiation of contracts is also beginning to become commonplace in IT outsourcing – see Lacity and Hirschheim [21] for several case examples.

Moreover, in many circumstances, screening contracts can improve contractual performance beyond what is possible through incentive contracting because they can incorporate dimensions of performance that can be observed but not verified, and thus could not otherwise be used in an incentive contract.

This paper provides an analytical screening model (in the spirit of Rogerson [31]) to examine the client's problem of contracting for a custom software application with one of many prospective vendors. Vendors are assumed to have better information about their capabilities to deliver the system than the client has. Project quality is assumed to be observable, but non-verifiable, in the sense that clients are able to assess the benefits they receive from the system during implementation, but these benefits cannot be verified by a third party (and thus cannot be a condition of an externally enforceable contract). Initially we consider a setting where there are no hidden actions or effort, and derive the optimal screening contract. We later discuss the impact of this approach on other common outsourcing risks including unobserved action and opportunism, and show that careful design of the project can partially alleviate these concerns or can be combined with other approaches such as performance-based contracts.

Under these information conditions, we show that by using a two-stage contract, clients are able to improve their chances of selecting a high quality vendor. In the first stage, the "pilot" phase, the vendor begins implementing the project. If performance of the pilot phase is informative with respect to the outcome of the entire project, this phase can be used to assess a vendor's quality. If the pilot project is successful in the sense that it exceeds an observable and predesignated performance objective, the client then opts to complete the project on the original terms; otherwise, the project is cancelled.

This mechanism is effective for screening because it forces vendors to invest resources in the pilot phase that will be recovered in the second phase only if the pilot outcome is successful. By setting the payments and thresholds correctly, we can assure that only qualified vendors are willing to take this risk because only they have an adequate chance of having a successful pilot and, in expectation, can profit from their up-front investment. Unqualified vendors choose not to bid, as there is no hope of recovering their initial losses.

We show that this screening mechanism has a number of desirable properties. Most importantly, if there is sufficient value in the final project, the client can always choose the best

vendor. However, we also find that it is not always optimal to screen vendors. Screening involves a trade-off between selecting the best vendor and the chance that a good vendor will perform unexpectedly badly in the pilot and have the contract prematurely terminated. When the cost of premature termination is high relative to the value of screening, the client will opt not to screen vendors.

The remainder of this paper is structured as follows. In the next section we discuss current uses of pilot phases in IT projects, emphasizing their importance as part of a risk mitigation process. The relationship between our model and previous literature is discussed in Section III. Section IV presents the analytical model deriving the optimal screening contract. Section V examines the viability of screening, identifying necessary conditions that justify implementing the optimal two-stage contract. Section VI provides a discussion of our results, limitations of the proposed contract and opportunities for future research, followed by the conclusion in Section VII.

II. Vendor Selection and Pilot Phases

While pilot projects can potentially benefit any contracting situation, there are several characteristics of IT projects that make pilot projects particularly attractive. IT projects are unique in that they involve both heterogeneity in vendor quality and non-verifiable outcomes. Traditional contracting solutions can be ineffective when both attributes appear. Therefore, while incentive contracts for IT have been found to be better than fixed fee contracts or those with ill-defined service agreements (Lacity and Hirschheim [21]), there are still substantial failure rates (Bartram [2], Violino and Caldwell [38]).

A number of factors exacerbate the vendor selection problem for IT projects. First, the unprecedented rate of technological change in IT makes it difficult at the outset to lock project specifications into an enforceable contract that could be externally monitored or verified. Second, project management of software development initiatives is much less predictable than other engineering activities (Brooks [3]). Finally, the IT industry has a high degree of heterogeneity. Large consulting firms (e.g., Andersen Consulting, IBM), mid-sized specialty systems developers (e.g., Cambridge Technology Partners or Sapient), and small firms all

compete for the same clients. Even within firms there is considerable variation.³ More recently, a large number of startup “Application Service Providers” have appeared which purport to possess improved technology, but have virtually no track record. The diversity of service providers is further compounded by the diversity of technology platforms making it difficult to compare vendors or projects.

While previous literature on IT contracting does not provide substantial evidence on the extent to which pilot projects are currently used for vendor screening, the outcome of our analysis is consistent with several observations about the IT outsourcing market. First, our model is consistent with the existence of “loss-leader” contracts where a vendor underbids early on a project and makes up the difference in full implementation. While this behavior is typically attributed to vendor opportunism, it could also be a mechanism to allow clients to observe vendor behavior at low cost and improve long-term contractual outcomes. Second, IT contracts are increasingly being structured as multi-stage agreements (DiRomuldo and Gurbaxani [8]). It may be that the early stages represent pilot projects to help resolve uncertainty in vendor quality.⁴ Finally, pilot projects are regularly used in IT contracting for technology exploration and technical risk reduction (McConnell [27]) as they enable both clients and vendors to learn more about the needs of a project. For instance, when USAA, the large insurance company, began the first implementation of its \$10 million image processing integration project, project feasibility was still an open question (Moad [28]; Sviokla and Elam [34]). Imaging technology was readily available from several boutique vendors, but no one had implemented the technology on a large scale. USAA did not even write a formal request for information (RFI) for the full project until they had completed two pilots – one for exploring operational integration and the other for requirements definition. To the extent that a pilot project is undertaken to mitigate technological risk, the additional incentive benefits of pilot projects can be realized at little incremental cost. By evaluating vendor performance as well as technological feasibility, pilot project can be doubly worthwhile.

There are also numerous examples in the case literature where a screening-oriented pilot might have been useful. One example is Geophysical Systems, a small energy exploration

³ For instance, two major stock exchanges utilized the same systems development vendor to redesign their trading and settlement systems. One is considered a resounding success while the other has been such a tremendous failure that it became an acquisition target.

company that contracted with Data General Corp. to develop software for processing of seismic information provided by an innovative data acquisition device. Data General proposed to develop the system for \$15 million in 4 months, half the estimated time for in-house development. However, after beginning the project, it became clear that Data General was not capable of meeting the performance levels required by the client. The subsequent project failure created over \$50 million in losses and ultimately caused Geophysical Systems' to file for Chapter 11 bankruptcy protection (Moad [28]). While it is possible that this failure was due to improperly developed requirements, forcing Data General to bear some of the costs of the early stages of the project may have led them to be more active in understanding the exact requirements and more realistic about their familiarity with the problem domain.

Some new markets in the IT contracting domain, especially short term employment markets such as the Monster.com Talent Market (now discontinued) and eLance.com, have significant problems with adverse selection (a disproportionate number of low quality vendors participate in the market) that also could be allayed by screening-oriented pilot projects. More generally, whenever quality uncertainty is a significant problem, pilot projects can generally improve overall performance when used in conjunction with other contractual mechanisms.

III. Literature Review

While practitioners and empirical studies have begun to examine the difficulties of IT outsourcing (Moad [28]; Rothfeder [32]; and Lacity and Hirschheim [21]) almost all of previous work has focused on principal-agent and transactions cost approaches. DiRomualdo and Gurbaxani [8] emphasize the need to align incentives with the type of services procured, and recognize that outcome based contracts may be more readily implemented in routine automation projects than in strategic systems or new product development. While incentive contracting will typically improve contract success and client satisfaction (Lacity, Willcocks and Feeny [22]; Saunders, Gebelt and Hu [33]), there are still significant failure rates even when performance measures are included (Lacity and Hirschheim [21]). Poorly structured contracts and those with a high degree of client dependency on the vendor have been shown to be much less successful (Lacity, Willcocks and Feeny [22]; Grover, Cheon and Teng [11]; Lee and Kim [24]; Hirschheim

⁴ We thank a referee of an earlier draft of this paper for this observation.

and Lacity [17]). These studies collectively suggest that while prescriptions of transactions cost and agency theory are useful in improving contractual performance in IT outsourcing, there is still significant room for improvement, particularly in contracts where performance is hard to measure.

In this paper, we focus specifically on the issue of vendor selection when there is uncertain vendor quality and an inability to verify vendor performance. When either problem is present in isolation, there are simple mechanisms to achieve the optimal result (outcome-based contracts for the former, as in McAfee and McMillan [26], and competitive bidding for the latter as in Chaudhury, Nam and Rao [4]). Neither of these mechanisms can be employed without significant modification when both problems are present simultaneously. Similarly, approaches that can handle these problems directly, such as relational contracting and partnerships, do not address the issue of vendor selection.

III. A. Vendor Selection with Uncertain Quality

A consequence of the diverse nature of outsourcing projects is the inability to identify vendor quality before signing a contract. In many instances vendors can mislead clients about their capabilities in attempts to win contracts. Although clients know this to be the case, it is often difficult to determine which vendors have adequate capabilities before the contract is signed. One possible solution is to offer an outcome-based contract where payment is contingent on the results of the project. Hence, a low quality vendor receives a low payment, or alternatively chooses to seek other projects where his payment can be higher. However, contracts of this sort require that all relevant dimensions of outcome be measurable and verifiable.

A solution to this problem is to screen vendors by designing contracts that are robust to uncertainty in quality. One classic approach is to design and offer contracts that are desirable to high quality vendors but unattractive to low quality vendors (McAfee and McMillan [25], [26]). For example, a firm might offer two sales contracts to their independent salespeople – a small fixed fee with high commission or a large fixed fee with a low commission. Highly productive salespeople, knowing that they can earn more through a high commission will accept the high commission contract, while low productivity salespeople will prefer a larger fixed component. Knowing that their salespeople will reveal their productivity in this way, the firm can offer different contracts to different “types” (productivity) of salespeople without having to know their

type beforehand. A related literature suggests that principals can offer contracts based on costly “signals” of type where the signaling cost is used to separate the market (Spence [35]).

Another vendor selection process is competitive bidding, which can (under some circumstances) reveal vendor capabilities along specified dimensions (Chaudhury, Nam and Rao [4]). For example, a client could receive bids for cost and delivery time for a specified systems project and then choose the bidder that offered the best tradeoff between these factors.

Unfortunately, with some minor exceptions,⁵ the strategies discussed above require that *all* dimensions of outcome that the client values be known, observable, and verifiable by a third party. When outcomes are not known or verifiable, they cannot be included in an enforceable contract. When only some of the outcomes are contractible, the client faces the multi-task problem (Holmstrom and Milgrom [18]) -- high performance and capability on verifiable dimensions of the contract come at the expense of other potentially valuable dimensions. For example, aggressive selection on vendor cost will often select a vendor that utilizes low quality staff and thus produces low quality product. As a result, it is not clear that clients are better off utilizing these contracting approaches instead of fixed-price contracting when there are important outcomes that are not verifiable.

