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CONTRACT CHOICE IN SOFTWARE DEVELOPMENT OUTSOURCING: A MULTIDIMENSIONAL VIEW OF PROJECT ATTRIBUTES

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Abstract

Recently, there is a growing interest in the contractual mechanisms that govern software development outsourcing (SDO). Studies on SDO frequently draw their predictive power from the identification of project attributes that explain why firms choose either fixed-price (FP) or time-and-materials (T&M) contracts. However, studies seem to adopt a unidimensional view, in the sense that they examine how contract choice is associated with isolated attributes. The present study contributes to the literature by adopting a multidimensional view of contract choice. The main benefit of such a view is its ability to serve as a platform for exploring the interrelationships among project attributes.

The literature suggests that both transaction cost economics (TCE) attributes (uncertainty, specificity and complexity, and frequency) and software engineering (SE) attributes of project size (duration and price) explain contract choice. However, while the theoretical reasoning underlying the effect of TCE attributes on contract choice draws on three decades of research, the theoretical reasoning for the effect of SE attributes on contract choice is practically nonexistent. In this study, we offer an explanation for the results related to both TCE and SE. We show that TCE attributes mediate the effect of SE attributes on contract choice. We assert that researchers and practitioners regard SE attributes as important for contract choice as a result of their being predictive of TCE attributes, and that a multidimensional view should be able to uncover this effect. The research model is empirically tested using a dataset of 237 contracts entered into by a leading international bank over a period of three years.

Keywords: Software Development Outsourcing, Contract Choice, Project Attributes, Transaction Cost Economics, Software Engineering.

1 INTRODUCTION

In recent years, there is a growing interest in the contractual mechanisms that govern information technology (IT) outsourcing (e.g., Argyres et al. 2007, Chen and Bharadwaj 2009, Dey et al. 2010, Gefen et al. 2008, Heiskanen et al. 2008, Jiang et al. 2008). The economics literature shows that the domain of procurement contracts is dominated by two contract types, fixed-price and cost-plus (Bajari and Tadelis 2001, Laffont and Tirole 1993, McAfee and McMillan 1986). Research on software development outsourcing (SDO) similarly distinguishes between fixed-price (FP) contracts, in which the price for delivery is prespecified, and time-and-materials (T&M) contracts, in which the vendor is reimbursed for its costs plus a predetermined profit (Banerjee and Duflo 2000, Gopal et al. 2003, Lichtenstein 2004, Whang 1992). Whether contract choice is motivated by ex ante asymmetric information (Laffont and Tirole 1993) or by ex post adaptation (Bajari and Tadelis 2001), research generally treats these contract types as two unique incentive mechanisms that are associated with opposite project attributes. FP arrangements are considered more effective in situations characterized by low uncertainly and complexity. In FP arrangements, risk is allocated primarily on the vendor, who is motivated to minimize costs. Conversely, T&M arrangements are considered more effective in situations characterized by high uncertainty and complexity. In T&M arrangements, risk is allocated primarily on the client, and thus the vendor is motivated to maximize quality. Bajari and Tadelis (2001) described these opposite attributes as the "conventional wisdoms" about FP and T&M contracting.

Studies on SDO arrangements frequently draw their predictive power from the identification of project attributes that explain why firms prefer one contract type over the other. For example, Gopal et al. (2003) found that numerous attributes, such as requirements uncertainty, project size, client size, and number of prior projects, are associated with higher probabilities of either FP or T&M contracts. Researchers made similar observations about other attributes, such as business familiarity (Gefen et al. 2008), project uncertainty (Kalnins and Mayer 2004), and project complexity and duration (Dey et al. 2010). However, studies seem to adopt a *unidimensional* view of the project attributes that explain contract choice in the sense that they conceptualize how contract choice is associated with isolated attributes. This unidimensional view is evident in the formulation of hypotheses that associate a single attribute with the likelihood of preferring one contract type over the other. Even Gopal et al. (2003), who performed one of the most comprehensive investigations of contract choice determinants, included a single attribute in each of their hypotheses.

Against this background, the present study contributes to the literature by adopting a *multidimensional* view of project attributes in the context of contract choice. The main benefit of such a multidimensional view is its ability to serve as a platform for exploring the interrelationships among project attributes. As a consequence of the dominance of the unidimensional approach, the literature describes a relatively large set of attributes that explain contract choice. However, the literature tells us little about the interrelationships among those attributes in determining contract choice. In contrast, the multidimensional view developed in this study allows the analysis of multiple attributes, based on multiple perspectives, in a single model. In particular, the multidimensional view developed here analyzes attributes that are based on the main theoretical perspectives of SDO contract choice. These perspectives are transaction cost economics (TCE) and software engineering (SE).

