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DESIGNING THE BUYER–SUPPLIER CONTRACT FOR RISK MANAGEMENT: ASSESSING COMPLEXITY AND MISSION CRITICALITY

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In this study, we argue that contract design is a predominant strategy to set contractual expectations among supply chain partners to manage risk. We draw upon resource dependence theory and transaction cost economics to suggest that variation in risk management strategies is dependent upon both the complexity of the procured product or service and the extent to which it is mission critical. In this preliminary study of public-sector supply chains, we find evidence based on an analysis of over 240,000 buyer–supplier contracts that when both mission criticality and service complexity are low, suppliers tend to bear most of the disruption risk by agreeing to fixed-price contracts. When mission criticality is high, we find that the federal government is more likely to share risk with suppliers by utilizing incentive contracts. Evidence suggests that cost-reimbursement and incentive contracts are preferred when service complexity is high.

Keywords: *contract design; risk assessment, legal and regulatory issues; secondary data; econometric modeling*

INTRODUCTION

Supply chains are complex in at least two fundamental aspects—the complexity or complicatedness of the product, and challenges of information exchange across different organizations (Flynn & Flynn, 1999; Galbraith, 1973, 1977; Vachon & Klassen, 2002). Supply chains are dynamic, adaptive systems that can be difficult to both predict and control (Carter, Rogers & Choi, 2015). Numerous issues can arise both within the supply chain and external to it, and as such, supply chain disruptions are unavoidable (Ellis, Shockley & Henry, 2011). Markets can be volatile, in terms of either the resources required in the manufacturing of a product or the stability of demand for the final good, and this volatility can reduce the stability of the supply chain. Further, there may be communication challenges between supply chain partners, or some actors in the chain may violate the expectations of their partners (Zsidisin, 2003). At a more external level, complications can come from a variety of sources such as geopolitical factors or natural disasters. Whatever the case, information will always be incomplete, which makes committing resources to production risky, particularly if those investments are highly specific to the product in question (Williamson, 2008). In short, as products become more complicated and as more actors with diverse goals become involved in the production of some good or service, coordination becomes more difficult.

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These disruptions can be, and often are, addressed ex post, but partners also try to anticipate the types of disruptions that may occur while designing or negotiating the terms of the contract (Smeltzer & Siferd, 1998). Risk management, or turning attention to the potential for supply chain disruptions proactively, is a common way for managers to deal with uncertainty (Monczka, Handfield, Giunipero & Patterson, 2016). While there are a number of methods through which ex ante action can be taken, it is common for the formal contract to set the framework for how the inevitable disruptions that arise can be managed (Kleindorfer & Saad, 2005). This framework can specify responsibilities and accountability standards (i.e., monitoring), but it can also specify how disruptions will be managed when they occur; in short, the contract sets the expectations of how risk will be shared between supply chain partners. At the simplest level, in a dyadic relationship the buyer may bear the most risk, the supplier may, or risk can be shared by the parties, and these specifications are determined in the development of the contract (Wever, Wognum, Trienekens & Omta, 2012).

Our interest is in a domain where we know little about supply chain risk management approaches: public management. We conceive of a public-sector supply chain as a physical structure of nodes and links connecting suppliers to the customer, where the government is the ultimate customer. Not unlike private-sector supply chains, a network of nodes is linked to provide a relative product, and each node in the supply chain has power over its performance and accountability (Carter et al., 2015). Yet more prevalent in public-sector supply chains is the reliance on formal contracts to govern production (Eckerd & Eckerd, 2016). To date, risk management approaches in the public-sector contracting realm have usually framed risks in terms of transaction costs related to monitoring or potential supplier opportunism (Brown & Potoski, 2006). While these are certainly aspects of supply chain risk, there are many considerations of risk that extend beyond monitoring costs and opportunism, including issues common in private-sector supply chains such as delays, shortages, systems outages, or disasters (Chopra & Sodhi, 2004). We build upon the work of Hajmohammad and Vachon (2016), who draw from resource dependency theory to propose a typology of risk mitigation strategies depending upon the nature of perceived buyer risk and the dependence structure of the relationship. In this research, we apply this model to the public-sector context, asking how risk is managed in public-sector supply chains and, further, whether there are differences in risk management depending on the potential impact of that risk for achieving organizational missions or whether the final products or services are more or less complex. We contend that public-sector supply chain risk management primarily occurs ex ante given the highly regulated nature of government procurement, and that distributing risk among the parties is largely dependent upon the complexity and mission criticality of the procured product or service.