III. B. Non-verifiability

Another section of the literature deals exclusively with the issue of contracting with non-verifiable outcomes. With the increased complexity of IT services and the varying nature of outsourcing projects it often becomes difficult to verify the value brought by a vendor (Clemons and Kleindorfer [6]). Lack of verifiability also inhibits the use of performance-based contracts. For example, a common goal of modern investments in manufacturing systems is to enable more flexibility and product variety—unless the benefits of these capabilities can be quantified there may be no way to effectively contract for their delivery. Moreover, if these benefits are dependent on unobserved investments by the client (for example, actually designing new

⁵ Tournaments only require that the firm commit to selecting a vendor, but do not require an explicit incentive contract. These are only appropriate, however, when there are multiple vendors simultaneously performing comparable projects. Tirole (1986) and Hart and Moore (1988) consider models where renegotiation circumvents the verifiability problem, although these tend to be focused on incentive contracting in the former, and maximization of total welfare by preventing inefficient production in the latter. Neither approach is a screening model.

products) vendors will be reluctant to accept payment based on surrogate high-level performance measures such as client profitability.

One class of papers that deals with such non-verifiable investments, referred to as the “incomplete contracts” literature (Hart and Holmstrom [14]; Grossman and Hart [10]; Hart and Moore [15], [16]), focuses on obtaining optimal investment in a relationship when the outcome of this investment is non-contractible. By allocating bargaining power (through ownership of critical assets) the parties can have the proper incentives to make non-contractible investments since their bargaining power ensures that they will get their appropriate share of the benefits. The key idea is that as long as parties have the right levels of bargaining power and can bargain freely, contracts can be renegotiated *ex-post* to ensure proper behavior *ex-ante*.

Richmond, Seidmann and Whinston [30] utilize this approach to address the outsourcing problem for software development when both vendor and client have the ability to make valuable, project-specific, non-contractible investments. When the vendor’s investment is more important, outsourcing is recommended and an optimal sharing rule is proposed to encourage maximum value to the client. When client investment is more important, the project is insourced. Their model proposes a mechanism to decide whether to outsource a project or develop it in-house, but does not solve the problem of vendor choice for those projects that are outsourced.

Another approach is to design contracts that provide parties with incentives to reveal private information. In this spirit, Whang [39] models the decision of a client to reveal the value of a project so that inefficient projects, where benefits are less than costs, are not pursued. By basing payment on the revealed value and requiring the vendor to complete the project or pay restitution, it is shown that both parties have incentives only to contract for and complete socially efficient projects. While this mechanism encourages optimal project selection when value is private information, it too does not address the issue of vendor selection.

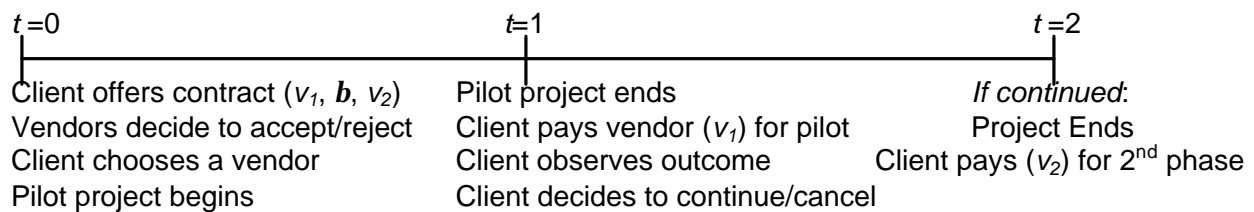
IV. The Screening Model

At $t=0$, a risk-neutral client announces her interest in selecting a vendor to implement a project, and engages in a period of non-binding, pre-contractual discussions with one or more vendors. This process could be a request for information (RFI), a vendor pre-qualification round, a request for quote (RFQ) or any other process that does not create binding commitment

on the client. This requirement is very general and simply rules out forced commitments such as a binding reverse auction where the client must accept the lowest bid. At the end of this process, there is a large⁶ pool of risk-neutral prospective vendors of two types, low and high quality, who claim they can complete the project, have passed the initial phase, and are seemingly equally qualified from the clients' perspective.

The client proposes a contract to all prospective vendors and chooses randomly from those vendors who accept the terms of the proposed contract. We assume, without loss of generality, that all necessary negotiations of terms or other aspects of the contract have been resolved in the pre-contractual bargaining phase. The client is interested in offering a contract that only a subset of the vendors accepts, screening out inefficient vendors. The offered contract specifies a nonnegotiable payment for a pilot phase (v_1), a threshold for project completion (\mathbf{b}) and a payment for full implementation (v_2) if the client elects to complete the project (see timeline, Figure 1). All vendors are assumed to have the same risk-free interest rate and all costs and benefits are discounted to time $t=0$. If the vendor accepts the contract, a pilot phase is commenced. At $t=1$, the pilot project ends, providing some observable but non-contractible benefit to the client and a payment of a prespecified amount to the vendor. At this point, she (the client) decides to continue if the observed quality in the pilot phase is above the threshold, adhering to the originally agreed terms. If the client chooses to cancel the project, she can derive no additional benefits from the mutual investments, beyond those generated by the pilot.⁷

Figure 1: Time Line



⁶ By large, we mean that no vendor has market power at this stage. Typically, this requires only two vendors.

⁷ This may be due to high technological/business obsolescence that renders these investments worthless concurrent with long project development lead-times that inhibit contracting with additional vendors.

IV. A. Assumptions

The vendor pool consists of two types (\mathbf{q}) of vendors, low quality vendors (\mathbf{q}_L) and high quality vendors (\mathbf{q}_H). The fraction of low quality vendors is q where $q < 1$. Denote the (discounted) expected benefit to the client from the entire project as $B_{\mathbf{q}}$ if a vendor of type \mathbf{q} develops the project. Vendor development cost is represented by $C_{\mathbf{q}}$. This cost includes all actual and opportunity costs the vendor may have. Client benefits and vendor costs are both assumed to be increasing in type \mathbf{q} . That is, clients prefer better vendors, but these vendors have greater opportunity costs. Furthermore, client benefits are observable but unverifiable at contract completion, so contracts cannot be contingent on their realization (see Tirole [37] for discussion of the generality of this particular assumption). As described earlier, a project is broken into two phases, a pilot (phase 1) and the full implementation (phase 2).

For ease of exposition, the distribution of vendor types, costs and benefits are assumed to take specific functional forms. Without loss of generality the type of high quality vendors will be normalized to $\mathbf{q}_H = 1$. The client's benefits derived from each phase of the project are independent draws from a specified distribution that depends on the vendor's type $\mathbf{q} \leq 1$. This distribution arises for at least two possible reasons. First, it may arise due to imperfect "fit" between the client and the vendor – the vendor may know the range of possible results, but not necessarily the exact value. Second, this can arise due to uncertainty about the overall likelihood of success of the project due to technical or business risks beyond the control of the client or the vendor.

In the pilot phase, benefits are given by the random variable $B_{1,\mathbf{q}} \sim U[0,\mathbf{q}]$, with $E[B_{1,\mathbf{q}}] = \mathbf{q}/2$. The benefit from the second phase may have any general distribution with $E[B_{2,\mathbf{q}}] = (w^{-1/2})\mathbf{q}$, where $w > 1$. It is assumed that the index of overall project value (w) is common knowledge to both the client and vendor.⁸ If a vendor of type \mathbf{q} is chosen, the *ex-ante* expected benefit of the entire project is $E[B_{\mathbf{q}}] = E[B_{1,\mathbf{q}}] + E[B_{2,\mathbf{q}}] = w\mathbf{q}$. Denote the cost for type \mathbf{q} of implementing the i^{th} phase as $C_{i,\mathbf{q}} = k_i\mathbf{q}$, where $0 < k_1 < k_2$, and $k_1 + k_2 < w$ (these conditions guarantee value is positive and increasing in type). Since both benefits and costs are increasing in type, the client is trying to screen high quality, but high cost, vendors from the initial vendor pool. Note that we have implicitly assumed that all outcomes are dependent on type and not on effort. Simply stated, the

screening mechanism provides additional information on the characteristics of the vendor – such information can only improve the ability to reach a beneficial contract when properly designed.

The client has a decision at the end of the pilot project. She may either continue to implement the entire project, or she may cancel the project, receiving no additional benefits. Contracting with additional vendors is assumed prohibitive because of project obsolescence. The proposed contractual structure has the client deciding to continue only if the outcome of the pilot is higher than some threshold value \mathbf{b} . The use of a threshold to screen vendors is the important aspect of the pilot project. By “raising the bar”, the client should be able to assure herself that she is choosing the best among the potential vendors. Define $p_q(\mathbf{b})$ as the probability that vendor of type \mathbf{q} achieves outcome of at least \mathbf{b} (i.e., $p_q(\mathbf{b}) \equiv \text{Prob}\{B_{I,\theta} > \mathbf{b} \mid \mathbf{q}\}$). Since $B_{I,\mathbf{q}} \sim U[0,\mathbf{q}]$, $p_q(\mathbf{b}) = 1 - \mathbf{b}/\mathbf{q}$, which is strictly increasing in \mathbf{q} . Raising the threshold value for success in the pilot project reduces the probability that low type vendors will profit from the contract and, therefore, these vendors choose not to participate.

For this contract to work, the client must be credibly committed to cancel projects that fall below this threshold (our model formulation already guarantees that the client will never want to cancel a successful project prematurely). One possible mechanism is based on the client’s reputation in similar contracts. When a client outsources many projects, clients will have a verifiable history of project completion or cancellation. While the reasons for cancellation are not observable, the action of discontinuing a project at the end of the pilot phase is easily observed by outside parties. By evaluating the aggregate percentage of terminated contracts,⁹ vendors can validate that the client is adhering to her cancellation policy. This type of commitment mechanism is common in renegotiations models (see the introduction of Tirole [37] for a discussion of typical remedies for this problem including the one we utilize). Moreover, it does not seem particularly unusual from a practical perspective – a client must only be willing to cancel failed projects even when it is possible that the reason for failure was adverse events rather than vendor misrepresentation. This need for commitment does, however, affect how

⁸ This assumption is sufficient but not necessary. The necessary condition is the vendor knows that w exceeds some minimum bound, such that it is beneficial to complete the second phase of the project.

⁹ For a large number of similar contracts, this probability of failure is equal to the probability that a high type vendor ($\mathbf{q}=\mathbf{q}_H=1$) does not achieve the threshold (Type II error), which is equal to \mathbf{b} , as derived in Theorem 2.

clients manage projects, as discussed in Section VI where we consider practical implementation details of this contract.