TCE has turned the spotlight on a set of project attributes – uncertainty, specificity and complexity, and frequency – that should largely guide organizations' boundary choices between internal and external governance mechanisms. SE has long recognized the importance of project size and the critical effect of resource constraints – schedule and cost – on software development outcomes (Nan and Harter 2009). The literature suggests that both TCE attributes and SE attributes explain contract choice. However, while the theoretical reasoning underlying the effect of TCE attributes on contract choice draws on three decades of research, the theoretical reasoning for the effect of SE attributes on contract choice is practically nonexistent.

In this study, we offer an explanation for the results related to both TCE and SE. We show that TCE attributes mediate the effect of SE attributes on contract choice, i.e., uncertainty, complexity, and

frequency mediate the effect of project size on contract choice. We assert that researchers and practitioners regard SE attributes as important for contract choice as a result of their being reflective of TCE attributes, and that a multidimensional view should be able to uncover this effect. Such a multidimensional lens therefore bears important practical implications. It has been shown that executives often make contract choices based on a single project attribute, such as price, instead of basing their choices on multiple economic and technical attributes (Lichtenstein 2004). This study shows that relying on project size considerations in contract choices is inferior to relying on TCE considerations. However, such a practice should be preferred when the costs involved in assessing TCE attributes are relatively high.

2 THEORETICAL BACKGROUND AND HYPOTHESES

Research repeatedly acknowledges the prevalence of FP and T&M contracts in procurement arrangements. While the normative literature models the procurement problem as one of asymmetric information, and thus predicts the use of menus of contracts, the empirical literature suggests that menus of contracts are not used in practice, and that the vast majority of contracts are variants of simple FP and T&M contracts (Bajari and Tadelis 2001). This empirical observation is supported by formal models showing that "the optimal contract is always either a fixed-price or a time and materials contract" (Banerjee and Duflo 2000, p. 996). The choice between FP and T&M mechanisms of contracting determines the allocation of risk between client and vendor and the nature of their incentives. Therefore, this choice is a crucial decision in an SDO project, and it bears directly on the likelihood of successfully completing the project.

Given this importance, studies have aimed at identifying project attributes that explain the variance in contract choice. The most comprehensive attempt was performed by Gopal et al. (2003), who formulated 11 hypotheses on attributes that should be associated with higher probabilities of either FP or T&M contracts. Each of the attributes in that study was conceptualized separately against the dependent variable of contract choice. This unidimensional view of project attributes characterizes other studies on contract choice. This line of research shows that such attributes as project uncertainty and complexity (Gopal et al. 2003), business familiarity (Gefen et al. 2008), and project duration (Dey et al. 2010) explain significant variance in the choice between FP and T&M contracts. What is missing in the literature is a multidimensional analysis of the interrelationships among project attributes in the context of contract choice. We draw on two very distinct perspectives, TCE and SE, to identify five project attributes that may be considered predictive of contract choice in SDO. The relevance of TCE is derived from its centrality in explaining transaction governance choices, and the relevance of SE is derived from its focus on software development processes. Simply put, TCE is relevant to understanding outsourcing, while SE is relevant to understanding software development. Together, these two perspectives are pertinent to understanding SDO phenomena.

2.1 The TCE perspective of contract choice

TCE is the theory most frequently invoked to explain why organizations decide to outsource (Dibbern et al. 2004). Studies frequently use this theory to analyze the antecedents and consequences of IT sourcing decisions (e.g., Ang and Straub 1998, Aubert et al. 1996, Clark et al. 1995, Lacity and Willcocks 1995). TCE is rooted in the work of Coase (1937), who originally distinguished between the allocation of resources in a firm and the allocation of resources in the economic system. The balance of transaction and production costs outlined by Coase (1937) was later formalized into TCE, which claims that firms minimize the costs associated with commercial transactions by considering the trade-off between transaction and production costs (Williamson 1979, 1981). Whereas internal forms of governance ("hierarchies") are presumed to offer the advantage of lower transaction costs, external forms of governance ("markets") are presumed to offer the advantage of lower production costs.

