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Aligning flexibility with uncertainty in software development arrangements through a contractual typology

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Aligning flexibility with uncertainty in software development arrangements through a contractual typology

Abstract

Purpose – The motivation for this study is to identify a typology of procurement contracts in the context of software development projects that allows firms to align design flexibility with design uncertainty at the project level. The theoretical lenses of contract theory and software engineering are used (i) to explain why the five archetypes in the proposed typology provide gradually increasing levels of design flexibility, and (ii) to develop hypotheses about the associations between design flexibility and a set of project cost dimensions.

Design/methodology/approach – The hypotheses are tested with objective contractual data from 270 software development contracts entered into by a leading international bank over a period of three years.

Findings – Data analysis confirms the existence of the proposed typology and shows that design flexibility is negatively associated with control, and positively associated with coordination, trust, duration, and price.

Research limitations/implications – Although the findings are based on the contracting practices of a single, albeit sophisticated, organization, they shed light on the ability of firms to align flexibility with uncertainty at the onset of new projects by taking advantage of nuanced contractual mechanisms to produce a broader set of contractual archetypes.

Originality/value – This paper is the first in the outsourcing literature to analyze a nuanced contractual typology in software development projects through the perspectives of both contract theory and software engineering.

Keywords: Outsourcing, software development, projects, contracting, flexibility, costs

Introduction

Although information technology (IT) outsourcing is a mature practice, it remains a managerial challenge, with the fundamental issues of developing an outsourcing capability, defining the scope of outsourcing, and selecting an outsourcing partner as the most pressing issues (Gewald and Schäfer, 2017). Of the variety of IT activities, software development remains one of the most complex, uncertain tasks to outsource and its outsourcing continues to grow at an annual rate of over 10%, according to authoritative estimates (Deloitte, 2016). A major challenge in outsourced software development projects is bridging the gap between the frequent need to modify the design of the system under development and the binding nature of the contract governing the relationship between the parties (Goo *et al.*, 2009; Sia *et al.*, 2008). Custom-made software is often developed through a time-consuming process, during which environmental changes may occur and render previous development efforts ineffective (Austin and Devin, 2009). However, adaptations in ongoing external development efforts are not easily attained. The contractual nature of external development processes constrains their ability to accommodate change relative to development processes that are confined within organizational boundaries. When the external competitive environment, the internal organizational environment, or the technological environment changes in a manner that necessitates software design modifications, adaptability is constrained by the contractual rigidity of software development arrangements.

This challenge is not unique to outsourced software development projects. Discrete resource acquisition through procurement projects is a common interorganizational situation. Firms rely on procurement projects to acquire various resources, such as building constructions (Bajari and Tadelis, 2001), offshore drilling (Corts and Singh, 2004), and marketing campaigns. All these examples represent discrete project relationships. Although such relationships may be repeated between the same two partners, the distinctive feature of such relationships is that a separate contract is negotiated and signed for each new project. This contractual nature of procurement projects may limit their adaptability to environmental changes.

The motivation behind this study was thus to identify contractual mechanisms that can sustain the adaptability of software development arrangements. The study, therefore, had two objectives. The first objective was to address the gap between the various needs for business adaptability and the limitations of formal contracts in the *practice* of software engineering. Although the literature focuses on two types of contracts, fixed-price and time-and-materials

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3 (Gopal *et al.*, 2003), practitioners are aware of the limitations of the dichotomy (Gaebert, 2015)
4 and find nuanced approaches to narrow this gap (i.e., to align flexibility with uncertainty). The
5 second objective was to analyze the *theoretical* mechanisms underlying these nuanced
6 approaches, as identified by contract theory (Bolton and Dewatripont, 2005; Hart and
7 Holmstrom, 1985).
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12 The rationale underlying our approach may be described as follows. Different procurement
13 projects are associated with different levels of uncertainty about design adaptations (Bajari and
14 Tadelis, 2001). Sustaining the adaptability of procurement projects requires the alignment of
15 design flexibility with design uncertainty at the project level. This proposition is in line with the
16 study of Anderson and Dekker (2005), who showed that misalignment between uncertainty and
17 contract design is associated with performance problems. It is also in line with the findings of
18 Gulati *et al.* (2005), who showed "that performance differences across modes of procurement
19 arise as a function of the match between adaptive capacity and adaptation requirements" (p. 415).
20 Because uncertainty represents a continuum (Harrington *et al.*, 2004), i.e., it is not necessarily
21 either high or low, such alignment is unlikely when firms use a very narrow set of procurement
22 arrangements. Hence, firms seek to institute a variety of procurement arrangements that range
23 from extremely inflexible to extremely flexible. Firms moving along the design flexibility
24 continuum face two opposing incentives. On the one hand, they are motivated to move up the
25 continuum to increase flexibility. On the other hand, design flexibility is associated with project
26 costs and process inefficiencies (Gopal and Koka, 2010), which motivate firms to restrict it.
27 Therefore, sustaining the adaptability of procurement projects is contingent upon the institution
28 of a design flexibility continuum and the capacity to align design flexibility with design
29 uncertainty at the onset of each new project. If such adaptability is absent, the probable
30 consequence is either projects with suboptimal flexibility (when uncertainty exceeds flexibility)
31 or projects with suboptimal costs (when flexibility exceeds uncertainty).
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48 In the context of software development arrangements (SDAs), we define design flexibility
49 as the degree to which an SDA provides structural mechanisms to accommodate changes in the
50 specifications of the software product. To validate the approach presented above, we examine
51 two of its key assumptions in the context of SDAs. The first assumption is that firms use an
52 institutionalized variety of procurement arrangements with increasing levels of design flexibility.
53 The second assumption is that design flexibility is associated with project costs. These two
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3 assumptions, which research has not addressed to date, are empirically tested in this study to offer
4 an explanation of how adaptability is sustained in SDAs.
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7 To examine the two assumptions, we draw on the theoretical frameworks of contract theory
8 and software engineering. Consequently, this study contributes to two streams of literature. The
9 contribution of this study to the *contract theory* literature stems from addressing an important gap
10 in this literature, that between theoretical predictions and empirical evidence. Studies have shown
11 that in situations of asymmetric information (one party has information that is not available to the
12 other party), characterized by a screening problem, the uninformed party screens the informed
13 party by offering a menu of contracts from which the informed party selects a specific contract,
14 thus revealing its private information (Bajari and Tadelis, 2001; Bolton and Dewatripont, 2005).
15 However, empirical studies have not been able to confirm this normative prediction and have
16 shown that menus of contracts are not used in practice (Bajari and Tadelis, 2001; Laffont and
17 Tirole, 1993). The present study offers a unique interpretation of the concept of "menu of
18 contracts". It aims at demonstrating that menus of contracts do indeed exist in practice to align
19 the incentives of buyers and sellers, even though those incentives may be associated with
20 motivations other than ex ante screening. The contribution of this study to the *software*
21 *engineering* literature is the novel demonstration of the need for and the costs of facilitating the
22 flexibility of software development. Research has generally addressed the need for design
23 flexibility in software projects by focusing on the development methodologies. In this regard, a
24 notable trend in the past decade has been the embracing of agile methodologies (Boehm, 2002;
25 Dingsøyr *et al.*, 2012; Martin, 2003), because "the traditional, plan-driven software development
26 methodologies lack the flexibility to dynamically adjust the development process" (Nerur *et al.*,
27 2005, p. 73). However, in the quest for agility, software engineering research has largely
28 overlooked other project governance issues, in particular those related to the interorganizational
29 mechanisms underlying the development process. Against this backdrop, this study is the first to
30 demonstrate the importance of client-vendor arrangements in determining software design
31 flexibility as well as the consequences of such flexibility for project performance.
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51 The outline of this paper is as follows. The next section develops a contractual typology of
52 SDAs, demonstrates why this typology represents a continuum of design flexibility, and analyzes
53 the consequences of each contractual archetype for different project cost dimensions. The third
54 section builds on this theoretical framework to formulate a set of hypotheses about the
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3 associations between design flexibility and cost dimensions. The fourth section describes the
4 research methodology used in this study to collect objective contractual data from 270 software
5 development contracts made by a leading international bank over a period of three years. The
6 fifth section describes the data analysis techniques used in this study to test the hypotheses and
7 the results obtained. Finally, the last section discusses the findings and their implications.
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13 14 **Theoretical framework: A contractual typology**