IV. B. Screening Potential Vendors

Before analyzing the client's optimal screening policy in the next section the screening mechanism is derived. Assume the client wishes to screen vendors of low quality (type) \mathbf{q}_L , since benefits are increasing in type. The client proposes a contract $\mathbf{G} \equiv \{v_1, \mathbf{b}, v_2\}$ where v_i is the payment by the client for the i^{th} phase and the total payment is $v = v_1 + v_2$. Continuation of the project beyond the pilot phase is conditional upon an outcome of at least \mathbf{b} . The client designs the contract to be attractive only to high quality vendors, and unattractive to low quality vendors (\mathbf{q}_L). A type \mathbf{q} vendor accepts the contract *ex-ante* if his expected income ($E_q[v]$) exceeds his expected costs ($E_q[C]$). Thus: $E_q[v] \geq E_q[C]$, or:

$$v_1 + p_q v_2 \geq C_{1,q} + p_q C_{2,q} \quad (1)$$

To separate the vendor pool into high and low types, the contract must be attractive to high types and unattractive to low types. In identifying the optimal screening policy the Revelation Principal (Myerson [29]) is useful in limiting the analysis to those policies where the client induces vendors to reveal their types. The Revelation Principle assures that other mechanisms, where types are identified through untruthful claims, can be replicated by truth-inducing mechanisms.

The client's optimization problem is to maximize her net expected benefits of the project, subject to the constraint that the most efficient vendor $\mathbf{q}=1$ accepts the contract and vendors of type \mathbf{q}_L do not accept the contract, thus:

$$\begin{aligned} \text{Max}_{\mathbf{b}, v_1, v_2} \quad & E[B | \mathbf{q}=1] - E_{\mathbf{q}=1}[v] = \frac{1}{2} + (1-\mathbf{b})(w-\frac{1}{2}) - [v_1 + (1-\mathbf{b})v_2] \quad (2) \\ \text{st:} \end{aligned}$$

$$v_1 + (1-\mathbf{b})v_2 \geq k_1 + (1-\mathbf{b})k_2 \quad (3) \quad \text{IR1}$$

$$v_1 + (1-\frac{\mathbf{b}}{\mathbf{q}_L})v_2 < k_1 \mathbf{q}_L + (1-\frac{\mathbf{b}}{\mathbf{q}_L})k_2 \mathbf{q}_L \quad (4) \quad \text{IC1}$$

$$\forall \mathbf{q} \quad v_1 < k_1 \mathbf{q} \quad (5) \quad \text{fly-by-night}$$

$$v_2 \leq (w-\frac{1}{2}) \quad (6) \quad \text{IR2}$$

Non-negative payments ($v_1 \geq 0; v_2 \geq 0$).

The client maximizes her net expected benefit (2) subject to participation constraints by proposing contract $G(v_1, \mathbf{b}, v_2)$. Constraint (3) is the Individual Rationality constraint for a vendor of type $q=1$ that assures that it is in his best interest to accept the proposed contract. The Incentive Compatibility constraint (4), for a vendor of type q_L , assures that low quality vendors do not accept the contract, effectively separating the vendor pool. Additional IC constraints (5), one for each vendor type, are the fly-by-night constraints that assure that vendors do not accept the contract solely for profiting from the pilot phase without any intention of completing the project. The final constraint (6) assures vendors that the *client* will want to complete a successful project – the second phase benefits cannot be less than the second phase payment. Without this constraint, efficient vendors would recognize that it is not profitable for the client to complete the project and would therefore require full compensation for their first period cost, eliminating the possibility of screening.

Theorem 1 identifies conditions required for vendor screening to be feasible. When the total value of the project, w , is low, there does not exist a solution to the client's optimization problem in (2) subject to constraints (3)-(6). The trivial solution of setting the threshold higher than the highest possible outcome for inferior vendors (i.e., $\mathbf{b}=q_L$) does not suffice because fly-by-night vendors may compete for the pilot phase knowing that there is no probability of completing the project, thus violating constraints (5). Figure 2 examines the feasibility of screening. When project value is sufficiently high ($w \geq w^m(q_L)$), the client can always offer a contract that is attractive only to desirable vendors, as shown in Regions A and B. With low valued projects ($w < w^m(q_L)$) screening cannot be achieved, as depicted in Region C. After we formalize these observations in Theorem 1, for the remainder of the paper it is assumed that projects have sufficient value so that screening is feasible.

INSERT FIGURE 2 HERE

We first examine the conditions under which screening is feasible and define a lower boundary on project value for screening to be useful (Theorem 1). We then derive the structure of the optimal contract (Theorem 2).

Theorem 1: There exists a contract that is attractive only to vendors of type $q=1$ if

$$w \geq w^m(q_L) \text{ where } w^m(q_L) \equiv k_1 + k_2 + \frac{1}{2}$$

Otherwise screening is not feasible.

Proof: See Appendix for all proofs.

This theorem essentially says that there must be enough additional surplus from using a high quality vendor to enable a screening contract to be used. When vendor screening is possible, Theorem 2 describes the optimal screening mechanism for separating the vendor pool screening into two groups with high quality vendors ($q=1$) accepting the contract and low quality vendors finding it in their best interest to reject the proposed contract.

Theorem 2: Although there exists a set of screening contracts, which are attractive to vendors of type $q=q_H$ and are not attractive to vendors of type $q=q_L$, the optimal contract $G^*(v_1(q_L), b(q_L), v_2(q_L))$ utilizes the maximum payment for the second phase (v_2) and the lowest threshold $b(q_L)$ that assures vendor screening. In addition, the client's expected payment equals the best vendor's expected cost (i.e., $E[v_1 + (1-b)v_2] = E[k_1 + (1-b)k_2]$).

Let the optimal threshold level for screening out the low type vendor when the project has sufficient value be represented by $Y(q_L) \equiv \frac{(1+q_L)(1+k)}{2} - \sqrt{\frac{(1+q_L)^2(1+k)^2}{4} - q_L(1+k)}$

Let the minimum project value for which screening can be accomplished without a payment in the first phase be $w^c(q_L)$, where $w^c(q_L) \equiv \frac{k_1}{1-Y(q_L)} + k_2 + \frac{1}{2}$. (see details in the proof)

The form of the optimal screening contract depends on project value.

- a) When the expected benefit from the entire project is sufficiently high (i.e., $w \geq w^c(q_L)$) the following screening contract is offered (with $k \equiv k_1/k_2$):
- i) The client does not compensate the vendor for the pilot phase ($v_1=0$);
 - ii) Second phase payment is $v_2(q_L) = k_1/(1-b(q_L)) + k_2$
 - iii) $b(q_L) = Y(q_L)$

b) When the expected benefit from the entire project is not sufficiently high (that is, $w \in [w^m(\mathbf{q}_L), w^c(\mathbf{q}_L)]$) the following screening contract is offered:

- i) The client compensates the vendor for the pilot $v_1(\mathbf{q}_L) = k_1 - (1 - \mathbf{b}(\mathbf{q}_L))(v_2 - k_2) > 0$
- ii) Second phase compensation equals the expected value of the second phase $v_2 = (w - 1/2)$
- iii) $\mathbf{b}(\mathbf{q}_L) = (k_1 + k_2)\mathbf{q}_L / (w - 1/2)$

Proof: See Appendix.

Before examining the implications from Theorem 2 Lemma 1 provides motivation for increasing contingent payments (v_2). The Lemma demonstrates that for any screening threshold \mathbf{b} , increasing the contingent portion of the payment and reducing the compensation for the pilot (v_1) also screens vendors. This suggests that the client could not gain by increasing compensation for the pilot phase and lowering the threshold.

Lemma 1: If contract $\mathbf{G}(\mathbf{b}, v_1, v_2)$ satisfies constraints (3)-(6) of the client's optimization problem then contract $\mathbf{G}(\mathbf{b}, v'_1, v'_2)$ with $v_1 + (1 - \mathbf{b})v_2 = v'_1 + (1 - \mathbf{b})v'_2$; $v'_2 > v_2$; that satisfies constraint (6) also satisfies these constraints, and provides vendors \mathbf{q}_L with lower expected payoffs.

Proof: See Appendix.

Theorem 2 identifies the optimal screening contract, when screening is possible. In part (a), where project value is sufficiently high ($w \in [w^c(\mathbf{q}_L), w^m(\mathbf{q}_L)]$), all payment is contingent on project continuation and there is no first period payment at all ($v_1=0$), as seen in Region A of Figure 2. When the project's profitability is low ($w \in [w^m(\mathbf{q}_L), w^c(\mathbf{q}_L)]$), in part (b), not compensating for the pilot phase requires that the contingent payment be no greater than the client's expected value from the second phase, knowing that only high type vendors ($\mathbf{q}=1$) accept the contract. In such instances the client sets the contingent payment equal to the expected value of the second phase, and provides some compensation for the pilot phase as seen in Region B of Figure 2. Finally, Theorem 2 states that the optimal contract provides the vendor with zero surplus *ex-ante* in

expectation, although there will typically be some surplus earned in the second period to compensate for first period investment and risk of premature cancellation.

IV. C. Illustration

It is useful to use a specific example to explain the results of Theorems 1 and 2. As an example we choose the low type vendor to be of quality level $q_L=0.4$ and maintain the quality of the high type vendor at $q=1$. The cost structure is assumed to be $k_1=1$ and $k_2=2$, as in Figure 2. For these parameter values screening is feasible when the project value, as measured by the benefit from full implementation (w), is greater than 3.5.

As shown in Figure 2 there is a range (Region B) where the client can offer a screening contract, but still has to pay the vendor in the first phase. From part (b) of Theorem 2 this occurs when the project value lies between 3.50 and 4.02, approximately. For any given project value in this region the threshold and compensation can be calculated from Theorem 2. If, for example, the project's value is $w=3.70$, the threshold is set to $b(q_L)=0.375$; payment for the first phase is $v_1=0.219$ and second phase compensation is set at $v_2=3.20$.

For a project with greater client benefits the client can offer a screening contract without any payment for the first phase (Region A in Figure 2). Part (a) of Theorem 2 provides the optimal solution for this case. If, for example, the project's value is $w=5$ the threshold is set to $b(q_L)=0.341$; and second phase compensation is $v_2=3.52$.

Under either set of contractual parameters both a high quality and low quality vendor have a positive probability of success in the pilot phase, but only a high quality vendor would accept the contract. The contract covers the high quality vendor's expected cost, with a low quality vendor realizing a loss, in expectation.

IV. D. Properties of Screening Contracts

The screening contract derived herein has a number of desirable properties. Corollary 1 derives some of the more interesting implications from the optimal screening contract in Theorem 2, including the comparative statics of this contract.

Corollary 1: The optimal contract has the following properties:

- a) The optimal threshold is lower than the trivial threshold: $b(q_L) < q_L$
- b) The optimal threshold is increasing in the low type's capabilities: $b'(q_L) > 0$
- c) Second phase compensation is increasing in the low type's capabilities: $v_2'(q_L) \geq 0$

Proof: See Appendix.