A major reason for the growing acceptance of TCE is the significant body of empirical research that is largely consistent with TCE predictions (Macher and Richman 2008). Empirical research in TCE is commonly a variation of the discriminating alignment hypothesis (Williamson 1991), according to

which "transactions, which differ in their attributes, are aligned with governance structures, which differ in their cost and competence, so as to effect a (mainly) transaction-cost economizing result" (Williamson 1998, p. 75). The basic model considers governance structure as the dependent variable, which is a function of certain attributes of the underlying transaction (Shelanski and Klein 1995). Governance structure is most frequently conceptualized as one of two discrete types, market or hierarchy (although various hybrid forms have also been considered in the literature). The transaction attributes that are considered predictive of governance structure are asset specificity, uncertainty, complexity, and frequency. Specifically, the TCE literature shows that more integrated governance structures are associated with a higher degree of asset specificity, greater uncertainty, more complex transactions, or more frequent exchange (Macher and Richman 2008, Shelanski and Klein 1995). Of these attributes, asset specificity is the most difficult to measure (Shelanski and Klein 1995), which is why product complexity has been widely used as a surrogate for asset specificity (Masten 1984, Novak and Eppinger 2001, Rangan et al. 1993). The logic underlying this association is that the probability of observing more relationship-specific investments depends positively on the complexity of the acquired product. Therefore, the present study analyzes the extent to which uncertainty, complexity, and frequency affect governance structure.

As implied earlier, research designed to validate the discriminating alignment hypothesis has used numerous variations of the dependent variable of governance structure. An important variation has been to model governance structure as a binary variable of FP versus T&M (Gopal et al. 2003). Such models are based on the implicit assumption that T&M arrangements represent more integrated governance structures than FP arrangements. As a consequence of the lower ex ante design completeness and higher ex post design adaptations in T&M arrangements (Bajari and Tadelis 2001), they involve significantly more interaction, coordination, and adaptation than FP arrangements. In a sense, T&M arrangements with their enhanced interaction between vendor and client are conceptually closer to an internally executed software development project, whereas FP arrangements are conceptually closer to a market transaction. Accordingly, the TCE discriminating alignment hypothesis in the present study takes the following form:

Hypothesis 1 (TCE). *Greater uncertainty, complexity, and frequency are associated with higher probabilities of T&M contracts.*

In the remainder of this section, we more explicitly define uncertainty, complexity, and frequency and theoretically justify their association with governance structure.

Uncertainty. Project uncertainty is defined in this study as the degree to which the specific outcomes of the project are unpredictable. Uncertainty arises from the limits of human cognition to plan for all possible contingencies (Simon 1957). It also occurs in real time and requires constant and ongoing agency adaptation (Slater and Spencer 2000). Consequently, both client and vendor share uncertainty about many important changes that may occur after the contract is signed and production begins (Bajari and Tadelis 2001). The degree to which future outcomes and contingencies are unpredictable is a critical attribute for characterizing transactions (Williamson 1979). TCE predicts that higher uncertainty is associated with a higher risk of opportunistic behavior and with higher transaction costs, which may increase the use of hierarchical governance structures (Williamson 1985). Therefore, greater uncertainty is associated with more integrated governance modes (Macher and Richman 2008). Kalnins and Mayer (2004) argued that when the exact specification of the final output is difficult to define, FP contracts become problematic, as variations from the agreed-upon requirements entail costly renegotiation. Bajari and Tadelis (2001) noted that a high probability of ex post design adaptations should entail the use of T&M contracts. Consistent with these predictions, research found that increased uncertainty is associated with a higher likelihood of using T&M contracts (Gopal et al. 2003).

Complexity. Although complexity and uncertainty are distinct analytical concepts, the two are often used interchangeably (Macher and Richman 2008). Slater and Spencer (2000) claimed that it is essential to distinguish between the difficulty of knowing what outcomes are probable through the course of development of the external environment (i.e., uncertainty) and the difficulty of assigning probability values to a preconstituted set of events (i.e., complexity). Whereas uncertainty is created

by an inherent lack of knowledge, complexity is the consequence of the existence of too many possibilities (Slater and Spencer 2000). This study draws on the work of Novak and Eppinger (2001) to define product complexity as contingent on the number of product components, the extent of interactions among these components, and the degree of product novelty. Product complexity is often considered to reflect the degree of asset specificity characterizing a transaction (Masten 1984, Novak and Eppinger 2001, Rangan et al. 1993). Greater complexity thus entails higher transaction costs and more integrated governance modes (Macher and Richman 2008, Shelanski and Klein 1995). Respectively, simple projects, which are cheap to design, should be procured using FP contracts, whereas more complex projects should be procured using T&M contracts (Bajari and Tadelis 2001).