Our study contributes to the study of supply chain management in a number of ways. First, we situate our study in the context of public procurement by analyzing data from the U.S. federal government, which is one of the world's biggest buyers, procuring over 5,000 different types of products and services (Brown 2013). In 2014, over $445B in contracts was obligated to private firms (accounting for approximately 2.5% of GDP). The sheer magnitude and importance of the government as a buyer underscores the need to better understand public-sector supply chains, which is underrepresented in supply chain research (Straight, 1999; Walker, Di Sisto & McBain, 2008). Further, we assess risk management techniques in an industry where risk cannot be assessed strictly on financial terms. While there are certainly nonfinancial aspects of risk in private-sector supply chains (Zsidisin, 2003), and there are financial considerations in public-sector supply chains, financial considerations are likely to be secondary for mission-based organizations (Frumkin & Galaskiewicz, 2004), particularly in governments where revenues are (generally) derived not through commercial activity but through a political legislative process. As such, our study contributes to a deeper understanding of supply chain risk management in highly regulated markets and markets where financial considerations may not be paramount. Next, we utilize an emerging conceptual model (Hajmohammad & Vachon, 2016) to assess risk management strategies under shifting contingencies of complexity and mission criticality. Finally, we examine contract type in our assessment of risk management strategies. We underscore the importance of studying the type of contract utilized in the supply chain (Gopal & Koka, 2010), particularly as an ex ante risk management strategy.

The paper proceeds as follows. First, we establish the context of the study by identifying the unique features of public-sector supply chains. Given the often highly asset specific and technical nature of many of the services that governments procure and the power issues that can arise with a dominant buyer and low number of suppliers, we next establish our theoretical frames by assessing risk management strategies and contract design choices in public-sector supply chains, drawing from transaction cost economics and resource dependence theory. We describe the data, method, and measures used in the study, and then move to address the empirical findings. Finally, we conclude

by discussing the management and policy implications of the research.

PUBLIC-SECTOR SUPPLY CHAINS

In addition to the common disruption risks noted in the introduction, public-sector supply chains are also subject to some distinct risk factors associated with the political system, legal institutions, bureaucratic processes, and geopolitics, in addition to product and service factors such as highly specific products and measurement complexity (Brown, Potoski & Van Slyke, 2006; Dixit, 2002). While managers take care of daily supply chain tasks, a public-sector supply chain is ultimately controlled by political authorities who decide to either allocate resources for the purchase of the goods or services in the supply chain or not. In some cases there is no functional market for the goods procured and political actors' responses to events are often unpredictable. Some public-sector supply chains, for things such as accounting services or janitorial work, may be relatively resilient to external events, while others, such as aerospace or military procurement, may reside in highly turbulent environments (Peck, 2005).

Public-sector supply chains are also highly regulated. At the federal government level, contracts are subject to the Federal Acquisition Regulation (FAR), which aims for contracting uniformity across the federal government. The FAR comprehensively covers the contract lifecycle (from preaward market research to contract management postaward), administration, socioeconomic programs, and supplier-related regulations. For example, suppliers are required to comply with "Buy American" policies, meet stringent cost accounting standards, and adopt unique health, safety and environmental protocols. Because of the extent of these formal requirements, those seeking government contracts must spend significant time and effort ensuring compliance with FAR regulations, potentially limiting the pool of potential suppliers. The general context of the public sector creates a distinct setting for studying supply chain management. We see at least four important distinctions: the political environment, the idiosyncratic nature of many of the goods that are secured in public-sector supply chains, a host of secondary policy goals, and the distinct characteristics of the government as the buyer.

Public managers face distinct circumstances in managing supply chains because the ultimate authority is not the market but rather the political environment (Hartmann, Roehrich, Frederiksen & Davies, 2014). Although in day-to-day management politics might not be the overriding concern of public contract management, neither is cost (Templin & Noffsinger, 1994). Owing to the complex environment of public-sector decision making and the often esoteric nature of the public goods and services that are produced, although always *a* goal, cost efficiency is not always going to be *the* overriding goal (see also Roehrich, Lewis & George, 2014; Zheng, Roehrich & Lewis, 2008). In the private sector, an efficiently operating supply chain that is producing a product that meets a market demand is likely in a good position to be resilient (Tang, 2006), but in the public sector this may or may not be the case. New political authorities may gain control and opt to pursue other priorities or a shock in some other policy area may convince policymakers to shift resources away. Moreover, wholly inefficient supply chains may thrive in the public sector if the good or service being produced is valued by powerful actors or if the production process benefits powerful actors (Eckerd & Snider, 2017; Kim & Brown, 2012).