The first part of Corollary 1 (a) simply shows that the trivial screen -- setting the threshold above what a low type could ever achieve -- is never optimal. This is because higher thresholds will sometimes cause projects to be cancelled even when the high quality vendor undertakes it. Result (b) shows that intuitive property that the screening threshold increases in the quality of the low type vendor (q_L). This result is depicted in Figure 3 where vendor profitability is graphed as a function of the threshold level. As the threshold level increases, expected profit for lower quality vendors becomes negative if they opt to compete for the project.

INSERT FIGURE 3 HERE

Finally, the last result in Corollary 1 (c) suggests that improvements in the quality of the low type vendor require increasing contingent compensation to screen vendors. This is because as the quality of the low type increases, the threshold must also increase (Corollary 1, result b), and therefore compensation for the second part of the project must be increased to ensure the high quality vendor sufficient profits to break even (offsetting a higher chance of accidental termination).

V. Optimal Screening of Vendors

The results of Section IV indicate when and how the client selects among potential vendors. However, with aggressive screens, the client is more likely to set a threshold that prematurely terminates a contract with a high quality vendor. As such, the optimal decision for the client trades the value of selecting the best vendor (avoiding Type I error) against the chance of wrongly terminating the project (avoiding Type II error).

The client's decision reduces to a choice of whether to screen out the low quality vendors using the optimal screening contract or not to screen vendors and choose randomly.¹⁰ If the client decides to screen vendors, then the expected profit includes the client's net benefit in the pilot phase and the net profit in the second phase, conditional on success in the pilot phase. This profit is given by:

$$P_s(q_L, q, w) = \frac{1}{2} - v_1(q_L) + [1 - b(q_L)][w - \frac{1}{2} - v_2(q_L)]$$

If the client decides not to screen vendors her gross expected payoff is given by the payoff from each type of vendor, multiplied by the frequency of the vendor type. The client sets the payment to $k_1 + k_2$, assuring that the high quality vendor agrees to the contract (otherwise, she effectively screens out the high type vendors). Therefore, the client's net profit when she does not screen vendors is given by:

$$P_n(q_L, q, w) = (1 - q)w + qwq_L - (k_1 + k_2)$$

We can now identify that client's value from screening as: $S(q_L, q, w) = P_s(q_L, q, w) - P_n(q_L, q, w)$. When S is positive, the client prefers to screen vendors. Using the results of Theorem 2, we can identify the comparative statics of the screening value, denoting partial derivatives by subscripts.

Theorem 3: Each of the following can be demonstrated:

- a) The value of screening increases with the frequency of the low type vendor ($S_q > 0$)
- b) As the quality of the low type vendor increases, screening value decreases ($S_{q_L} < 0$)
- c) Screening value decreases with project value if and only if the frequency of low type vendors is sufficiently low (i.e., $S_w < 0$ iff $q < q^c$).

Proof: See Appendix.

Theorem 3 identifies how key variables affect the value of screening. Intuitively, as the dispersion in vendor quality increases, the client should be more willing to screen vendors. The first two results in the theorem correspond to two sources of dispersion: the probability of drawing a low type vendor and the benefit derived from low type vendors. As either the frequency of inefficient vendors increases or the benefit provided by them decreases, overall

¹⁰ Even if the client proposes a bidding mechanism to discern between vendors who accept the contract, vendor misrepresentation inhibits identifying efficient vendors and the client will *de-facto* choose randomly among them.

dispersion increases and random contracting raises the impact of Type I error (contracting with the low quality vendor), encouraging clients to screen.

The first result is pictured in Figure 4 for $q_L=0.4$. For any project value, the client's value from screening out a vendor of type q_L increases with the frequency of that vendor in the pool. The profitability of screening vendors depends on whether the value of screening is greater than the expected loss from increasing the threshold, due to the high quality vendor providing poor results in the pilot phase and the client canceling the project. For example, if the project has relatively low value (with $w=5$) screening vendors is in the client's best interest only if the frequency of low quality vendors is above $q=0.284$. As project value increases screening becomes less attractive because of the probability of canceling a project with a high quality vendor. As an example when the project's benefits are higher with $w=12$, screening is beneficial only when the frequency of low quality vendors is greater than $q=0.45$.

INSERT FIGURE 4 HERE

As Figure 5 shows, the impact of changes in the project's value (the last part of Theorem 3) is less obvious. More profitable projects increase the value of vendor screening by raising the cost of contracting with vendors of low type. However, the cost of wrongful termination, associated with increasing the threshold, is also higher for these projects. Our results capture the client's tradeoff between these costs. If the frequency of low quality vendors is sufficiently small, screening has little value and the value of screening decreases with project value. When the probability of choosing a low quality vendor is high, the opposite results hold and vendor screening becomes more valuable with project value.

INSERT FIGURE 5 HERE

VI. Discussion

In this paper we address the problem of vendor selection under uncertainty in vendor quality and an inability to fully contract on the outcome of an outsourcing project. We demonstrate the existence of a separating contract that allows clients to distinguish between high and low quality vendors, even when performance is non-verifiable. The fundamental tradeoff of this contracting

approach is to balance the gains from selecting efficient vendors against the losses incurred when a high quality vendor fails to achieve the threshold required in the pilot project (due to random variation). This implies that the threshold for continuing to the second phase is set low by the client, to increase the probability that the best vendor completes the project.¹¹ In addition, it is not always in the client's interest to screen potential vendors – the costs imposed by premature termination may outweigh the gains from vendor selection, especially when the vendors have little quality variation. Finally, this contract does not achieve first best, as there is a social cost of $p_q(\mathbf{b})[w^{-1/2}-k_I]$ from premature vendor termination. This can be viewed as the cost of uncertainty in vendor quality or the cost of non-verifiability of outcome. Nonetheless, when screening is viable, it can create significant improvements in vendor selection

VI. A. Alternative Screening Mechanisms

The model we propose emphasizes a two-phase contractual relationship as a mechanism to implement vendor selection when output is non-verifiable. However, there are alternative screening mechanisms that are commonly used in practice to evaluate vendor ability. It is useful to consider their efficacy relative to the efficacy of pilot projects.

First “deep pockets” are often an important criterion when selecting vendors. The reasoning behind choosing financially secure partners is that the vendor has the ability compensate the client if he cannot correct deficiencies in service. While choosing financially strong vendors is intuitively appealing, it has the same difficulty as other incentive based contracts - outcomes must be observable and verifiable by third parties (usually courts). When output is difficult to measure, as often occurs in IT contracts, resorting to legal venues to gain restitution for inferior service is difficult.

A second factor that is often used in vendor selection is reputation. The rationale for choosing vendors that have reputations for providing high quality service is that clients believe that as an intangible asset, vendors should have an interest in maintaining their reputations. With long-lived and patient vendors, the value of reputation in future relationships should be more important than the short-term advantages of accepting contracts that they cannot successfully

¹¹ This is an interesting empirical implication. We should find clients setting thresholds that are frequently satisfied by pilot phases. This is the rational outcome of the client's optimization. She is interested in setting a

complete (Kreps [20]). Thus, a reputation-based market enforces a match between projects and vendors.

There are two critical limitations to selecting vendors based on their reputation. First, the reputation mechanism rests on the relationship between short-term and long-term profits. When the short-term payoff from providing low quality service exceeds the value of maintaining an untarnished reputation (at least for some vendors), reputation no longer guarantees against opportunistic behavior.

A second requirement is the credibility of available information regarding past performance by vendors. To collect such information a mechanism must exist for recording vendor behavior (Croson [7]). As the credibility of information regarding past performance deteriorates, reputation becomes more difficult to ascertain from available data (Kreps [20]). Vendors who believe that their reputation will not be tarnished by low performance may periodically accept contracts knowing that they will provide inferior service. The IT industry currently has no efficient means for the transfer of vendor reputations. Word of mouth and limited publication in the popular press are the only means of following vendors' reputations. Lacity and Hirschheim [21] argue that few companies publicly air their IT failures, and information regarding failed outsourced projects is not readily available. Without consistent and credible information concerning the fate of a significant number of outsourced projects, reputation cannot be used effectively to manage the vendor selection problem.

Finally, in certain instances, clients find that they have the ability to identify verifiable measures for a subset of the project's important outcomes. In these cases, clients may opt to sign a performance-based contract that provides incentives only for those outcomes that are verifiable, without compensating non-verifiable benefits. This strategy is effective in screening vendors when either the verifiable outcomes are of critical importance to the client, or when vendors with competencies in verifiable outcomes will also deliver high quality on non-verifiable dimensions. However, when non-verifiable performance dimensions are important and require a different set of competencies, clients who provide incentives for a subset of important attributes may screen out the wrong vendors (Holmstrom and Milgrom [18]). Using our proposed two-

threshold that is easily achieved by the contracting vendor, while vendors that opt not to contract could not achieve the threshold.

stage contract, clients can set the completion threshold based on their aggregate utility over all observable outcomes, better aligning vendor interests with their own, and filling in the gaps that would otherwise exist if they used performance-based incentive contracts in isolation.

VI.B. Limits to Vendor Screening

The assumptions of the analytical model point to a number of limitations to the ability to screen vendors using pilot projects. First, screening is not always feasible. If the overall gains from trade are low, the client has to offer a significant first-period payment to induce efficient vendors to participate. If these payments are too high, inefficient vendors may agree to the contract, profiting from the pilot phase and quitting the project after the pilot phase. Laffont and Tirole [23] label this as “take-the-money and run”. Second, it may not be in the client’s best interest to screen vendors because it leads to canceling projects with efficient vendors (see Section V). Third, it requires that both the client and vendor are can commit to the terms of the contract – clients must be willing to cancel failed projects and able to demonstrate that fact to the market – otherwise, the screening threshold (**b**) is not a credible requirement. Finally, the client must be able to design the pilot so that low quality vendors cannot profitably mimic high quality vendors through extraordinary effort in the pilot phase (this is the problem of “pooling” in combined adverse selection and moral hazard models – see Tirole [37] and Laffont and Tirole [23]).

VI. B. Implementation Details

These limitations of vendor screening can be reduced and sometimes avoided entirely by careful design of the pilot project. If vendors can improve pilot outcomes by additional effort or investment, a properly designed pilot must either: 1) make it prohibitively expensive for low quality vendors to mimic high quality vendors, 2) facilitate monitoring to observe enable effort and quality effects on performance to be separated, or 3) commit the vendor to the same levels of effort in full implementation as in the pilot. The first condition may be met as a natural consequence of software projects – productivity of vendors can vary considerably and thus it is possible that the low quality vendors are so unproductive that the necessary investment to mimic high quality would be too high. A difficult pilot may be sufficient to achieve this separation. The second and third conditions can be met by designing the pilot to facilitate monitoring. For instance, the client can audit time cards; identify specific personnel used on the project; or work

collaboratively with the vendor to gain an in-depth understanding of their work practices and competencies. It is not critical that much of the information gathered through this inspection is non-verifiable. The only requirement is that client can reach a reasonable conclusion about how much of the pilot outcome is due to vendor quality and how much is due to one-time effort. In some cases work practices of the pilot are verifiable (e.g., the names of the project manager and members of the development team, the identity of subcontractors, the languages, development tools and project management systems) and could be included as a part of the second period contract.