Frequency. This attribute represents the frequency of exchange between a specific dyad of client and vendor. The contracting literature suggests that relational contracting reduces the risk of adverse selection by revealing private information, and the risk of moral hazard because of the expectation that the relationship will continue (Bolton and Dewatripont 2005). Recurrent interactions, in which firms learn about each other and develop preferential and stable trading relationships, foster interorganizational trust (Gulati 1995). Bradach and Eccles (1989) defined trust as "a type of expectation that alleviates the fear that one's exchange partner will act opportunistically" (p. 104). Why does trust explain contract choice? Trust and detailed contracts are two mechanisms for making behavior predictable, which is perhaps the biggest concern of firms entering interorganizational relationships (Gulati 1995). Therefore, trust can serve as an alternative control mechanism (Bradach and Eccles 1989). Trust becomes more crucial when uncertainty increases and, consequently, detailed contracts and formal controls become more costly. Accordingly, studies have found trust, defined as the frequency of prior interactions with a specific vendor, to be positively associated with a higher likelihood of T&M contracts (Gefen et al. 2008, Gopal et al. 2003).

2.2 The SE perspective of contract choice

The size of the software product to be developed is a key attribute of software development projects. Research has demonstrated the presence of both scale economies and diseconomies in software development (Banker et al. 1994, Banker and Kemerer 1989). Increasing returns to scale arise from such factors as the increased use of software development tools and specialized personnel in larger projects and the distribution of fixed project management overhead over a larger base (Boehm 1981). Decreasing returns to scale arise from the increased complexity in larger projects related to the interfaces among system components, communication among project personnel, and project management activities (Banker and Kemerer 1989). Project size is commonly reflected in two different project attributes, schedule and cost. Schedule is defined as the development cycle time and cost is defined as the development budget. Given the intangible nature of software, the major part of the budget in software projects is allocated to manpower effort, measured in man-months. A significant stream of SE research has aimed at developing methods for the estimation of project schedule and cost, as well as understanding the trade-off between them, in particular the impact of schedule compression or expansion on cost (Boehm 1981, Brooks 1975, Putnam 1978). This stream of research has seemed to converge around the prediction of increased effort and cost when project schedule is compressed below the optimal level (Nan and Harter 2009).

Gopal et al. (2003) hypothesized and confirmed the effect of project size on contract choice. They theoretically justified this effect based on the following arguments:

> *"Larger projects in terms of effort are associated with time-and-materials contracts. As mentioned before, project size is a strong variable in software engineering and therefore is an important part of the contracting parties' decision-making process. Moreover, cost and schedule models show that estimation error is higher in larger projects. This is because the complexity of size increases the degree of task uncertainty, thus making the outcomes of the project riskier."* (Gopal et al. 2003, p. 1677)

As noted above, SE considers project size as reflected in the project attributes of schedule and cost. For the purpose of consistency with the economic literature, we shall use the equivalent attributes of duration and price. In the SDO context, schedule and duration have the same definition, and the

differences between cost and price are inconsequential because both are considered valid proxies of project size (as explained in the paragraph about price below). Based on the arguments of Gopal et al. (2003), it is possible to formulate a discriminating alignment hypothesis for SE that predicts the relationship between SE attributes and contract choice:

Hypothesis 2 (SE). *Greater duration and price are associated with higher probabilities of T&M contracts.*

In the remainder of this section, we more explicitly define duration and price and describe their association with contract choice.

Duration. Project duration is the estimated length of time for the project. According to TCE, "a long-term contract that specifies the terms and conditions for some set of future transactions ex ante, provides a vehicle for guarding against ex post performance problems" (Joskow 1987, p. 169). Empirical research shows that transaction cost factors, including uncertainty, incompleteness, and asset specificity, are associated with duration (Macher and Richman 2008). In particular, studies show that the larger are relationship-specific investments, the longer is the duration of the contract (Crocker and Masten 1988, Joskow 1987). T&M contracts should require a longer duration than FP contracts because time compensates for uncertainty and the need for ex post adaptation, which are higher in T&M contracts (Bajari and Tadelis 2001). Dey et al. (2010) suggested that FP contracts are more appropriate for simple software projects that require short development time.