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16 We define an SDA as a contractual arrangement that involves the development of full or partial
17 custom-made software by external vendors. In SDAs, software development activities are
18 managed by the vendor and performed outside the client's premises. This definition differentiates
19 SDAs from other forms of software-related outsourcing; contracting for consulting services or
20 "body leasing" is typical of projects managed by the client, and contracting for licensing of off-
21 the-shelf software usually does not involve significant software development (although it may
22 involve software customization by the client). Procurement arrangements in general have been
23 classified into two archetypes – fixed-price and cost-plus (Bajari and Tadelis, 2001). SDAs have
24 similarly been classified as either fixed-price (FP) or time-and-materials (T&M) (Banerjee and
25 Duflo, 2000; Gopal *et al.*, 2003; Lichtenstein, 2004; Schermann *et al.*, 2016; Whang, 1992). With
26 FP contracts, the price for completing the project is predetermined. Conversely, T&M contracts
27 do not specify a price, but rather reimburse the vendor for its costs plus a predetermined profit.
28 While contract theory suggests that contract diversification is the consequence of adverse
29 selection problems, Bajari and Tadelis (2001) argue that different types of contracts are needed
30 because of the importance of ex post adaptation, i.e., design changes that are required after the
31 contract has been signed. They note that "the procurement problem is primarily one of *ex post*
32 *adaptations* rather than *ex ante screening*" (Bajari and Tadelis, 2001, p. 388). Projects with high
33 levels of design completeness (i.e., adaptations are not likely to be needed) are procured using FP
34 contracts, whereas projects with low levels of design completeness are procured using T&M
35 contracts. Therefore, ex ante design completeness is related to ex post design flexibility (Tadelis,
36 2002). Design flexibility has been recognized in the management literature as a central concept in
37 new product development under uncertainty (Krishnan and Bhattacharya, 2002).
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55 Formal models show that "the optimal contract is always either a fixed-price or a time and
56 materials contract" (Banerjee and Duflo, 2000, p. 996). However, these two contractual
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3 archetypes offer a very limited choice between the extremely low design flexibility of FP
4 contracts and the extremely high design flexibility of T&M contracts. We argue that such a
5 narrow set of procurement arrangements cannot provide the continuum of design flexibility
6 necessary to align design flexibility with design uncertainty at the project level. On the one hand,
7 firms that opt for FP contracts are locked into inflexible arrangements that increase the likelihood
8 of suboptimal flexibility, whereas, on the other hand, firms that opt for T&M contracts benefit
9 from flexible arrangements that increase the likelihood of suboptimal costs. We thus posit that
10 adaptability in contracting for software development requires a broader variety of SDAs with
11 gradually increasing levels of design flexibility.
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19 Our conceptual analysis develops a novel typology of five contractual archetypes (Fink *et*
20 *al.*, 2013). We begin with the traditional distinction between FP and T&M contracts and rely on
21 two assumptions to combine and separate these two prevailing archetypes into five new
22 archetypes. The first assumption is that a continuum of design flexibility requires that FP and
23 T&M contracts should not remain mutually exclusive. This assumption leads to the definition of
24 an archetype that is based on a relatively balanced combination of FP and T&M arrangements –
25 the Mixed archetype. This archetype allows both low and high levels of design flexibility to
26 coexist within a single contract and thus affords an intermediate level of design flexibility. The
27 second assumption is that a continuum of design flexibility requires more variance at its low and
28 high ends, which can be achieved by defining archetypal variations of FP and T&M contracts.
29 We define two archetypal variations of FP contracts and two archetypal variations of T&M
30 contracts by drawing on contracting techniques described in the literature. We focus on a single
31 technique for each class of archetypes (FP or T&M) so as to maintain the relative simplicity of
32 the typology. The criterion for identifying the most relevant technique for each class of
33 archetypes is the ability of the technique to moderate the extreme level of design flexibility
34 characterizing the class. The most relevant technique for FP contracts is the *change provision*,
35 which is a specific contractual clause with explicit change management principles and guidelines.
36 The change provision is most relevant for FP contracts, because it addresses the need to introduce
37 design changes, which is the major risk associated with the low design flexibility of these
38 contracts. Consequently, we define two archetypal variations of FP contracts, FP contracts
39 without a change provision and FP contracts with a change provision, where the latter is
40 characterized by higher design flexibility than the former. The most relevant technique for T&M
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contracts is the *price cap*, which is a predetermined maximum price specified in the contract (Kalnins and Mayer, 2004). The price cap is most relevant for T&M contracts, because it addresses price escalation, which is the major risk associated with the high design flexibility of these contracts. Consequently, we define two archetypal variations of T&M contracts, T&M contracts without a price cap and T&M contracts with a price cap, where the latter is characterized by lower design flexibility than the former. This conceptual analysis produces the following contractual typology, which represents a continuum of design flexibility¹:

Archetype 1: *FP contracts without a change provision (FP-w/o-change)*

Archetype 2: *FP contracts with a change provision (FP-w/-change)*

Archetype 3: *Mixed FP and T&M contracts (Mixed)*

Archetype 4: *T&M contracts with a price cap (T&M-w/-cap)*

Archetype 5: *T&M contracts without a price cap (T&M-w/o-cap)*

We employ two theoretical perspectives, software engineering and contract theory, to identify the implications of using each contractual archetype in SDAs. Software engineering represents the actual craft through which the resource is acquired, and therefore this perspective is essential for identifying the implications of each archetype for project performance measures of time, cost, and quality. Contract theory, as a theory of incentives, information, and economic institutions (Bolton and Dewatripont, 2005), highlights the economic implications of the different relational arrangements. In concert, the two perspectives provide a conceptual platform to identify the task and relational implications of each archetype. Next, we describe the emerging typology of five contractual archetypes, demonstrate why they represent a continuum of design flexibility, and discuss their cost implications in the context of SDAs. We then build on these implications to develop a set of research hypotheses.

Archetype 1: FP contracts without a change provision

The FP-w/o-change archetype is an arrangement in which the price for project completion is predetermined. This characteristic creates inflexibility and increases the threat of holdup or costly renegotiation should there be a change in the desired specifications (Corts and Singh, 2004;

¹ Although we consider the contractual typology as representing a continuum of design flexibility, the five discrete archetypes that comprise the typology do not really provide a continuous range of contracts.

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3 Kalnins and Mayer, 2004). Furthermore, this archetype includes no provision for change, i.e.,
4 there is no structural mechanism in the contract to accommodate changes in the specifications of
5 the software product. Because the option of renegotiation is not formally defined, we view this
6 archetype as offering the lowest level of design flexibility.
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10 In software development projects characterized by high design completeness, structured
11 software engineering methodologies (e.g., waterfall model of the software development life
12 cycle) are most effective. Structured methodologies emphasize "fully elaborated documents as
13 completion criteria for early requirements and design phases" (Boehm, 1988, p. 63). The
14 complete and detailed specifications reduce the need for communication and coordination with
15 external stakeholders and increase the usefulness of control as a mechanism for revealing quality
16 problems in the early stages of development. The detailed specifications enable more accurate
17 cost estimation and minimize the premium for uncertainty. For this reason and because of the
18 intensive use of control, a high level of trust is not warranted (Mayer *et al.*, 1995). Accordingly,
19 vendor familiarity becomes less critical, bidding is highly competitive, and the likelihood of
20 selecting foreign vendors increases (Iacovou and Nakatsu, 2008). Because of the firmness of the
21 price for project completion (fixed without a renegotiation option), the vendor has the incentive
22 to reduce costs and shorten the project duration (Gopal *et al.*, 2003).
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35 **Archetype 2: FP contracts with a change provision**

36 The FP-w/-change archetype represents an FP contract that includes a specific clause with
37 explicit change management principles and guidelines. Such a clause may describe procedures
38 for change requests, for analyzing their impacts, and for renegotiation discussions. Research has
39 highlighted the importance of the inclusion or omission of such a clause in a contract (Chen and
40 Bharadwaj, 2009; Saunders *et al.*, 1997; Sia *et al.*, 2008). Contingency planning constitutes one
41 of the main categories of terms in which contractual safeguards are embedded (Argyres *et al.*,
42 2007). In principle, in most contractual arrangements the client is free to raise change requests,
43 which the vendor may reject or choose to accept contingent on ensuing changes to the project
44 scope, time, or price. However, we distinguish between FP-w/o-change and FP-w/-change
45 arrangements because the latter provides a structural mechanism for adaptation. This distinction
46 rests on the assumption that, *ceteris paribus*, a change request is more likely to be accepted when
47 a change provision clause has been included in the contract. This assumption implies that FP-w/-
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change arrangements are designed better than FP-w/o-change arrangements to deal with adaptation and, therefore, offer a higher level of design flexibility.