Another facet of the pilot project is that the client must be able and willing to exercise the option to terminate. In particular, the client should limit her relationship specific investment to eliminate potential lock-in. A pilot where the client either has no ability to make an informed decision or where the decision is already a foregone conclusion due to relationship specific investment is of limited value in screening vendors. Similarly, a client who has a reputation of retaining vendors after project failures will significantly undermine her ability to use pilots in the future as a basis for selecting vendors and evaluating capabilities.

Where pilots violate these design guidelines, they represent, at best, lost opportunities, and at worse can provide a false sense of security that increases project risk. For instance, a pilot project by Stasis Bank (a pseudonym) was constructed in a way that the vendor successfully constructed a mockup that the client believed was an operational system (Clemons [5]). The vendor also invested extraordinary talent and effort during the pilot phase to mislead the client about their capabilities and made a variety of misleading representations that were difficult to verify. While the subsequent failure of the full implementation due to the inability to complete the system that was purportedly demonstrated in the pilot ultimately led to a lawsuit and a substantial out-of-court financial settlement, these outcomes may have been avoidable. If the client had been more involved during the pilot phase, developed a greater understanding of the system produced in the pilot, and better understood the work practices of the vendor, they may have terminated the project. Had they taken the lead in defining the pilot, rather than the vendor, they may have been able to better discern vendor capability and thus used the pilot for effective screening. More important, had the client forced the vendor to commit to use the same resources and staff in the pilot and the full implementation, and made it clear that they would aggressively and actively monitor the progress of the pilot, the chosen vendor may have avoided

misrepresentation entirely and tendered a more realistic bid. Finally, the client might have avoided a significant relationship specific investment in hardware until the pilot phase was truly completed and the client could adequately assess vendor quality. The inability to recover this investment (sunk as it may have been) substantially influenced the client's decision to continue, even when negative information about the prospects of the project and the capabilities of the vendor became apparent.

VI. D. Future Research

Our emphasis in this paper has been to demonstrate the applicability of two-stage contracts for screening vendors in IT contracts. The paper does include some distributional assumptions that drive many of the algebraic expressions we derive, but these should have little impact on the qualitative predictions. Similarly, while our proofs focus on the case when firms take no hidden actions in the second period, they are fully general to most types of second period incentive contracting methods when "high type" clients in our screen also have the highest payments under their incentive contracts. More work is certainly worthwhile in understanding the types of dynamic incentive contracts that are most applicable to IT outsourcing.

Whenever an incentive contract is based on information collected after contracting, there are issues of renegotiation (such as the ratchet effect) that might limit the use of any form of incentive contracting or create new opportunities for gains for trade. In particular, to the extent that screening is important and vendors can take hidden actions during the pilot phase, it is an open question as to whether better mechanisms exist to avoid pooling problems that prevent screening.

Furthermore, our assumption of risk neutrality eliminates considerations of risk bearing which are also important in IT contracting. When either clients or vendors are risk averse, the viability of screening is reduced. Introducing vendor risk aversion when all vendors exhibit identical behavior would not affect the results qualitatively, but would require compensation for the uncertainty of a two-stage contract, leading to an increase in expected cost to the client. This becomes more complex if we consider multiple risks (project risk, software development risks) where different parties may have different capabilities in managing and bearing these risks, and where risk aversion may be correlated with other vendor characteristics such as quality. For instance, if vendor quality is correlated with risk aversion, it may enable low quality vendors to

mimic high quality vendors, limiting the use of screening. It is likely that a more detailed examination of risk bearing (especially for different types of risk) would enhance research on IT contracting in general.

VII. Conclusion

With the recent growth of IT outsourcing clients and vendors are recognizing that contracting for these services is often difficult. Often these difficulties have led clients to avoid potentially beneficial contracting opportunities with outside parties. In other instances where outsourcing is a necessity (such as Internet development and hosting services), firms are forced to bear substantial risks of contracting with the wrong vendor. These difficulties arise because of the dual problem of uncertainty in vendor quality coupled with the inability to write complete, verifiable contracts for the outcome of projects to provide IT-related services. Most existing contractual approaches can deal with each of these problems separately, but are unable to address them simultaneously, making insourcing the only viable alternative.

In circumstances where projects can be or already are divided into a pilot phase and an implementation phase and where the pilot is informative as to the quality of the full implementation, we show that a two-stage contracting procedure can improve a client's ability to contract with a high quality vendor. In some cases the losses imposed by this contract from accidental project termination outweigh the gains. Where feasible, however, this contract matches, and in many cases outperforms other common vendor selection approaches. The conditions under which this contract can improve performance are becoming increasingly common as firms choose to outsource more complex projects with shorter technological and business lifecycles to an ever-expanding pool of vendors. Moreover, as firms choose to undertake pilot projects for other reasons, such as to reduce software development risk, our contractual structure enables these firms to get the added benefit of improving performance in vendor selection at little incremental cost.

References:

1. G. A. Akerlof, "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism," *The Quarterly Journal of Economics*, vol. 84, no. 3, Aug. 1970, pp. 488-500.
2. P. Bartram, "It's Still a Risky Business," *Financial Director*, Mar. 12, 1999, pp. 47.
3. J. Brooks Jr., "No Silver Bullet: Essence and Accidents in Software Engineering," *IEEE Computer*, Apr. 1987, pp.10-19.
4. A. N. Chaudhury, K. Nam and H. R. Rao, "Management of Information Systems Outsourcing: A Bidding Perspective," *Journal of Management Information Systems*, vol. 12, no. 2, Fall 1995, pp. 131-159.
5. E. K. Clemons "Stasis Bank," *Unpublished Teaching Case, Wharton School, University of Pennsylvania*, 2000.
6. E. K. Clemons and P. R. Kleindorfer, "An Economic Analysis of Interorganizational Information Technology," *Decision Support Systems*, vol. 8, no. 5, Sep. 1992, pp. 431-446.
7. D. C. Croson, "A New Role for Middlemen: Centralized Reputation in Repeated Exchange," *Working Paper, Harvard University*, Apr. 1994.
8. A. DiRomualdo and V. Gurbaxani, "Strategic Intent for IT Outsourcing," *Sloan Management Review*, vol. 39, no. 4, Summer 1998, pp. 67-80.
9. S. J. Grossman and O. D. Hart, "An Analysis of the Principal-Agent Problem," *Econometrica*, vol. 51, no. 1., Jan. 1983, pp. 7-46.
10. S. J. Grossman and O. D. Hart, "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *The Journal of Political Economy*, vol. 94, no. 4, Aug. 1986, pp. 691-719.
11. V. Grover, M. J. Cheon, and J. T. C. Teng, "The Effect of Service Quality and Partnership on the Outsourcing of Information Systems Functions," *Journal of Management Information Systems*, vol. 12, no. 4, Spring 1996, pp. 89 - 116.
12. V. Gurbaxani and S. Whang, "The Impact of Information Systems on Organizations and Markets," *Communications of the ACM*, vol. 34, no. 1, Jan. 1991, pp. 59-73.
13. P. H. Harris, "Leveraging the Outsourcing Advantage" *White Paper, The Yankee Group*, 1995.
14. O. D. Hart and B. Holmstrom, "The Theory of Contracts," *Advances in Economic Theory: Fifth World Congress, Econometric Society Monographs Series no. 12*, T. F. Bewley, ed., Cambridge University Press, Cambridge, New York and Melbourne 1987 pp. 71-155.
15. O. D. Hart and J. Moore, "Incomplete Contracts and Renegotiation," *Econometrica*, vol. 56, no. 4, July 1988, pp. 755-85.
16. O.D. Hart and J. Moore, "Foundations of Incomplete Contracts," *The Review of Economic Studies*, vol. 66, no. 1, Jan. 1999, pp. 115-38.
17. R. Hirschheim and M. C. Lacity, "The Myths and Realities of Information Technology Insourcing," *Communications of the ACM*, vol. 43, no. 2, Feb. 2000, pp. 99-107.
18. B. Holmstrom and P. Milgrom "Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design," *Journal of Law Economics & Organization*, vol. 7, no. 0, Special Issue 1991, pp 24-52.
19. J. King, "New Age IT Must Manage Outside Help," *Computerworld* vol. 32, no. 43, Oct. 26, 1998, pp. 1,10.
20. D. M. Kreps, "Corporate Culture and Economic Theory," *Firms, Organizations and Contracts: A Reader in Industrial Organization*, P. J. Buckley and J. Michie, eds., *Oxford Management Readers*, Oxford University Press, Oxford and New York, pp. 221-75.
21. M. C. Lacity and R. Hirschheim, *Information Systems Outsourcing: Myths, Metaphors, and Realities*, Wiley, Chichester, 1993.

22. M. C. Lacity, L. P. Willcocks and D. F. Feeny, "The Value Of Selective IT Sourcing," *Sloan Management Review*, vol. 37, no. 3, Spring, 1996, pp. 13-25.
23. J. J. Laffont and J. Tirole, *A Theory of Incentives in Regulation & Procurement*, MIT Press, Cambridge, Mass., 1993.
24. J. N. Lee and Y. G. Kim, "Effect of Partnership Quality on IS Outsourcing Success: Conceptual Framework and Empirical Validation," *Journal of Management Information Systems*, vol. 15, no. 4, Spring 1999, pp. 29-62.
25. R. P. McAfee and J. McMillan, "Bidding for Contracts: A Principal-Agent Analysis," *Rand Journal of Economics*, vol. 17, no. 3, Autumn 1986, pp. 326-338.
26. R. P. McAfee and J. McMillan, "Competition for Agency Contracts," *Rand Journal of Economics*, vol. 18, no. 2, Summer 1987, pp. 296-307.
27. S. McConnell, *Rapid Development: Taming Wild Software Schedules* Microsoft Press, Redmond, Wa., 1996.
28. J. Moad, "Contracting with Integrators, Using Outside Information System Integrators on an Information Systems Project," *Datamation*, vol. 35, no. 10, May 15 1989, pp. 18.
29. R. B. Myerson, "Incentive Compatibility and the Bargaining Problem," *Econometrica*, vol. 47, no. 1, Jan. 1979, pp. 61-73.
30. W. B. Richmond, A. Seidmann, and A. B. Whinston, "Incomplete Contracting Issues in Information Systems Development Outsourcing," *Decision Support Systems*, vol. 8, no. 5, Sep. 1992, pp. 459-477.
31. W. P. Rogerson, "Incentive Models of the Defense Procurement Process," *Handbook of Defense Economics. Volume 1, Handbooks in Economics vol. 12*, K. Hartley and T. Sandler, eds., Elsevier Science, Amsterdam, New York and Oxford, pp. 309-46.
32. J. Rothfeder, "It's Late, Costly, Incompetent -- But Try Firing a Computer System," *Information Processing*, no. 3078, Nov. 7 1988, pp. 164.
33. C. Saunders, M. Gebelt, and Q. Hu, "Achieving Success in Information Systems Outsourcing," *California Management Review*, vol. 39, no. 2, Winter 1997, pp.63-79.
34. J. J. Sviokla and J. J. Elam, *Image Processing Project at USAA*, Case 9-190-155 Harvard Business School, Cambridge Mass., 1992.
35. M. Spence, *Market Signaling: Informational Transfer in Hiring and Related Screening Processes* Harvard University Press, Cambridge, Mass., 1974.
36. C. Stedman, "Outsourcing Won't Always Pay Off With Huge Savings," *Computerworld*, vol. 34, no. 6, Feb. 7 2000, pp.12.
37. J. Tirole, "Procurement and Renegotiation," *The Journal of Political Economy*, vol. 94, no. 2, Apr. 1986, pp. 235-259.
38. B. Violino and B. Caldwell, "Analyzing The Integrators -- Systems Integration and Outsourcing is a \$300 Billion Business, But are Customers Really Getting Their Money's Worth? Here's What IT Managers Really Think About Their Hired Guns," *Informationweek*, vol. 709, Nov. 16 1998, pp. 45-113.
39. S. Whang, "Contracting for Software Development," *Management Science*, vol. 38, no. 3, Mar. 1992, pp. 307-324.