This is not to say that the cost efficiency of the supply chain and the quality of the end product are unimportant, but the overriding goal may be ensuring that the supply chain is buffered from external volatility, protecting the less clear notions of public value than specific notions of cost efficiency (Kivleniece & Quelin, 2012; Moore, 1995). For some public products and services, cost efficiency and product/service quality are likely good buffering techniques in that they are producing a good or service that has wide political support. In more politically turbulent areas maintaining the support of key political actors may be more important, or it may be best to stay "off the radar" as much as possible. In other words, the interests of the principals in political environments may be fickle, and public-sector contract managers may have to manage a variety of expectations from actors who are external to the direct interests of the organizations involved. Frumkin and Galaskiewicz (2004) find that public managers tend to be more externally focused in their management decisions than private managers are. Governmental organizations "[lack] a single stakeholder group to monitor the organization" such as a board of directors or investors (Frumkin & Galaskiewicz, 2004: 289). As such, public managers, as compared with business organizations" are more likely to embrace external referents of accountability to legitimate their operations," and "should be more susceptible to institutional pressures and more likely to be swayed by exposure to environmental pressures that promise an organization greater legitimacy" (Frumkin & Galaskiewicz, 2004: 289).

A second distinction centers on the nature of the goods and services procured in government supply chains. While many of the services purchased by governments are not complex (such as janitorial services), many are quite idiosyncratic, found only in other public supply chains, if at all. This means that there is

often considerable internal supply chain risk owing to the high level of asset specificity that might be required of suppliers to produce goods or services for the government and the technical complicatedness of these goods and services may require numerous subcontractors and sources of suppliers for the final product, with each relationship adding complexity to the management of the supply chain (Eriksson, 2015). There may also be very few potential suppliers for complex goods, limiting the choices available to contract managers (Brown et al., 2006; Girth, Hefetz, Johnston & Warner, 2012). While asset specificity and limited contractor options are not unique to the public sector (Lonsdale, 2001), the end goals of the procurement process are much more uncertain, which further complicates the determination of supply chain performance.

A third distinction of public-sector supply chains is the preponderance of secondary policy goals that affect contract choices. As noted above, the key goals of particular public-sector supply chains are not easily defined, but even beyond these key goals, there are a number of broad public policy goals that are expected of government procurement. Suppliers may be required to be located within the jurisdiction; for example, national security procurement may be limited to American companies and those companies may not be permitted to utilize assets for any purpose other than the goods procured by the federal government. In addition, many contracts are subject to set-asides that are intended to serve some broader public policy goal that has little to nothing to do with the focal contract, such as preferences for small businesses, or firms owned by women, minorities or veterans.

Finally, public-sector supply chains are distinct given the nature of the buyer. The government as buyer alters the nature of a supply chain in several ways beyond those noted above. When the government is a buyer in a particular market, it can have a tendency to control the nature of the market, whether by being able to dictate the terms of contract agreements, or by ensuring domestic protection of the industry itself (Green, Fernie & Weller, 2005). Put simply, the government is in a dominant position (Hartmann et al., 2014; Kivleniece & Quelin, 2012). In particularly narrow industries, such as aerospace or defense products, government may be the only buyer, likely giving government purchasers a distinct advantage in contract negotiations. In fact, governments, and the federal government in particular, rarely negotiate the type of contract (Feldman, 1990). While the specific terms of the deal can be negotiated, the federal government typically posts a request for proposals (RFP) that describes the nature of the work and expected terms, giving government power over the most basic nature of the agreement. Suppliers are less apt to influence governance structures when government is a buyer, as past contract choices are more likely to predict structures (Kivleniece & Quelin, 2012). Further, in highly technical areas, there may be mutual dependence, with government being the only buyer and only one or a few potential suppliers. The classic example of these markets exists in the "military industrial complex," potentially resulting in situations where large industries capture the relationship and dictate the terms of agreements (Leitzel, 1992). However, the potential for the political process to address the situation is always possible, maintaining some level of mutual dependence in the market.

Suppliers are willing to cede this power and enter markets where governments dominate because governments rarely refuse to pay the amounts stipulated in the contract (Feldman, 1990). Further, with the full faith and credit of the law behind the buyer, contractors can have confidence that government will not default or be unable to adhere to the terms of payment, and once a supplier receives a government contract it is more likely to have the contract renewed and to receive additional contracts (Roehrich et al., 2014; Thompson, 2011). Thus, even for products that are not complex, where government may not offer the highest bids for services, the process of bidding for a government contract can be worthwhile given the low risk of buyer default.