The FP-w/-change archetype, like the FP-w/o-change archetype, requires a high level of design completeness and frequently uses structured software engineering methodologies. However, the inclusion of a change provision mechanism in the contract loosens the implications attributed above to the FP-w/o-change archetype. First, greater familiarity and trust are needed because of the higher expectation and likelihood of renegotiations. Second, the price for project completion should be higher to reflect the premium for the renegotiation option. Changes increase cost volatility, thus affecting the premium for cost risk (Eremenko, 2007). Third, control may be less intensive and project duration may be longer in order to facilitate the adaptability enabled by the change provision.

Archetype 3: Mixed FP and T&M contracts

In the Mixed archetype, the product is delivered through a relatively balanced combination of FP and T&M arrangements. This archetype combines the strengths of both arrangements – work packages with high levels of design completeness can be procured using FP mechanisms, and work packages with low levels of design completeness can be procured using T&M mechanisms. Hence, the client is able to align, to a limited extent, design flexibility with design uncertainty at the work package level rather than at the project level. Because of this higher sensitivity of Mixed arrangements to uncertainty, and because they include T&M mechanisms, we consider them as superior to FP-w/o-change and FP-w/-change arrangements in terms of design flexibility.

Mixed arrangements require the integration of work packages with high design completeness and work packages with low design completeness within a single project. Lacity and Willcocks (1998) define "mixed" outsourcing contracts as combinations of "detailed" contracts, in which requirements are fully specified, and "loose" contracts, in which requirements are loosely defined. Because uncertainty is high in the early stages of software development and decreases in later stages (Boehm *et al.*, 2000), FP arrangements should replace T&M arrangements as the project progresses. Accordingly, Banerjee and Duflo (2000) define "mixed" software development contracts as contracts in which specifications tend to be written on a T&M basis, and the rest of the work (development and testing) tends to be done on an FP basis. In such projects, semi-structured software engineering methodologies, such as rapid application

development, may prove most effective, because these methodologies advocate the combination of structured techniques and prototyping techniques (Martin, 1991). In Mixed contracts, control still plays an important role as a consequence of the FP arrangements, and coordination and trust play an important role as a consequence of the T&M arrangements. The combination of FP and T&M arrangements also leads to risk being shared between vendor and client. Mixed arrangements represent an aggregation of several project phases or sub-systems, and thus their price is expected to be relatively high.

Archetype 4: T&M contracts with a price cap

This archetype is a T&M contract that includes a price cap. As with any T&M arrangement, the vendor is not limited in the use of resources, but only up to a predetermined maximum price. The price cap indicates that the client has performed some evaluation of the main features of the software and has evaluated, to some degree, the overall price of these features. In this sense, T&M-w/-cap arrangements resemble FP arrangements. The difference between the two lies in the fact that in FP arrangements these evaluations are binding, whereas in T&M-w/-cap arrangements they represent a general threshold.

Placing a price cap on a T&M contract represents another approach to combining the features of T&M and FP arrangements and to balancing incentives for quality and cost efficiency (Kalnins and Mayer, 2004). Using reasoning similar to ours, Kalnins and Mayer (2004) argue that the parties may choose to employ a T&M-w/-cap contract when uncertainty is at an intermediate level. We agree, but argue that T&M-w/-cap arrangements afford a higher level of design flexibility than Mixed and FP arrangements, because they by and large rely on T&M mechanisms. However, T&M-w/-cap arrangements afford a lower level of design flexibility than T&M-w/o-cap arrangements, because they embed an FP element that increases the vendor's motivation to control costs, vulnerability to costly renegotiation, and hence reluctance to accept proposed changes.

The T&M-w/-cap archetype should be employed in projects with low design completeness. In such projects, unstructured software engineering methodologies, such as agile software development, should be more effective (Austin and Devin, 2009). Agile development is an overarching concept used to describe a group of methods designed to reduce the cost of change throughout a project (Highsmith and Cockburn, 2001). These methods are characterized by short

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3 iterative cycles of development driven by product features, incorporation of rapid feedback and
4 change, and continuous integration of code changes into the system under development
5 (Cockburn, 2002; Nerur *et al.*, 2005). Because design completeness is low, there is a need for
6 more intensive coordination, higher familiarity and trust, and longer duration to allow for
7 experimentation and feedback and to accommodate probable specification changes. The existence
8 of a price cap reduces the risk of project escalation. The intensity of control is low to facilitate
9 change, although the price cap warrants some control. Risk is allocated mainly to the client, but
10 the vendor bears some risk because of the price cap.
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19 **Archetype 5: T&M contracts without a price cap**

20 This archetype is a typical T&M contract, in which the price for project completion is not
21 constrained. The client reimburses the vendor for its costs plus a predetermined profit. The
22 primary benefit of this archetype, relative to an FP contract, is the reduced renegotiation cost
23 (Bajari and Tadelis, 2001), which comes at the expense of introducing a moral hazard problem
24 (Corts and Singh, 2004). As requirements change in T&M contracts, the vendor is more likely to
25 accept changes requested by the client without any need for renegotiating the initial contract
26 (Kalnins and Mayer, 2004). Among the archetypes in the proposed typology, this archetype
27 offers the best conditions to satisfactorily address situations in which adaptation is needed,
28 because the contract places no limitations on the vendor's ability to allocate resources to the
29 project. We thus view this archetype as offering the highest level of design flexibility.
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39 T&M-w/o-cap arrangements are similar to T&M-w/-cap arrangements in many respects:
40 both are characterized by low design completeness, use of unstructured software engineering
41 methodologies, intensive coordination, low control intensity, and longer duration. However,
42 because price is not constrained in T&M-w/o-cap arrangements, project escalation poses a
43 significant risk. As risk is borne mainly by the client, high familiarity and trust are very
44 important, and, consequently, the likelihood of selecting foreign vendors is low.
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49 Table 1 summarizes the implications of the five archetypes in the proposed contractual
50 typology based on the theoretical perspectives of software engineering and contract theory.
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Research hypotheses: Design flexibility and cost dimensions

The five contractual archetypes described in the previous section represent a continuum of design flexibility, which is lowest in FP-w/o-change arrangements and increases with each transition from one archetype to the next. Previous research has relied on a *dichotomous view* of procurement contracts as either FP or T&M to offer a dichotomous view of their associated costs. For instance, Bajari and Tadelis (2001) summarize the "conventional wisdoms" about the consequences of procurement contracts (e.g., risk allocation, client administration, flexibility for change) in the form of a table with two columns, one describing the consequences of FP contracts and the other describing the consequences of T&M contracts. In the preceding section, we extended previous research by developing a *continuum view* of procurement contracts. In this section, we further advance the literature by offering a continuum view of the costs associated with different contractual archetypes.

Table 1 shows that moving along the design flexibility continuum, from FP-w/o-change arrangements to T&M-w/o-cap arrangements, has implications for key project cost dimensions. Moreover, the Table implies that design flexibility is monotonically associated with these cost dimensions, so that increasing levels of design flexibility are associated with either increasing or decreasing levels of cost dimensions. In the following sections, we analyze the implications presented in Table 1 to identify a set of five project cost dimensions – coordination, control, trust, duration, and price – and to describe how they are associated with design flexibility. The complete research model developed and tested in the following sections is presented in Figure 1.