Price. Price is the estimated monetary value of the project at the time the contract is signed. Custom software is priced differently than packaged software (Ethiraj et al. 2004). In the case of packaged software, costs are not a significant driver of price, because of the zero marginal cost of mass producing packaged software (Shapiro and Varian 1999). Conversely, in the case of custom software, the costs of each project need to be covered by the price paid by a single client. Ethiraj et al. (2004) argued that while resource costs are a significant determinant of prices in custom software projects, prices are also driven by ex ante uncertainty about project specifications and by the relative allocation of risk between the client and vendor. Therefore, "the nature of the contract is an important determinant of price in custom software projects" (Ethiraj et al. 2004, p. 9). The price of T&M contracts is expected to be higher than that of FP contracts mainly because of the inclusion of a premium for uncertainty and design incompleteness in the project price.

2.3 A multidimensional view of contract choice

Hypothesis 1 (TCE discriminating alignment hypothesis) and Hypothesis 2 (SE discriminating alignment hypothesis) describe the effect of TCE attributes (uncertainty, complexity, and frequency) and SE attributes (duration and price) on contract choice. These hypotheses, portrayed in Figure 1, follow the common path of considering each attribute in isolation as a direct determinant of contract choice.

Interestingly, as evident from the arguments supporting Hypothesis 2, the effect of project size (duration and price) on contract choice mostly relies on the tenets of TCE, not on SE research. SE is typically brought forward to motivate the investigation of project size, whereas TCE is used to explain why project size considerations are important in SDO.

Similarly interesting is our observation that TCE research has paid little attention to the size of the product involved in the transaction. In the most recent and comprehensive review of TCE research, performed by Macher and Richman (2008), scarce attention is paid to the attributes of size, schedule, and cost (excluding the concept of transaction cost) or to the attributes of volume, duration, and price. On the one hand, TCE rationale and the concepts of uncertainly, complexity, and frequency are invoked to explain the importance of size by those who are motivated by SE. On the other hand, the TCE literature mostly ignores the attribute of size. The challenge here is to reconcile the following observations: (a) SE perceives size as predictive of contract choice, (b) this prediction is explained by concepts drawn from TCE, and (c) TCE itself generally ignores the attribute of size.

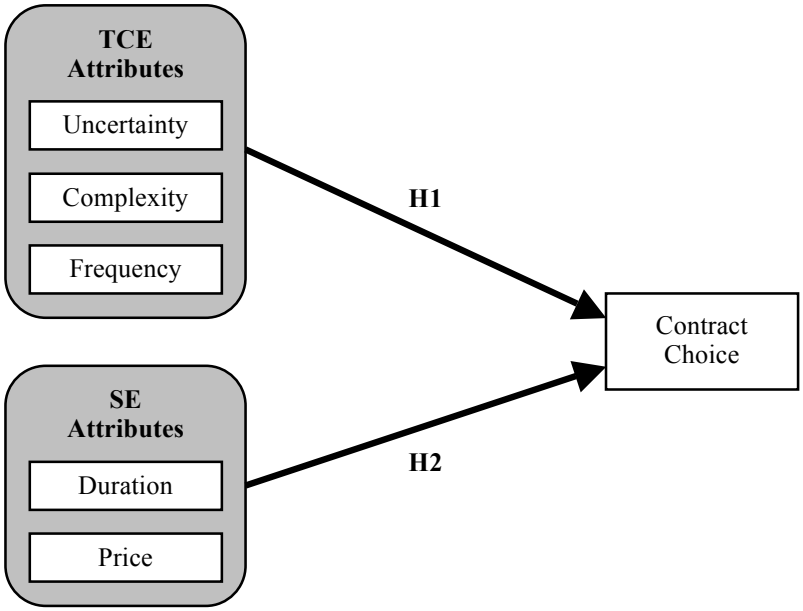

Figure 1. The TCE and SE Perspectives of Contract Choice.