RISK MANAGEMENT IN PUBLIC-SECTOR SUPPLY CHAINS

One key difference between risk management in public-sector supply chains is the restriction on the ability of governments to manage risk ex post. As noted above, the terms and regulation of public-sector contracting are relatively strict. Although contract managers possess more discretion than implied by the FAR, they are still constrained by a legal orientation to adhere to the terms of the written contract (Brown et al., 2006; Cohen & Eimicke, 2008). Indeed, while public-sector supply chain managers utilize informal tools for risk management, they tend to rely on the terms of the written contract when supply chain disruptions occur (Eckerd & Eckerd, 2016). Risk management in the public sector is therefore more likely to be an ex ante consideration than an ex post. That is, the risk management approach will be part of the contract design process rather than an adaptive management process that occurs after a disruption. We expect the nature of the contract and the implied distribution of risk exposure to frame the risk management strategy.

Despite this key difference, we see several corollaries to existing supply chain management theory. Drawing on literature assessing the relative power of buyers

and suppliers, we take a resource dependence perspective (Salancik & Pfeffer, 1978) particularly noting results in industries with one or few buyers (Cox, Sanderson & Watson, 2001). In buyer-dominated markets, the buyer tends to control the market in terms of the technical requirements and, through the process of supplier selection, determines who is permitted to enter the market (Holmlund & Kock, 1996). In these markets, buyers control the terms of the agreements, and indeed the context of the entire market. Buyers would be willing to bear risk only in situations where there are a limited number of suppliers, in which case the buyer will likely be willing to share disruption risk with the supplier (Cox et al., 2001). In either case, when a buyer has power (either in the form of dominance of many suppliers or interdependence with one or a few suppliers), the basis of that power rests on the asset specificity needed for production (Williamson, 2008). This asset specificity can be conceived as the literal assets required for production, or as the administrative capacity required bidding for and managing government contracts.

In these circumstances where assets are sufficiently specific that power imbalances will arise but not so specific that production is brought in-house, the situation requires what Williamson (2008) refers to as hybrid contracting. Simply stated, there are three potential approaches a buyer can take in managing the contract: muscular, benign, or credible. A muscular buyer utilizes its market power to dictate the terms of the contract and place risk with the supplier. A benign buyer prefers a cooperative approach and will likely bear risk as a means of protecting suppliers. A credible approach rests in between; a buyer will recognize and utilize its market power, but offer protection to suppliers. The credible approach is adaptive and focuses on developing a framework for an appropriate sharing of risk. We expect that under most circumstances, governments act as dominant buyers and can employ these three different strategies.

Second, we see a similarity with supply chains in which buyers have considerations that are beyond to the usual considerations of cost, timeliness, and the quality of inputs. While there are many potential circumstances where these additional considerations are important, the literature provides the most guidance with respect to supplier sustainability or environmental standards. Government buyers will certainly consider the nature of environmental effects of inputs, but as noted above, these considerations may be extended to labor requirements (i.e., using local suppliers), small business, minority or women owned firms, or even general adherence to "public interest." Given our interest in public-sector supply chains generally, we are not concerned with the particulars of sustainability practices, but rather take cues from this literature in terms of how buyers manage the risk of suppliers violating noncost requirements to avoid the potential fallout from stakeholders (Foerstl, Reuter, Hartmann & Blome, 2010; Hofmann, Busse, Bode & Henke, 2014)—which in the federal government context may be Congress, the President, or the media.

Specifically, we build on the model developed by Hajmohammad and Vachon (2016) who draw on resource dependence theory to derive a typology of risk mitigation strategies that buyers employ to deal with supplier sustainability risk. Hajmohammad and Vachon (2016) propose a set of four strategies depending upon the nature of perceived buyer risk and the dependence structure of the relationship ranging from monitoring and collaboration when buyers have at least some power, to risk avoidance or acceptance when suppliers have power.