[Insert Figure 1 about here]

Coordination

Coordination is the management of dependencies among activities (Malone and Crowston, 1994), and it is central to the literature about procurement, outsourcing, and software engineering (Cataldo and Herbsleb, 2013; Dibbern *et al.*, 2008; Gopal *et al.*, 2011; Gulati *et al.*, 2005; Herbsleb *et al.*, 2006). Gulati *et al.* (2005) argue that coordination problems can persist even after cooperation is achieved because "cooperation problems are rooted in motivation, whereas coordination problems arise due to the cognitive limitations of individuals" (p. 419). Coordination is required either when environmental contingencies influence the terms and conditions of a transaction (Williamson, 1985), or when reciprocal interdependencies, such as

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3 ongoing decision making about task allocation and continuous communication, are needed
4 (Gulati *et al.*, 2005). Coordination in software development is achieved when different people
5 involved in a common project agree to a common definition of what they are building, share
6 information, and mesh their activities (Kraut and Streeter, 1995). Empirical studies have shown
7 that coordination is one of the most difficult and pervasive problems in development projects
8 (Herbsleb *et al.*, 2006). Coordination breakdowns can occur at different levels, including the team
9 level (related to system design and implementation) and the corporate level (related to product
10 attributes, schedules, and resources) (Curtis *et al.*, 1988). Such breakdowns in coordination
11 negatively affect the outcomes of software projects (Faraj and Sproull, 2000).

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Following these conceptualizations, we define coordination in procurement projects as a formal mechanism that enables both the client and the vendor to manage interdependencies among activities during the project. Such a mechanism should facilitate access to resources, information sharing, problem solving, and decision making. For instance, such a mechanism can allow the vendor to access users to get their feedback on partial deliverables, or allow the client to access the vendor's development team when design changes are required. Coordination differs from control, because the former focuses on managing interdependencies among individuals or activities, whereas the latter focuses on improving performance relative to the overall goal (Sabherwal, 2003).

We expect coordination to be more intensive as design flexibility increases. First, environmental contingencies are associated with coordination problems (Gulati *et al.*, 2005), and research has found that coordination is more difficult in software projects that are uncertain, unstable, or involve novel technical problems (Kraut and Streeter, 1995). Therefore, projects with high uncertainty, in which T&M contracts are more frequently used, should involve more intensive coordination. Second, FP contracts involve considerable coordination in the contract negotiation and drafting stage, whereas T&M contracts trade-off *ex ante* coordination for *ex post* coordination. The detailed specifications in FP contracts demand little coordination during the project. Conversely, the ongoing modification of specifications in T&M contracts requires substantial coordination beyond the formal contract. These two observations are also valid for the specific archetypes in our contractual typology. FP-w/o-change arrangements have the highest level of design completeness, and thus coordination is expected to be minimal in these arrangements. Because changes are not planned, coordination for change management is also not

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3 required. FP-w/-change arrangements are less stable because of the change provision, and they
4 require a higher level of coordination to identify opportunities for change and to manage its
5 consequences. Similarly, T&M-w/o-cap arrangements require more intensive coordination than
6 T&M-w/-cap arrangements as a consequence of the lower design completeness. As design
7 completeness diminishes, coordination mechanisms should be institutionalized to allow the
8 project to advance successfully.
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14 *Hypothesis 1: Design flexibility is positively associated with coordination.*
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17 **Control**

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19 Control refers to attempts by one individual or organization to motivate another to act in a
20 manner consistent with specific expectations and objectives (Ouchi, 1979). We focus on *formal*
21 *outcome control* rather than on informal or behavior control, because such control is central to
22 legally binding contracts governing procurement projects in general and software development
23 projects in particular (Choudhury and Sabherwal, 2003; Gopal and Gosain, 2011; Gregory *et al.*,
24 2013; Sabherwal, 1999). *Formal control* is exercised when targets are prespecified and rewards
25 are contingent on the achievement of targets (Eisenhardt, 1985). *Outcome control* involves the
26 definition of specific desired outputs, where the client explicitly defines goals and the vendor is
27 rewarded for meeting those goals (Kirsch *et al.*, 2002). The primary mechanism of formal
28 outcome control in external software development is the deliverable and payment schedules,
29 known as project milestones. Milestones are described as "the bedrock of successful software
30 development" (Roditti, 1998, p. 7-21), as they provide a mutually agreed upon sequence of
31 activities and results and allow the client to either accept or reject intermediate and final
32 deliverables (Roditti, 1998; Sommerville, 2000). Empirical studies have shown a positive
33 relationship between control and performance (Bartölke *et al.*, 1982). However, cost-benefit
34 considerations may limit the intensity of control, because milestones that are too close together
35 may cause the project team to spend much of its time preparing deliverables that are not essential
36 for the progress of the project (Sommerville, 2000). Empirical studies of the antecedents of
37 control have mostly tied sources of uncertainty to *types* of control, as in the relation of outcome
38 measurability and behavior observability to outcome and behavior controls (Eisenhardt, 1985;
39 Henderson and Lee, 1992).
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3 It becomes more difficult to define formal outcomes as design uncertainty increases.
4 Moreover, the definition of formal outcomes constrains the ability to introduce changes in the
5 progress of a project. Hence, the client is less motivated to control formal outcomes as design
6 flexibility increases. These two predictions lead to the following hypothesis:
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10 *Hypothesis 2: Design flexibility is negatively associated with control.*
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13 **Trust**

14 Trust is the expectation that alleviates the fear that an exchange partner will act opportunistically
15 (Bradach and Eccles, 1989). At the organizational level, firms develop close bonds with other
16 firms through recurrent interactions that create preferential and stable trading relationships
17 (Gulati, 1995). Trust becomes more important as uncertainty increases and as detailed contracts
18 and formal controls become more costly (Gefen and Reychav, 2014; Gefen *et al.*, 2008; Oshri *et*
19 *al.*, 2015). FP arrangements are characterized by low design uncertainty, and thus the risks of
20 unforeseen contingencies and vendor opportunism are small. FP arrangements are also
21 characterized by high design completeness, which facilitates formal control. Consequently, FP
22 arrangements are more likely to be used with relatively unfamiliar, less trusted vendors. In
23 contrast, T&M arrangements, as well as agile methodologies, are characterized by high design
24 uncertainty and low design completeness, and thus the risk of vendor opportunism is considerable
25 and formal controls are more difficult to implement. The result is that trust becomes critical
26 (McHugh *et al.*, 2012) and T&M arrangements are more likely to be used with trusted vendors.
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38 We hypothesize that our contractual typology also demonstrates this positive association
39 between design flexibility and trust, namely, we suggest that trusted vendors are more likely to be
40 contracted as design flexibility increases along the typology. FP-w/-change contracts include a
41 change provision that facilitates renegotiation. This provision increases the risk that the vendor
42 will take advantage of the client's new needs to opportunistically renegotiate higher prices or
43 reduced effort. Thus, we expect higher levels of trust in FP-w/-change arrangements than in FP-
44 w/o-change arrangements. T&M-w/-cap contracts include a price cap that limits the risk of cost
45 escalation. Therefore, we expect lower levels of trust in T&M-w/-cap arrangements than in
46 T&M-w/o-cap arrangements. Finally, Mixed arrangements should involve intermediate levels of
47 trust because they combine FP (less risky) and T&M (more risky) mechanisms.
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55 *Hypothesis 3: Design flexibility is positively associated with trust.*
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Duration

Duration is the estimated length of time for the procurement project, namely, it is the expected time period for the project at the time the contract is signed. The duration of a project has been found to influence outsourcing arrangements (Gefen *et al.*, 2016). In FP arrangements, the duration is defined clearly in the contract's binding deliverables schedule. In arrangements that include T&M mechanisms, duration is typically estimated and agreed upon by both client and vendor, but the estimate is not binding. We expect a positive association between design flexibility and duration. First, long-duration projects require more flexible arrangements because of the higher likelihood that the business and technological environment will change during the project. As a consequence of environmental turbulence, the longer the project is in progress, the higher the likelihood that business changes (e.g., mergers and acquisitions, strategic reorientation) or technological changes (e.g., emerging architectures and standards) will require design modifications in the software being developed. Second, more flexible arrangements require a longer duration because time compensates for uncertainty and design incompleteness. When uncertainty is high and design completeness is low, more time has to be allocated to the project to allow more degrees of freedom in accommodating the probable design adaptations. In developing Hypothesis 1, we discussed the positive association between design flexibility and coordination. Coordination mechanisms require time, and we expect arrangements with higher design flexibility to accommodate the need for more intensive coordination by allowing longer duration. FP-w/-change arrangements, for instance, should have longer duration than FP-w/o-change arrangements because of the time involved in coordinating changes and negotiating their implications. T&M arrangements should have longer duration than FP arrangements because of the time involved in ongoing coordination regarding the detailed software specification. Such a process may require input and approval from multiple stakeholders, which are time-consuming activities.