We address this challenge by suggesting that TCE attributes (uncertainty, complexity, and frequency) fully mediate the effect of SE attributes (duration and price) on contract choice. Full mediation implies that SE attributes indeed have an overall effect on contract choice (observation a). However, this overall effect is the product of two sequential effects: the effect of SE attributes on TCE attributes and the effect of TCE attributes on contract choice. The latter effect is explained by Hypothesis 1 and the former effect can be easily found in the justification for Hypothesis 2, which mostly takes the following form: size is associated with contract choice because larger projects entail greater uncertainty, complexity, and frequency (observation b). SE research uses no theoretical mechanism other than TCE (e.g., scale economies) to explain the importance of SE attributes for contract choice, which is why we consider this relationship to be fully mediated rather than partially mediated by TCE attributes. Finally, TCE research probably ignores the attribute of size for reasons of parsimony (observation c); this attribute is not a direct determinant of governance structure, but rather a determinant of other important attributes. This model of full mediation, hidden in previous research on the relationship between project size and contract choice, is formulated in Hypothesis 3 and portrayed in Figure 2:

Hypothesis 3 (Multidimensional). *Uncertainty, complexity, and frequency fully mediate the effect of duration and price on contract choice.*

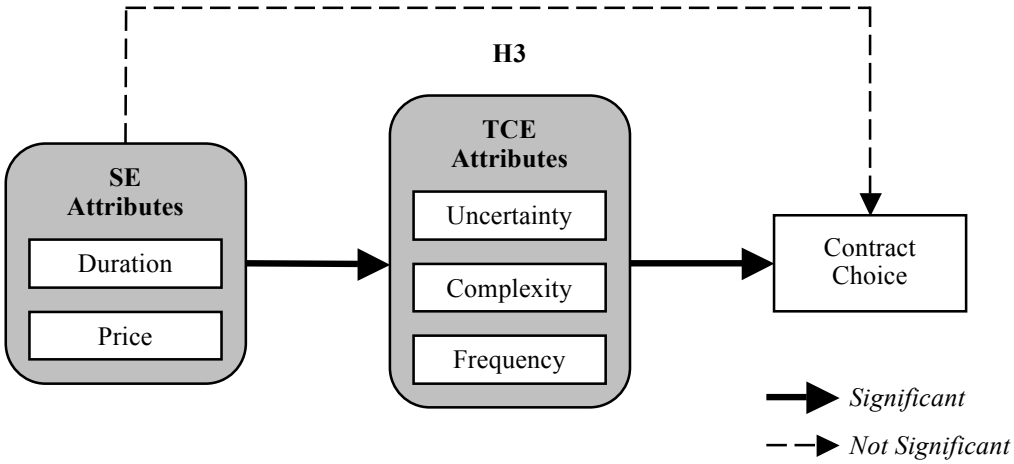

Figure 2. A Multidimensional View of Contract Choice.

3 METHODOLOGY

We collected data on SDO contracts in a leading international bank. The bank provides retail and commercial banking, wealth management, and investment banking in dozens of countries and has tens of thousands of employees. The bank contracts out system development through about 100 local and international vendors. Its methods of managing SDO are typical of other banks and large institutions.

Consistent with previous research, the unit of analysis in this study is the contract (e.g., Ethiraj et al. 2005, Gopal et al. 2003, Gulati 1995). We collected detailed data from the bank's contract repository. We were given access to all software development contracts signed between January 2000 and April 2003 – 424 contracts in total. Due to time constraints, we were able to collect detailed data only on the 270 most recent contracts. After dropping the mixed contracts (contracts with both FP and T&M elements), our dataset consisted of 237 contracts. The distinction between FP and T&M contracts was explicitly stated in the contracts. Project attributes were evaluated as follows:

- Uncertainty – operationally defined as the intensity of milestones specified in the contract: the sum of payment, delivery, and project milestones, divided by contract price.
- Complexity – a factor comprised of two subjective items: (1) system complexity – the extent to which the system is complex and interconnected; (2) system novelty – the extent to which the endeavor that the contract specifies is new, unknown, and original.
- Frequency – the accumulated price of previous contracts signed with the same vendor after January 2000 (in all 424 contracts signed during the period we studied).
- Duration – operationally defined as the number of days between the contract's start date and its expected completion date, as recorded in the contract repository.
- Price – operationally defined as the total price of the contract in U.S. dollars.

We plan to test Hypotheses 1 and 2 with a logistic regression. This method is appropriate because contract choice is a dichotomous variable, whose values are either FP or T&M. We intend to test Hypothesis 3 with the procedure for testing mediation outlined by (Baron and Kenny 1986).

This paper describes a study that is currently in progress. We are currently engaged in data analysis and we plan to present our findings at the conference.

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