Appendix: Proofs

Proof of Theorem 1:

See proof of Theorem 2 for the required conditions and construction of the screen.

Proof of Lemma 1:

Under both contracts vendor $q=1$ is compensated according to his expected cost, thus, it is sufficient to show that the proposed contract $G(v'_1, \mathbf{b}, v'_2)$ provides vendor q_L with lower expected payoffs than $G(v_1, \mathbf{b}, v_2)$, and satisfies the fly-by-night constraints (5). Constraints (5) are satisfied trivially, because $v'_1 < v_1$. Thus, it is sufficient to show that:

$$v'_1 + (1 - \mathbf{b}/q_L)v'_2 < v_1 + (1 - \mathbf{b}/q_L)v_2$$

substituting v'_1 yields:

$$v_1 + (1 - \mathbf{b})v_2 - (1 - \mathbf{b})v'_2 + (1 - \mathbf{b}/q_L)v'_2 < v_1 + (1 - \mathbf{b}/q_L)v_2 \Leftrightarrow$$

$$(1 - \mathbf{b})v_2 - (1 - \mathbf{b})v'_2 + (1 - \mathbf{b}/q_L)v'_2 < (1 - \mathbf{b}/q_L)v_2 \Leftrightarrow$$

$$(1 - \mathbf{b}/q_L)[v'_2 - v_2] < (1 - \mathbf{b})[v'_2 - v_2]$$

which holds trivially $q_L < 1$.

QED

Proof of Theorem 2:

Lemma 2 shows that by increasing the part of the payment that is contingent upon successful completion of the pilot the client can increase the contract's ability to screen vendors, while reducing expected cost. Thus, to identify a contract that screens vendors, it is sufficient to concentrate on those contracts that maximize the contingent payment. In any screening contract the client always offers the best vendor a contract that equals his expected costs. From (3) and (6) we get: $v_2 = \min\{(1 - \mathbf{b})^{-1}k_1 + k_2, (w - 1/2)\}$ and $v_1 = k_1 - (1 - \mathbf{b})(v_2 - k_2)$. Throughout the proof it is assumed that $\mathbf{b} \leq q_L$, which is verified in Corollary 1.

Case 1

The client prefers to make all payment contingent upon success in the pilot phase ($v_1=0$). For this to hold constraint (6) must be met $v_2 < (w-1/2)$, requiring: $(1-\mathbf{b})^{-1}k_1 + k_2 \leq (w-1/2)$ or¹²:

$$\mathbf{b} \leq 1 - k_1 / [(w-1/2) - k_2] \tag{A.1}$$

For such a threshold to screen vendor of type $\mathbf{q} \leq \mathbf{q}_L$ constraint (4) must hold for type \mathbf{q}_L . Thus:

$$v_1 + (1-\mathbf{b}/\mathbf{q}_L)v_2 < k_1\mathbf{q}_L + (1-\mathbf{b}/\mathbf{q}_L)k_2\mathbf{q}_L$$

Since $v_1=0$ and $v_2=(1-\mathbf{b})^{-1}k_1 + k_2$ this requires that:

$$k_1/(1-\mathbf{b}) + k_2 < k_1\mathbf{q}_L/(1-\mathbf{b}/\mathbf{q}_L) + k_2\mathbf{q}_L$$

It can be shown that the lowest threshold this allows is¹³:

$$\mathbf{b}(\mathbf{q}_L) = \frac{(1+\mathbf{q}_L)(1+k)}{2} - \sqrt{\frac{(1+\mathbf{q}_L)^2(1+k)^2}{4} - \mathbf{q}_L(1+k)} = Y(\mathbf{q}_L) \tag{A.2}$$

For a solution to exist for both (A.1) and (A.2) the following condition must hold:

$$1 - \frac{k_1}{(w-1/2)-k_2} \geq Y(\mathbf{q}_L)$$

which requires that $w \geq w^c(\mathbf{q}_L)$, where

$$w^c(\mathbf{q}_L) \equiv \frac{k_1}{1-Y(\mathbf{q}_L)} + k_2 + 1/2$$

When w is sufficiently large, expression (A.2) defines $\mathbf{b}(\mathbf{q}_L)$.

¹² There is no guarantee that constrain (A.1) holds for any $\mathbf{b} > 0$. For certain values of $w, \mathbf{q}_L, k_1, k_2$ the result may require $\mathbf{b} < 0$ and the client cannot make all compensation contingent.

¹³ The function that defines $\mathbf{b}(\mathbf{q})$ has two roots. The smaller root is chosen because it is sufficient to assure screening. It is important to note that the larger root is always greater than \mathbf{q} , the trivial threshold. This can be seen by setting $k=0$ and verifying that the root is equal to 1, while its derivative w.r.t. k is increasing, for all non-negative k .

Case 2

When the expected marginal value of the project is not sufficiently high $w < w^c(\mathbf{q}_L)$ the client can not make all payment contingent upon success in the pilot phase, and the contingent compensation is bounded by the expected value of the second phase by (6) $v_2=(w-1/2)$, so $v_1(\mathbf{q}_L)$ is set to satisfy the IR1 constraint (3): $v_1(\mathbf{q}_L) = k_1 - (1-\mathbf{b}(\mathbf{q}_L))(v_2 - k_2)$. To assure that vendor of type \mathbf{q}_L finds the contract unattractive the threshold $\mathbf{b}(\mathbf{q}_L)$ is set so that:

$$v_1 + (1-\mathbf{b}(\mathbf{q}_L)/\mathbf{q}_L)v_2 < k_1\mathbf{q}_L + (1-\mathbf{b}(\mathbf{q}_L)/\mathbf{q}_L)k_2\mathbf{q}_L$$

Since $v_1 = k_1 - (1-\mathbf{b}(\mathbf{q}_L))(v_2 - k_2)$ and $v_2=(w-1/2)$ this requires that:

$$k_1 - (1-\mathbf{b}(\mathbf{q}_L))(v_2 - k_2) + (1-\mathbf{b}(\mathbf{q}_L)/\mathbf{q}_L)(w-1/2) \leq k_1\mathbf{q}_L + (1-\mathbf{b}(\mathbf{q}_L)/\mathbf{q}_L)k_2\mathbf{q}_L$$

It can be shown that the lowest threshold this allows is:

$$\mathbf{b}(\mathbf{q}_L) = (k_1 + k_2)\mathbf{q}_L / [(w - 1/2)]$$

This threshold is less than the trivial threshold of $\mathbf{b}(\mathbf{q}_L) = \mathbf{q}_L$ iff $(k_1 + k_2) \leq (w - 1/2)$.

Rearranging yields the lowest project value that permits vendor screening:

$$w^m(\mathbf{q}_L) \equiv k_1 + k_2 + 1/2$$

When $w \in [w^m(\mathbf{q}_L), w^c(\mathbf{q}_L)]$ and $\mathbf{b}(\mathbf{q}_L) = (k_1 + k_2)\mathbf{q}_L / [(w - 1/2)]$ it has to be demonstrated that the fly-by-night constraints (5) holds for all vendors, including the low type vendor $\mathbf{q}=\mathbf{q}_L$. Thus it is required that:

$$v_1(\mathbf{q}_L) < k_1\mathbf{q}_L \quad \Leftrightarrow$$

$$k_1 - (1-\mathbf{b}(\mathbf{q}_L))(v_2 - k_2) < k_1\mathbf{q}_L \quad \Leftrightarrow$$

$$k_1 - [1 - (k_1 + k_2)\mathbf{q}_L / (w - 1/2)](w - 1/2 - k_2) < k_1\mathbf{q}_L \quad \Leftrightarrow$$

$$k_1 + k_2 - (w - 1/2) + [(k_1 + k_2)\mathbf{q}_L(w - 1/2 - k_2)] / (w - 1/2) < k_1\mathbf{q}_L \quad \Leftrightarrow$$

$$k_1 + k_2 - (w - 1/2) + (k_1 + k_2)\mathbf{q}_L[1 - k_2 / (w - 1/2)] < k_1\mathbf{q}_L \quad \Leftrightarrow$$

$$k_1 + k_2 - (w - 1/2) - k_1k_2\mathbf{q}_L / (w - 1/2) + k_2\mathbf{q}_L[1 - k_2 / (w - 1/2)] < 0 \quad \Leftrightarrow$$

$$k_2\mathbf{q}_L[-k_1 + (w - 1/2) - k_2] / (w - 1/2) < (w - 1/2) - (k_1 + k_2) \quad \Leftrightarrow$$

$$k_2\mathbf{q}_L < (w - 1/2)$$

which holds $\forall \mathbf{q} < 1$ since $k_2 < (w - 1/2)$ by assumption.