Hypothesis 4: Design flexibility is positively associated with duration.

Price

Price is the estimated monetary value of the procurement project at the time the contract is signed. The size of a software development project, which is reflected in its price, has a strong

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3 influence on the manner in which the project is managed (Sommerville, 2000) and on its
4 contracting terms in an outsourcing context (Fink and Lichtenstein, 2014). By definition, the
5 predetermined price in FP arrangements is binding. Conversely, the *ex ante* price in arrangements
6 that include T&M mechanisms is based on non-binding estimates of the expenses incurred by the
7 vendor. We anticipate a positive association between design flexibility and price. This association
8 is largely explained by the inclusion of a premium for uncertainty and design incompleteness in
9 the project price. Design adaptations are unlikely in FP-w/o-change arrangements, and therefore
10 their price need not include a premium for uncertainty and design incompleteness. A
11 renegotiation option is embedded in FP-w/-change arrangements, and their price should be higher
12 to reflect a premium for this option. The price of Mixed arrangements should be relatively high,
13 not only because of their partial T&M orientation, but also because of the additional effort and
14 resources involved in integrating the FP and T&M elements. The price of T&M-w/-cap and
15 T&M-w/o-cap arrangements should be high as a consequence of the significant premium for their
16 high uncertainty and low design completeness. This premium should be higher for T&M-w/o-cap
17 arrangements because of their higher uncertainty, which is reflected in the absence of a price cap.

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30 *Hypothesis 5: Design flexibility is positively associated with price.*

31 32 33 **Methodology**

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35 This section presents the research methodology by describing the research setting and the process
36 of data collection, including the measures used to proxy for the various cost dimensions. The next
37 section presents the procedures used to analyze the data and the results we obtained.

38 39 40 41 42 **Research setting**

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44 The research setting for this study is the financial services industry, which is considered to be
45 highly competitive, dynamic, and information intensive. This industry is the largest user of IT in
46 the industrial sectors (Zhu *et al.*, 2004) and tends to have the highest IT investment risk (Dewan
47 *et al.*, 2007). While almost all industries are currently influenced by digital technology, banking
48 is at the forefront of digital competitive pressures (e.g., Fintech), significant regulatory changes,
49 and opportunities for new efficiencies (Constâncio, 2016). We collected data on SDAs in a
50 leading international bank. The bank, headquartered in Europe, is among the largest in the world.
51 It provides retail and commercial banking, wealth management, and investment banking in
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dozens of countries and has tens of thousands of employees. The bank's IT department employs about 3,000 permanent employees and 2,000 contractors.

The bank's systems are either developed in-house, by internal staff complemented by external consultants and programmers, or they are developed through SDAs. The bank contracts out system development through about 100 local and international vendors. Its methods of managing SDAs are typical of other banks and large institutions. The bank maintains a software acquisition process that includes eight main steps: request for proposals (RFP), vendor evaluation, vendor selection, negotiation, closure, fulfilment, extension, and cancellation. The bank aims at using its standard SDA contracts wherever possible. The standard contract is similar to contract forms described in the literature (e.g., Kutten, 1988; Pearson, 1984). This contract is about 10 pages in length, excluding appendices for scope and schedule. The contract itself includes a definition of its purpose and content, the vendor's obligations, scope changes, acceptance testing, warranty and guarantee, expenses and payment terms, training, ownership of intellectual property, breach penalty, liability, confidentiality and data protection, and prohibition against enticement or employment of bank staff. The appendices describe project scope, milestones, payment details, the bank's obligations, and project organization. The standard contract also defines actions to be taken if the schedule is not maintained, which include either setting a new schedule or the option of canceling the contract. The bank's contracting guidelines permit changes to the standard contract within defined limits.

Data collection

This study continues the recent trend toward the quantitative analysis of contractual provisions in actual outsourcing contracts (e.g., Argyres *et al.*, 2007; Chen and Bharadwaj, 2009). 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 quantitative data from the bank's contract repository. Each record in the repository represented a single contract and included the contract number, start and end dates, contract price, vendor name, and an electronic scan of the contract. 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 a representative sample of 270 contracts, which formed our dataset.

We followed a systematic scheme to categorize the contracts into the five archetypes in our contractual typology. The distinction between FP and T&M contracts was explicitly stated in the contracts. We classified contracts as Mixed when they combined both FP and T&M arrangements. Pure FP contracts were classified as either FP-w/-change, if they included a change provision (i.e., a specific clause with explicit change management principles and guidelines, describing procedures for change requests, for analyzing their impacts, and for renegotiation discussions), or FP-w/o-change, if such a provision was not included. Contracts that were pure T&M were classified as either T&M-w/-cap, if they included a price cap (i.e., a predetermined maximum price), or T&M-w/o-cap, if such a cap was not included. Among the 270 contracts in our dataset, there were 42 FP-w/o-change, 139 FP-w/-change, 32 Mixed, 14 T&M-w/-cap, and 43 T&M-w/o-cap arrangements.

Cost dimensions were evaluated as follows. *Coordination* was operationally defined as the frequency of routine meetings between client and vendor representatives defined in the contract. Coordination was assigned a value of '0' when regular meetings were not defined in the contract, a value of '1' when regular monthly meetings were defined, or a value of '2' when regular bi-weekly or weekly meetings were defined. *Control* was operationally defined as the intensity of milestones specified in the contract. Control intensity was calculated as the sum of the numbers of payment, delivery, and project milestones, divided by contract price. Payment milestones were taken as those milestones at which a portion of the price was due. Delivery milestones were taken as delivery dates at which a work package had to be delivered to the client without a payment. Project milestones were neither payment nor delivery milestones; rather, they represented defined end-points in the progress of the project. They could describe certain compulsory meetings, client sign-off of specification documents, or the end of internal testing. *Trust* was operationally defined as client-vendor familiarity (Gefen *et al.*, 2008), which was measured with two variables. The first variable was vendor experience, which we calculated as the accumulated price of previous contracts signed with the same vendor after January 2000 (in all 424 contracts signed during the period we studied). The second variable was vendor locality, which was a dichotomous variable that indicated whether the vendor was international ('1') or local ('2'). *Duration* was operationally defined as the number of days between the contract's start date and its expected completion date, as recorded in the contract repository. This value represented the duration of the project as contracted between the bank and the vendor. *Price* was defined as the total price of the contract

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3 in U.S. dollars. The price of each contract was copied as explicitly stated in the contract. This
4 value represented the binding price for FP contracts or the estimated price for T&M contracts.
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6 To control for project size, we used two scope dimensions, which served as proxies for the
7 size of the software product being developed. The first dimension was *external scope*, which was
8 operationally defined as the number of external scope documents (e.g., requirements, system
9 specifications, and system design documents) referred to in the contract. The second dimension
10 was *total scope*, which was operationally defined as the extent of both internal and external scope
11 documents. This dimension could be awarded a value of '0' (no scope documents), '1' (one non-
12 detailed internal scope document), '2' (1-2 scope documents), '3' (3-4 scope documents), '4' (5-9
13 scope documents), or '5' (10 or more scope documents). All measures used in this study were
14 objective and involved no subjective judgment. Descriptive statistics are presented in Table 2.
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23 [Insert Table 2 about here]