As illustrated in Figure 1, we conceive of this typology slightly differently with government as the buyer. Most basically, as we noted above, risk management in the public sector is mostly an ex ante exercise, and thus, the risk management approach is generally about determining how the contracting parties will distribute the risk burden. Most simply, government can place all the risk on the supplier, take on all the risk itself, or the parties can share risk. While there are situations of supplier dominance of government, when we would expect government to bear all of the risk, we expect these to be comparatively rare, and even in situations where government is but one of

FIGURE 1
The Supply Manager's Choice among Risk Management Strategies

		Product/Service Complexity	
		High	***Low***
Mission criticality	*High*	Government bears risk	Shared risk, government onus
	Low	Shared risk, supplier onus	Supplier bears risk

Note: Adapted from Hajmohammad and Vachon (2016)

many buyers and there is a lone supplier, a government can always internalize production if it chooses to do so. While the politics might be challenging, the costs of entry into a market are unlikely to sway a government, particularly the federal government, from bringing production in-house to avoid a supplier-dominated market. Thus, government is unlikely to ever need to fully internalize risk in a supply chain because it always has the option to accept risk by producing in-house.

Additionally, we conceive of perceived risk differently given the public-sector context. Public managers are notably risk averse (Bellante & Link, 1981; Dong, 2014), so perceived risk is likely proportional to how important the purchased input is perceived to be. In government parlance, this is referred to as mission criticality. The risk of disruption and thus of external attention will be greater when an input is mission critical. Mission-critical needs are salient across the domain of the public sector; while disruptions in noncritical areas may well garner unwanted attention, disruptions in mission-critical areas almost certainly will heighten political attention. Consider the implementation of healthcare.gov, the online portal designed to facilitate consumer access to the federal health insurance exchanges. The rollout of the federal health insurance exchanges was dependent upon a fully operational consumer-facing website. Because of the mission criticality of the product, the buyer, the U.S. Department of Health and Human Services, and the suppliers within the supply chain that were failing to deliver a functional system, were subject to intense political and public scrutiny.

We also conceive of dominance slightly differently. While dominance can be thought of as the dyadic level of resource dependence between the parties, governments will never be purely resource-dependent, even in a market with one supplier and many buyers. With the power of the purse, governments can raise resources in a variety of different ways and although they may be loath to raise taxes or user fees, they can do so. Thus, the level of dominance may be less important than the amount of flexibility that governments possess. For more complex products, there will likely be fewer and more specialized suppliers. Governments will have two expensive alternatives—bring production in-house or raise revenues to meet supplier demands. For less complex products, there are likely many suppliers and in addition to the option of bringing production in-house, government can likely find alternate suppliers. Hence, the competitive environment, dictated in large part by the complexity of the product itself, can affect government's willingness to bear disruption risk.

We therefore expect government to manage supply chain disruption risk as illustrated in Figure 1. For products with low complexity and low mission criticality, government buyers will follow the muscular (Williamson, 2008) or risk-avoidance (Hajmohammad & Vachon, 2016) risk management approach. In these circumstances, there are likely many possible suppliers and the need is not critical so government can shift the burden of risk onto the supplier. In the inverse situation, when both service complexity and mission criticality are high, governments are in more of a dependent position and will likely follow a more benign, monitoring-based approach. Again, there are unappealing options for government to remove its dependence, but it will likely be willing to accept some level of risk, provided that the supplier is acting according to expectations. The other two cases are expected to be variations on the government's willingness to share risk. With high complexity, but low mission criticality, a collaboration-based (or credible) approach may be employed. In these cases, government may be in a position of dependence and thus willing to bear some risk, but will also want to share that risk with the supplier. Finally, with high mission criticality but low complexity, government may be willing to accept more risk than in the previous scenario, but still expect the supplier to bear its fair share as well.

CONTRACT CHOICE AS RISK MANAGEMENT

One of the key ways to manage risk is through the governance of the supply chain relationship (Folta, 1998) and specifically through the structuring of the contract between supply chain partners. There are two general types of contracts, the formal or written contract and the informal or relational contract (Poppo & Zenger, 2002). The relational contact is the ongoing establishment and reinforcement of norms between contracting partners that can be used to facilitate the resilience of the supply chain (Ring & Van de Ven, 1994), but our interest here, given the nature of government contracting, is with respect to the design of the formal contract which better represents an ex ante risk management strategy (Monczka et al., 2016).

In public-sector contracting, there are four general approaches to a formal contract, each representing different approaches to dealing with risk. Although there are many variations of these three different types of contracts, a contract falls under an umbrella of being a fixed-price, incentive, time and materials, or cost-reimbursement structure. A *fixed-price* contract is just that—the government will propose a price that it is willing to pay for some good or service, and solicit bids from suppliers to provide the good or service. Fixed-price contracts are often short term in nature and place relatively few constraints on suppliers.