Proof that $v_1(\mathbf{q}_L) = k_1 - (1 - \mathbf{b}(\mathbf{q}_L))(v_2 - k_2) > 0$ for $w < w^c(\mathbf{q}_L)$:

$$\begin{aligned} v_1(\mathbf{q}_L) &= k_1 - v_2 + k_2 + (k_1 + k_2)\mathbf{q}_L - \mathbf{b}(\mathbf{q}_L)k_2 \\ &= (k_1 + k_2)(1 + \mathbf{q}_L) - (w - \frac{1}{2}) - \mathbf{b}(\mathbf{q}_L)k_2 \end{aligned}$$

At $w = w^c(\mathbf{q}_L)$

$$v_2(\mathbf{q}_L) = (w - \frac{1}{2}) = k_1 / [1 - \mathbf{b}(\mathbf{q}_L)] + k_2 \quad \Rightarrow$$

$$v_1(\mathbf{q}_L) = k_1 - (1 - \mathbf{b}(\mathbf{q}_L))(k_1 / [1 - \mathbf{b}(\mathbf{q}_L)]) = 0$$

For $w \neq w^c(\mathbf{q}_L)$

$$\frac{\partial v_1}{\partial w} = \frac{(k_1 + k_2)\mathbf{q}_L k_2}{[(w - \frac{1}{2})]^2} - 1 < 0$$

because $w \geq w^m(\mathbf{q}_L)$

Case 3: $w < w^m(\mathbf{q}_L)$

If $(k_1 + k_2) > (w - \frac{1}{2})$ the only feasible threshold is $\mathbf{b}(\mathbf{q}_L) = \mathbf{q}_L$. However setting $\mathbf{b}(\mathbf{q}_L) = \mathbf{q}_L$ leads to $v_1 \geq k_1 > k_1 \mathbf{q}_L$, so constraints (5) cannot be satisfied.

In this case (since $v_2 \leq (w - \frac{1}{2})$):

$$\begin{aligned} v_1(\mathbf{q}_L) &= k_1 - (1 - \mathbf{b}(\mathbf{q}_L))(v_2 - k_2) = k_1 - (1 - \mathbf{q}_L)(v_2 - k_2) = \\ &= k_1 + (1 - \mathbf{q}_L)(k_2 - v_2) > k_1 + (1 - \mathbf{q}_L)k_1 > (2 - \mathbf{q}_L)k_1 > k_1. \end{aligned}$$

QED

Proof of Corollary 1:

(i) $\mathbf{b}(\mathbf{q}_L) < \mathbf{q}_L$ is shown for the two cases of:

Case 1: $w \in [w^m(\mathbf{q}_L), w^c(\mathbf{q}_L)]$. In this case $\mathbf{b}(\mathbf{q}_L) < \mathbf{q}_L$ is immediate since $\mathbf{b}(\mathbf{q}_L) = (k_1 + k_2)\mathbf{q}_L / [(w - \frac{1}{2})]$ and $(k_1 + k_2) < (w - \frac{1}{2})$ by the assumption that $w > w^m(\mathbf{q}_L)$.

Case 2: $w \geq w^c(\mathbf{q}_L)$

Proof for Case 2: $w \geq w^c(q_L)$

$b(q_L) < q_L$ requires that:

$$\frac{(1+q_L)(1+k)}{2} - \sqrt{\frac{(1+k)}{4} [(1-q_L)^2 + k(1+q_L)^2]} < q_L \Leftrightarrow$$

$$(1+q_L)(1+k) - 2q_L < 2 \sqrt{\frac{(1+k)}{4} [(1-q_L)^2 + k(1+q_L)^2]} \Leftrightarrow$$

$$(1-q_L) + k(1+q_L) < \sqrt{(1+k) [(1-q_L)^2 + k(1+q_L)^2]} \Leftrightarrow$$

$$(1-q_L)^2 + k^2(1+q_L)^2 + 2k(1-q_L)(1+q_L) < (1+k) [(1-q_L)^2 + k(1+q_L)^2] \Leftrightarrow$$

$$2k(1-q_L)(1+q_L) < k(1-q_L)^2 + k(1+q_L)^2 \Leftrightarrow$$

$$2k(1-q_L^2) < 2k(1+q_L^2) \quad \text{which holds for non-negative } k, q_L.$$

(ii) $b'(q_L) > 0$ requires proof of three conditions:

(a) $Y(q_L) > 0$

(b) At $w = w^c(q_L)$: $(k_1 + k_2)q_L / [(w - 1/2)] \leq Y(q_L)$

(c) For $w \in [w^m(q_L), w^c(q_L)]$:

$$b'(q_L) > 0, \text{ which is immediate since } b(q_L) = (k_1 + k_2)q_L / [(w - 1/2)].$$

Proof of (a):

$$Y(q_L) = \frac{(1+q_L)(1+k)}{2} - \sqrt{\frac{(1+q_L)^2(1+k)^2}{4} - q_L(1+k)}$$

$$Y(q_L) = \frac{(1+q_L)(1+k)}{2} - \sqrt{\frac{(1+k)}{4} [(1+q_L)^2(1+k) - 4q_L]}$$

$$Y(q_L) = \frac{(1+q_L)(1+k)}{2} - \sqrt{\frac{(1+k)}{4} [(1-q_L)^2 + k(1+q_L)^2]}$$

$$Y'(q_L) = \frac{(1+k)}{2} - \frac{\frac{(1+k)}{4}[-2(1-q_L) + 2k(1+q_L)]}{2\sqrt{\frac{(1+k)}{4}[(1-q_L)^2 + k(1+q_L)^2]}}$$

$$Y'(q_L) = \frac{(1+k)}{2} \left[1 - \frac{[-(1-q_L) + k(1+q_L)]}{\sqrt{(1+k)[(1-q_L)^2 + k(1+q_L)^2]}} \right]$$

$$Y(q_L) > 0 \Leftrightarrow$$

$$\sqrt{(1+k)[(1-q_L)^2 + k(1+q_L)^2]} > q_L(k+1) + k-1 \Leftrightarrow$$

$$(1+k)[k+1+2(k-1)q_L + (k+1)(q_L)^2] > (q_L)^2(k+1)^2 + 2q_L(k+1)(k-1) + (k-1)^2$$

$$\text{that requires: } (k+1)^2 > (k-1)^2 \text{ that holds } \forall k > 0.$$

Proof of (b):

$$\text{At } w=w^c(q_L): (k_1 + k_2)q_L / [(w - 1/2)] \leq Y(q_L)$$

Requiring:

$$(k_1 + k_2)q_L \leq (w^c(q_L) - 1/2)Y(q_L) = \{k_1 / [1 - Y(q_L)] + k_2\} Y(q_L)$$

$$(k_1 + k_2)q_L \leq Y(q_L)k_1 / [1 - Y(q_L)] + Y(q_L)k_2 \Leftrightarrow$$

$$(k + 1)q_L \leq Y(q_L)k / [1 - Y(q_L)] + Y(q_L) \Leftrightarrow$$

$$k / [1 - Y(q_L)] + 1 - (k + 1)q_L / Y(q_L) \leq 0$$

It can be shown that this inequality holds with equality for $Y(q_L)$ as defined.

Result (iii) ($v_2'(q_L) > 0$) is immediate from the definition of $v_2(q_L)$ and the realization that $b'(q) > 0$ (result (ii) of Corollary 1).

QED

Proof of Theorem 3:

Proof for the case where $w \hat{=} [w^m(q_L), w^c(q_L)]$.

$$\Pi_S(q_L, q, w) \equiv \frac{1}{2} - v_1(q_L) + [1 - \mathbf{b}(q_L)][w - \frac{1}{2} - v_2(q_L)]$$

$$\Pi_n(q_L, q, w) \equiv (1 - q)w + qwq_L - (k_1 + k_2)$$

$$S(q_L, q, w) = \frac{1}{2} - v_1 + [1 - \mathbf{b}(q_L)][w - \frac{1}{2} - v_2] - [(1 - q)w + qwq_L - k_1 - k_2]$$

$$= \frac{1}{2} - [k_1 - (1 - \mathbf{b}(q_L))(w - \frac{1}{2} - k_2)] - [(1 - q)w + qwq_L - k_1 - k_2]$$

$$= \frac{1}{2} + [1 - \mathbf{b}(q_L)](w - \frac{1}{2} - k_2) - [(1 - q)w + qwq_L - k_2]$$

$$(a) \quad S_q = w - wq_L = w(1 - q_L) > 0$$

$$(b) \quad S_{q_L} = -\mathbf{b}'(q_L)[w - \frac{1}{2} - k_2] - qw < 0 \text{ because } \mathbf{b}'(q_L) > 0 \text{ from Corollary 1.}$$

$$(c) \quad S_w = [1 - \mathbf{b}(q_L)] + (w - \frac{1}{2} - k_2)(k_1 + k_2)q_L / (w - \frac{1}{2})^2 - (1 - q) - qq_L$$

$$= \mathbf{b}(q_L) + (w - \frac{1}{2} - k_2)(k_1 + k_2)q_L / (w - \frac{1}{2})^2 + q(1 - q_L)$$

$$= \mathbf{b}(q_L)[(w - \frac{1}{2} - k_2) / (w - \frac{1}{2}) - 1] + q(1 - q_L)$$

$$= -\mathbf{b}(q_L)k_2 / (w - \frac{1}{2}) + q(1 - q_L)$$

$$\text{so } S_w < 0 \text{ iff } q < \mathbf{b}(q_L)k_2 / (w - \frac{1}{2})(1 - q_L) = (k_1 + k_2)k_2q_L / [(w - \frac{1}{2})^2(1 - q_L)] \equiv q^c.$$

Proof for the case where $w > w^c$.

When $w > w^c$ from Theorem 2 and the definition of $S(q_L, q, w)$ it can be shown that:

$$S(q_L, q, w) = \frac{1}{2} + [1 - \mathbf{b}(q_L)][w - \frac{1}{2} - k_2] - [(1 - q)w + qwq_L - k_2]$$

So that:

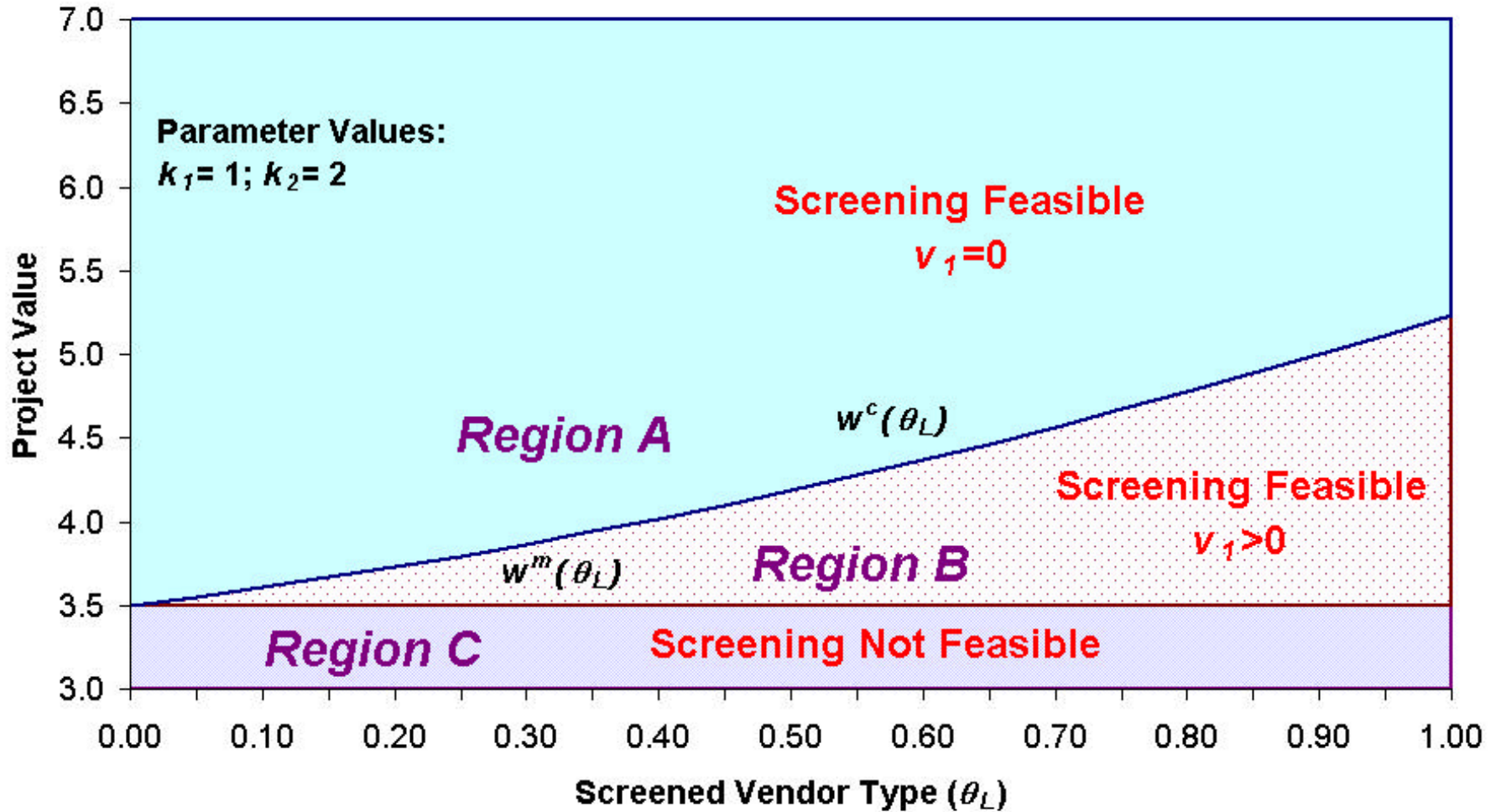
$$(a) \quad S_q = w - wq_L = w(1 - q_L) > 0$$

$$(b) \quad S_{q_L} = -\mathbf{b}'(q_L)[w - \frac{1}{2} - k_2] - qw < 0 \text{ because } \mathbf{b}'(q_L) > 0 \text{ from Corollary 1.}$$

$$(c) \quad S_w = [1 - \mathbf{b}(q_L)] - (1 - q) - qq_L = -\mathbf{b}(q_L) + q(1 - q_L) \text{ and } S_w < 0 \text{ iff } q < \mathbf{b}(q_L) / (1 - q_L) \equiv q^c.$$

QED

Figure 2: Screening Contracts



**Figure 3: Vendor Profitability
as a function of Threshold**

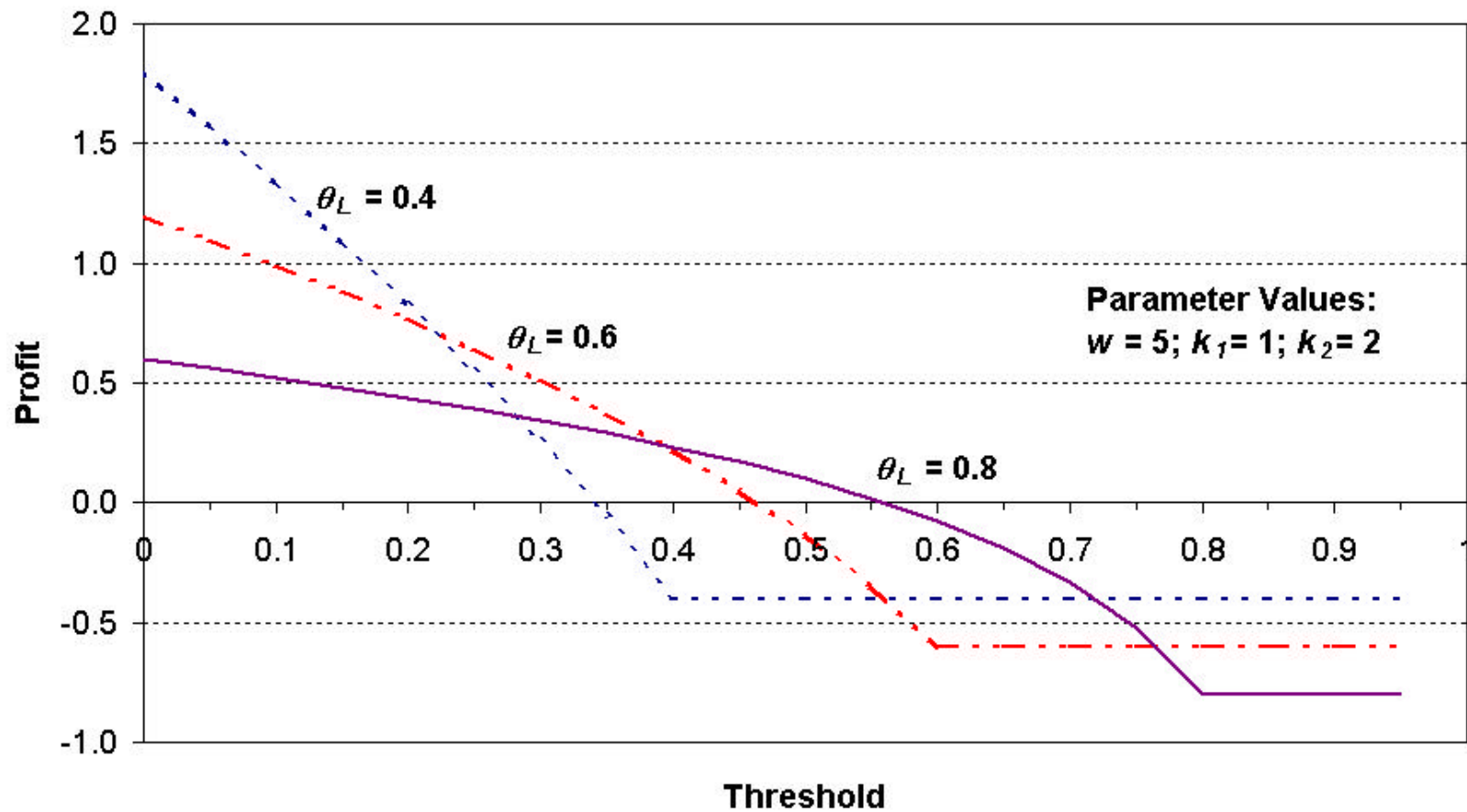


Figure 4: Value of Screening vs. Frequency of Low Type

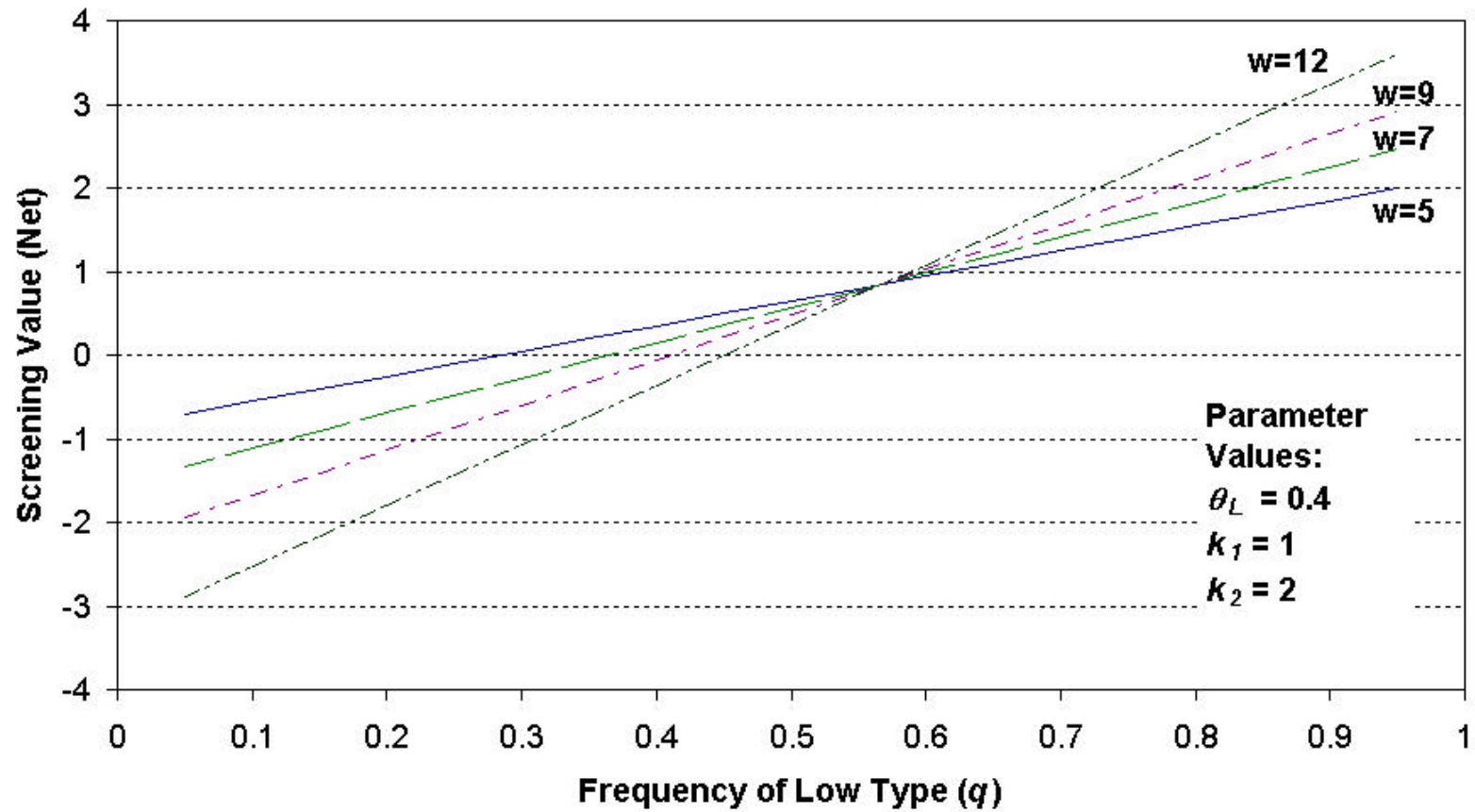


Figure 5: Value of Screening as a function of Project Value