24 Results

25 We used three statistical methods to test the five hypotheses about the associations between
26 design flexibility and cost dimensions – coordination, control, trust (vendor experience and
27 vendor locality), duration, and price. First, we used a one-way analysis of variance (ANOVA) to
28 test for differences among the five contractual archetypes for each cost dimension. The mean
29 values of cost dimensions across contractual archetypes and ANOVA results are presented in
30 Table 3. The ANOVA results were statistically significant at the 0.001 level (the F value for
31 duration was significant at the 0.01 level), indicating that there were significant mean differences
32 among contractual archetypes for all cost dimensions. Second, we used a Spearman correlation
33 analysis as an initial test of the hypotheses because the design flexibility scale was ordinal. This
34 analysis also minimized the effect of outliers. Spearman's rho values, also presented in Table 3,
35 were all statistically significant at the 0.001 level. They were all in the hypothesized direction –
36 positive for coordination (0.347), vendor experience (0.307), vendor locality (0.349), duration
37 (0.259), and price (0.358), and negative for control (-0.297).
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49 [Insert Table 3 about here]

50 We then repeated these analyses with the two scope dimensions as the dependent variables.
51 The results of these analyses are presented in Table 4. The ANOVA results were statistically
52 significant at the 0.001 level for both external scope and total scope. However, these effects were
53 the consequence of one archetype having significantly higher scope values than other archetypes:
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scope values were higher in Mixed contracts than in other archetypes. A Spearman correlation analysis, which tested whether design flexibility was associated with scope dimensions, showed no statistically significant correlation for either external scope ($\rho = -0.007$, $p = 0.905$) or total scope ($\rho = 0.078$, $p = 0.199$). These results rejected the possibility that design flexibility confounded with scope and enhanced the validity of our findings concerning the correlations between design flexibility and cost dimensions.

[Insert Table 4 about here]

Last, we performed six separate regression analyses to examine the effects of design flexibility, external scope, and total scope on each of the six cost dimensions. Because of the different types of dependent variables (i.e., cost dimensions), three different regression methods were used: (a) four ordinary least-squares (OLS) regression models estimated the effects of design flexibility and scope dimensions on control, vendor experience, duration, and price (continuous variables); (b) an ordinal regression model estimated the effects of design flexibility and scope dimensions on coordination (ordinal variable); and (c) a logistic regression model estimated the effects of design flexibility and scope dimensions on vendor locality (binary variable). A common approach in previous studies has been to use the log of variables that measure duration or monetary value because of their skewed distribution (e.g., Chen and Bharadwaj, 2009; Ethiraj *et al.*, 2005). We therefore used the log of vendor experience, duration, and price in the OLS models. The results of the regression analyses are presented in Table 5 (OLS regression models) and Table 6 (ordinal and logistic regression models). The results showed that design flexibility had a significant effect in the hypothesized direction in all six models – the regression coefficients of design flexibility were -0.043 for control, 0.251 for vendor experience, 0.065 for duration, 0.169 for price, 0.565 for coordination, and 0.699 for vendor locality. These effects of design flexibility on cost dimensions were all statistically significant at the 0.001 level. In contrast to design flexibility, external scope had no significant effect in any of the six models, and total scope had a significant effect only on price, with a coefficient of 0.189 ($p < 0.01$).² Taken together, the correlation and regression findings showed

² To ensure that our findings were not due to the log transformation of vendor experience, duration, and price, we reran the OLS models with the original values of these variables. The results were consistent with the findings for the log values – the regression coefficients of design flexibility were 1,210,742 for vendor experience ($p < 0.001$), 21.947 for duration ($p < 0.01$), and 39,364 for price ($p = 0.05$). The only significant effect of scope dimensions on cost dimensions was that of external scope on price, with a coefficient of 61,288 ($p < 0.001$).

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3 that design flexibility was associated with all cost dimensions, and that scope dimensions were
4 not associated with either design flexibility or cost dimensions (except for the effect of total
5 scope on price). Based on these findings, we concluded that all five hypotheses were supported
6 by the data collected in this study.
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10 [Insert Table 5 about here]

11 [Insert Table 6 about here]

12 Discussion

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17 Software development remains a complex task to outsource and, therefore, it continues to be a
18 suitable context for analyzing the nuances of flexibility, coordination, control, and trust in formal
19 contractual arrangements. In this study, we show that five contractual archetypes have evolved to
20 provide a continuum of design flexibility and that moving along this continuum is associated with
21 multiple project costs. Our findings shed light on the ability of firms to align flexibility with
22 uncertainty at the onset of new projects and on their incentives for doing so. Firms respond to
23 design uncertainty by seeking design flexibility. However, the need for design flexibility is
24 balanced by the need to minimize project costs. As the variance of uncertainty increases, these
25 conflicting needs should drive firms to break away from the prevailing typology of procurement
26 contracts as either FP or T&M and move toward a broader set of contractual archetypes.
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35 The contractual data we collected confirm that the proposed contractual typology does
36 indeed exist in practice. While some archetypes are employed more frequently than others – with
37 FP-w/-change being the most frequently used (51.5%) and T&M-w/-cap being the least
38 frequently used (5.2%) – all five archetypes defined in this study are unambiguously and
39 repeatedly detectable in the data. Furthermore, data analysis supports all five hypotheses. It
40 shows that higher flexibility is associated with higher coordination, lower control, higher trust
41 (vendor experience and locality), longer duration, and higher prices. It also shows that these
42 associations cannot be explained by scope differences across the archetypes.
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50 However, the significant associations between design flexibility and cost dimensions are not
51 reflected in every transition from one archetype to another for every cost dimension. While data
52 analysis illustrates that costs do increase with increasing design flexibility, we find particular
53 instances in which making a transition from an archetype with lower design flexibility to an
54 archetype with higher design flexibility does not have the hypothesized effect. This observation is
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3 more marked at the high end of the design flexibility continuum. The typology suggests that the
4 inclusion of a price cap in a T&M contract should have a limiting effect on project costs.
5 However, this hypothesized effect was not found consistently in our data. A plausible explanation
6 for this finding is based on the relatively small number of T&M-w/-cap contracts in the data (14
7 contracts). Such a number makes it difficult to draw firm conclusions about the cost differences
8 between T&M-w/-cap and T&M-w/o-cap contracts. The finding that T&M-w/-cap contracts
9 constituted the smallest share of the contracts in the data (5.2%), considerably smaller than that of
10 T&M-w/o-cap contracts (15.9%), may imply that when clients opt for T&M contracts, their
11 default choice is not to constrain the vendor's flexibility. In contrast, data analysis provides
12 stronger support for the hypothesized effects at the low end of the design flexibility continuum.
13 Our findings confirm that the inclusion of a change provision in an FP contract is sufficiently
14 significant to increase project costs.
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24 The Mixed archetype exhibits the most unexpected pattern of costs. The typology regards
25 this archetype as representing an intermediate level of design flexibility between the two
26 relatively inflexible FP archetypes and the two relatively flexible T&M archetypes. An
27 assumption underlying the typology is that a design flexibility continuum requires that FP and
28 T&M archetypes should not remain mutually exclusive. For a continuum to exist, there should be
29 an archetype that combines the different mechanisms into a single arrangement. Accordingly, we
30 expected Mixed contracts to be associated with intermediate levels of project costs. The results
31 show that the cost pattern of Mixed contracts is somewhat similar to that of the two T&M
32 archetypes. Moreover, price is highest in Mixed contracts. We propose two explanations for these
33 results. First, it may very well be that Mixed contracts are more flexible than we think. The
34 ability to mix FP and T&M mechanisms in a variety of combinations may yield flexible
35 arrangements that bring together the advantages of both mechanisms. Mixed contracts may
36 therefore be both the most flexible and the most costly. Second, Mixed contracts are frequently
37 an aggregation of several phases or sub-systems. The upside of this archetype is that it allows
38 different levels of design completeness to coexist within a single contract. Its downside lies in the
39 additional effort and complexity involved in bridging and integrating the different arrangements.
40 The relatively high costs associated with Mixed contracts may be the consequence of this
41 additional complexity. This explanation is supported by our findings that both scope dimensions
42 are significantly higher in Mixed contracts than in other archetypes.
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Theoretical contributions

This study uses the theoretical lenses of contract theory and software engineering to construct and test a contractual typology for software development. It therefore contributes to both streams of research. The study makes an important contribution to the general literature on procurement contracts (Bolton and Dewatripont, 2005; Hart and Holmstrom, 1985), particularly contractual arrangements aimed at software development. The contractual typology developed in this study is founded on a continuum perception of design uncertainty, completeness, and flexibility, which is conceptually distinct from the prevailing dichotomous perception of these concepts. To develop this continuum perception, we do not reject the traditional distinction between FP and T&M procurement contracts. On the contrary, we rely on this distinction in our proposition that archetypal variations of FP and T&M contracts have evolved to provide a continuum of design flexibility between the extreme levels of design flexibility characterizing these two dominant archetypes. This continuum perception of design flexibility and the ensuing contractual typology are novel. They have emerged from a conceptual analysis of the existing literature as well as from our extensive familiarity with the contractual mechanisms that are employed to adapt SDAs to environmental changes. We consider this perceptual change, which is supported by our empirical investigation, to be a valuable contribution to the state of the art. An implication of this perceptual change for research is that contractual nuances, such as the inclusion of a change provision in a contract, have important consequences for project performance. Researchers should pay careful attention to such minor variations when analyzing projects and contracts, as their identification and consideration can be helpful in understanding incentives and risk sharing in outsourcing arrangements.

Another important contribution comes from the multidimensional analysis of project costs associated with design flexibility. Many previous studies have focused on a single cost dimension as the endogenous effect of project characteristics (e.g., Rustagi *et al.*, 2008; Sabherwal, 2003). While such an approach has been valuable in unveiling the mechanisms that explain significant variance in project performance, it has not advanced our understanding of how multiple cost dimensions change in concert. This limitation is addressed in the present study, which explores the consequences of moving along the design flexibility continuum in terms of coordination, control, trust, duration, and price. The multidimensional approach taken in this study illustrates

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3 the trade-off between coordination and control. Hypotheses 1 and 2 describe the associations of
4 design flexibility with coordination and control, respectively. These hypotheses and their
5 underlying rationales suggest that coordination and control are substitutes in SDAs. Control,
6 defined here as an outcome-oriented concept, is a more effective interaction mechanism in
7 arrangements with low design uncertainty and high design completeness, i.e., where deliverables
8 are easier to define and less susceptible to change. In contrast, coordination, defined here as a
9 behavior-oriented concept, is a more effective interaction mechanism in arrangements with high
10 design uncertainty and low design completeness, i.e., where deliverables are harder to define and
11 more susceptible to change. This important observation about the substitutability of coordination
12 and control could not have emerged without a multidimensional approach to the implications of
13 design flexibility.
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24 **Practical implications**

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26 The present study offers insight into how adaptability is sustained in contracting for software
27 development. It is in this insight that the main practical implications of this study lie. Given the
28 trend toward the external acquisition of IT resources and the emergence of new business models
29 based on these resources, the management of relationships with IT vendors is a major challenge
30 facing managers (Applegate *et al.*, 2009; Gewald and Schäfer, 2017). The ability of managers to
31 meet this challenge is, in part, contingent upon their ability to design and use contractual
32 mechanisms that maximize the alignment between the environmental and structural
33 characteristics of their external relationships. However, with the increasing gap between the
34 complexity of contemporary business environments and the simplicity of prevailing contractual
35 arrangements, it is inevitable that many external relationships will fail to achieve their objectives.
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44 Firms increasingly find themselves in a situation of having to rely on external arrangements
45 to develop software, on the one hand, and having to adapt software resources to frequent
46 environmental changes, on the other hand. Those firms that rigidly use a single contractual
47 archetype or a narrow set of contractual archetypes may find that the variety in their environment
48 exceeds the repertoire of their potential actions. This gap may lead to low design flexibility (if FP
49 contracts alone are used), high project costs (if T&M contracts alone are used), or a failure to
50 balance design flexibility and project costs (if only FP and T&M contracts are used). The use of a
51 broader set of contractual archetypes may allow firms to improve the cost effectiveness of design
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3 flexibility. As demonstrated in the present study, such a broader typology does not have to be
4 formally defined at the organizational level. It may be based on variations of established
5 archetypes, as long as these variations are used consistently to increase the design flexibility of
6 constraining arrangements or reduce the design flexibility of costly and risky open-ended
7 arrangements, thus creating a continuum of design flexibility. This study shows that including a
8 change provision in FP contracts, including a price cap in T&M contracts, and mixing FP and
9 T&M mechanisms generate such a broader typology along a continuum of design flexibility. The
10 change provision and price cap are important for the construction of a broader typology because
11 they address the major risks associated with FP and T&M contracts and thus moderate their
12 extreme levels of design flexibility. Employing such a broader typology is a prerequisite to being
13 able to align flexibility with uncertainty for each new project. Overall, this study provides insight
14 into the contractual mechanisms that can allow clients to have SDAs with different levels of
15 flexibility, improving their capability to outsource (Pratap, 2014).
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28 **Limitations and future research**

29 This study has two major limitations, which restrict the generalizability of its findings, yet offer
30 avenues for future research. First, the data were collected in a single organization. While the bank
31 that granted us access to its contractual data is among the largest in the world, it is fair to assume
32 that its outsourcing and contracting practices have been shaped to some extent by the national
33 culture (Barthelemy and Geyer, 2001) and the existing organizational culture. This limitation
34 offers an interesting direction for future research. The logic of this study suggests that firms in
35 rapidly changing environments need to use a broader set of contractual archetypes. This logic
36 implies that firms in relatively stable environments may use a narrow set of one or two
37 contractual archetypes. Our research setting suggests that the breadth of contractual archetypes
38 needs to be higher in industries that are characterized by high levels of information intensity and
39 environmental turbulence, such as finance and digital media, but lower in industries that are less
40 information intensive and turbulent, such as manufacturing (Yap *et al.*, 2016). Future research
41 could employ a multi-site design to explore the relationship between environmental uncertainty
42 and dynamics, on the one hand, and the breadth of the contractual typology practiced, on the
43 other hand. Second, the data were collected from the bank's contract repository at a single point
44 in time. Therefore, the data are correlational in nature. Moreover, some of the cost dimensions,
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3 particularly duration and price, are based on project estimates rather than actual project
4 performance. The internal validity of the flexibility-cost relationship in SDAs should be further
5 demonstrated by additional research, designed to collect both contractual data and project
6 performance data. Finally, another direction for future research can be the relation between agile
7 software development methodologies (Dingsøy *et al.*, 2012) and formal contracting. As agile
8 methods have become increasingly popular, addressing the issues discussed in this paper in the
9 context of these methods can be a promising avenue for research on software development
10 outsourcing.
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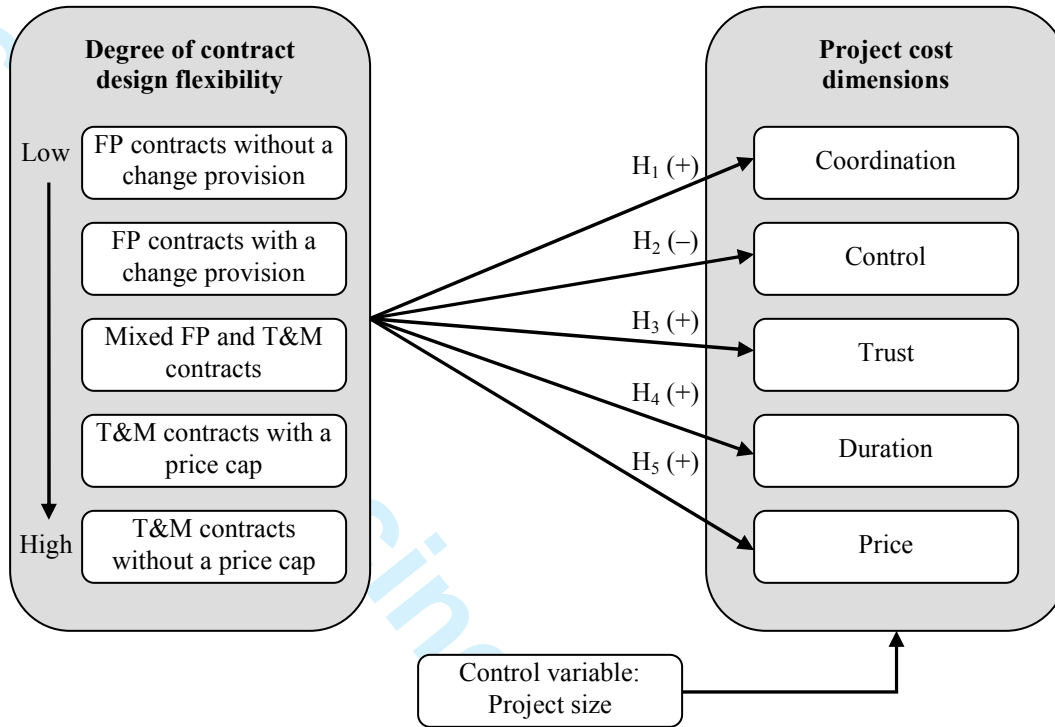


Figure 1. Research Model

Table 1. Implications of Contractual Archetypes Based on Software Engineering and Contract Theory Perspectives

Archetype	Software engineering perspective	Contract theory perspective
FP contracts without a change provision (FP-w/o-change)	<ul style="list-style-type: none"> ▪ High level of design completeness ▪ Structured software engineering methodologies ▪ Less coordination needed ▪ Control maximized to reveal quality problems early ▪ Good cost estimation 	<ul style="list-style-type: none"> ▪ Risk allocated mainly to vendor ▪ Competitive bidding ▪ High familiarity and trust not needed ▪ Relatively high likelihood of selecting foreign vendors ▪ Intensive control as a substitute for trust ▪ Vendor has incentive to shorten duration ▪ Minimal premium for uncertainty
FP contracts with a change provision (FP-w/-change)	<ul style="list-style-type: none"> ▪ High level of design completeness ▪ Structured software engineering methodologies 	<ul style="list-style-type: none"> ▪ Risk allocated mainly to vendor ▪ Somewhat higher familiarity and trust needed because of the renegotiation option ▪ Price should reflect a premium for the renegotiation option
Mixed FP and T&M contracts (Mixed)	<ul style="list-style-type: none"> ▪ Intermediate level of design completeness ▪ Semi-structured software engineering methodologies ▪ T&M fits early stages (high uncertainty) and FP fits late stages (low uncertainty) ▪ Control intensity should be related to the relative scale of FP and T&M arrangements 	<ul style="list-style-type: none"> ▪ Risk shared between vendor and client ▪ Price expected to be relatively high because Mixed contracts are an aggregation of several phases or sub-systems ▪ Familiarity and trust needed because of T&M segments
T&M contracts with a price cap (T&M-w/-cap)	<ul style="list-style-type: none"> ▪ Low level of design completeness ▪ Unstructured software engineering methodologies ▪ Price cap limits project escalation ▪ High coordination required ▪ Lower control intensity ▪ Longer duration to allow for experimentation, user feedback, and changes 	<ul style="list-style-type: none"> ▪ Risk allocated mainly to client, but vendor bears some risk because of the price cap ▪ High familiarity and trust needed
T&M contracts without a price cap (T&M-w/o-cap)	<ul style="list-style-type: none"> ▪ Low level of design completeness ▪ Unstructured software engineering methodologies ▪ Significant risk of project escalation ▪ High coordination needed ▪ Control minimized ▪ Longer duration 	<ul style="list-style-type: none"> ▪ Risk allocated mainly to client ▪ Familiarity and trust very important ▪ Relatively low likelihood of selecting foreign vendors

Table 2. Descriptive Statistics (N=270)

	Minimum	Maximum	Mean	Std. dev.
<i>Cost dimension</i>				
<i>Coordination</i> – Frequency of routine client-vendor meetings defined in the contract (0 = not defined; 1 = monthly meetings; 2 = bi-weekly/weekly meetings)	0	2	0.37	0.71
<i>Control</i> – Intensity of milestones specified in the contract (sum of payment, delivery, and project milestones, divided by contract price)	0	2.28	0.098	0.211
<i>Vendor experience (trust)</i> – Accumulated price of previous contracts with the vendor (in thousands of U.S. dollars)	\$0K	\$21,037K	\$4,426.36K	\$5,883.42K
<i>Vendor locality (trust)</i> – Whether the vendor was international or local (1 = international; 2 = local)	1	2	1.79	0.41
<i>Duration</i> – Period of time between the contract's start date and its completion date (in days)	3days	880days	189.60days	143.30days
<i>Price</i> – Total price of the contract (in thousands of U.S. dollars)	\$2K	\$3,490K	\$315.65K	\$474.77K
<i>Scope dimension</i>				
<i>External scope</i> – Number of external scope documents referred to in the contract (numeric)	0	33	2.02	3.80
<i>Total scope</i> – Extent of both internal and external scope documents (0 = no documents; 1 = one undetailed internal document; 2 = 1-2 documents; 3 = 3-4 documents; 4 = 5-9 documents; 5 = 10 or more documents)	0	5	2.43	0.90

Table 3. ANOVA and Correlation Results for Cost Dimensions

Archetype	Cost dimension					
	Coordination	Control	Vendor experience (trust)	Vendor locality (trust)	Duration	Price
(1) FP-w/o-change	0.05	0.246	\$406.02K	1.33	129.45days	\$169.64K
(2) FP-w/-change	0.24	0.091	\$4,594.00K	1.86	182.70days	\$284.01K
(3) Mixed	0.94	0.051	\$5,754.38K	1.94	230.45days	\$632.00K
(4) T&M-w/-cap	0.86	0.038	\$3,690.79K	1.93	242.46days	\$321.36K
(5) T&M-w/o-cap	0.51	0.026	\$7,062.47K	1.86	222.49days	\$323.61K
<i>F</i> (ANOVA)	12.441***	7.845***	8.380***	20.999***	3.590**	4.983***
<i>Rho</i> (Spearman)	0.347***	-0.297***	0.307***	0.349***	0.259***	0.358***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; two-tailed p values are reported.

Table 4. ANOVA and Correlation Results for Scope Dimensions

Archetype	Scope dimension	
	External scope	Total scope
(1) FP-w/o-change	1.02	2.02
(2) FP-w/-change	1.91	2.49
(3) Mixed	5.50	3.25
(4) T&M-w/-cap	0.79	2.07
(5) T&M-w/o-cap	1.16	2.16
<i>F</i> (ANOVA)	9.403***	12.137***
<i>Rho</i> (Spearman)	-0.007	0.078

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; two-tailed p values are reported.

Table 5. Results of OLS Regression Models

Variable	OLS regression model			
	Control	Log (vendor experience)	Log (duration)	Log (price)
Intercept	0.293*** (0.053)	5.374*** (0.232)	1.847*** (0.091)	4.175*** (0.150)
Design flexibility	-0.043*** (0.010)	0.251*** (0.043)	0.065*** (0.017)	0.169*** (0.028)
External scope	0.000 (0.005)	0.018 (0.022)	0.007 (0.009)	0.023 (0.014)
Total scope	-0.036 (0.021)	0.085 (0.093)	0.053 (0.037)	0.189** (0.061)
<i>F</i>	8.642***	13.504***	8.325***	28.202***
<i>R</i> ²	0.089	0.161	0.091	0.243
Adjusted <i>R</i> ²	0.079	0.149	0.080	0.234

Note. Unstandardized coefficients are shown with standard errors in parentheses.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; two-tailed p values are reported.

Table 6. Results of Ordinal and Logistic Regression Models

Variable	Ordinal regression model	Logistic regression model
	Coordination	Vendor locality (trust)
Intercept		-1.319 (0.813)
Design flexibility	0.565*** (0.116)	0.699*** (0.171)
External scope	0.114 (0.073)	0.396 (0.222)
Total scope	0.351 (0.283)	0.273 (0.405)
$\chi^2(3)$	46.318***	42.492***
Log likelihood	-88.353	-116.589
Pseudo <i>R</i> ² (Nagelkerke)	0.209	0.228

Note. Estimated coefficients are shown with standard errors in parentheses.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; two-tailed p values are reported.