However, with a predetermined price, fixed-price contracts shift risk primarily to the supplier. Fixed-price contracts are typically used for well-defined requirements and when suppliers are experienced (U.S. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, 2014). With fixed-price contracts, suppliers are incentivized to perform efficiently (Banerjee & Duflo, 2000), but there is usually no additional remuneration for any extenuating circumstances.

Under *cost-reimbursement* contracts, the government will propose a good, service, or task and solicit bids, reimbursing the supplier for the costs incurred in the delivering the product. In this type of contract, the government reimburses the supplier for relevant costs regardless of the actual amount of a service received. Because government is simply reimbursing the supplier's costs, risk is borne primarily by the governmental buyer. Any extenuating circumstances are paid for by the government and there is no particular incentive for suppliers to be efficient, although there will almost certainly be clauses for dealing with wasteful or fraudulent practices on the supplier's part. In federal contracting, cost-reimbursement contracts are most commonly used for research and development procurements (U.S. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, 2014).

Incentive contracts are in between; there will be some minimum commitment of funds provided by the government and services rendered by the vendor, and if the supplier exceeds that minimum, then the supplier receives additional money (or conversely if the supplier fails to meet expectations, there may be sanctions). Incentive contracts, which allow suppliers to earn an additional fee based on meeting specified cost, performance, or delivery metrics, is characterized as a risk-sharing position. The supplier bears the risk of sanctions should it not meet the minimum requirements, which can be subjective, and the government bears some risk by potentially reimbursing the supplier for units beyond the minimum. However, although risk is shared to an extent, clearly the supplier failing to meet minimum requirements places it in a riskier position than the government paying additional costs for production beyond the minimum. Appropriate incentives can be difficult to define for complex service procurements and so incentive contracts are less desirable for these acquisitions (U.S. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, 2014; see also Brown, Potoski & Van Slyke, 2013).

Time and materials contracts are another commonly used type of contract, but are referred to as the contract of last resort (Piper, 2008). They limit reimbursement to direct inputs of production, rather than the full breadth of indirect administrative costs associated with production (Kim & Brown, 2012). Time and materials are preferable when the buyer needs flexibility but the supplier has little incentive to optimize efficiency as they are compensated for inputs (Roels, Karmarkar & Carr, 2010). These contracts are again a risk-sharing approach, but with the balance of risk shifted to the government and away from the supplier, primarily because suppliers are only required to put forth their "best effort" (Piper, 2008). Governments pledge to remit payment for all time and materials for direct production regardless of extenuating circumstances. The risks for suppliers are the indirect costs related to the production.

The contract that is chosen offers a view of the supply chain risk management strategy as noted in Figure 2. A fixed-price contract can be viewed as representing government dictating the market and putting the onus of risk on the supplier. This provides the supplier with flexibility on how the task gets done, but if there are any disruptions the risk falls on the supplier who agreed to provide a certain amount of some product for the specified price. If disruptions occur and the contract is deemed unsatisfactory, the government can simply find a different supplier.

H1: When a supply chain is based on a product that is neither complex nor mission critical, fixed-price contracts will be favored to place the onus of risk on the supplier.

In situations where the product is both complex and mission critical, we expect that suppliers will be less willing to bear this risk. By internalizing risk with the buyer, governments can enable suppliers' willingness

FIGURE 2
Supply Chain Risk and Contract Design Choice

		Product/Service Complexity	
		High	***Low***
Mission criticality	*High*	H2: Cost Reimbursement	H3: Time and materials
	Low	H4: Incentive	H1: Fixed price

to shoulder the costs of highly specific assets and ensure a relatively stable supply of a needed product. There is clear potential for mutual benefit; suppliers face less risk knowing that investment costs will be recouped, while the government saves resources by not having to manage the highly specific assets required.

H2: When a supply chain is based on a product that is both complex and mission critical, cost-reimbursement contracts will be favored to place the onus of risk on the buyer (government).

We expect that the choice of contract type when complexity and criticality are mixed to be variations of risk sharing between the contracting partners. Given the importance of mission in public organizations, we expect that under mission-critcal conditions, government will be willing to bear comparatively more risk even with products that are not complex, but will expect suppliers to bear at least some risk.

H3: When a supply chain is based on a product that is low complexity, but is mission critical, time and materials contracts will be favored to share risk, but with the buyer taking on comparatively more risk than the supplier.

Finally, in cases where products have high complexity but are not mission critical, we expect government to share risk, but to place comparatively more onus on the supplier.

H4: When a supply chain is based on a product that is high complexity, but is not mission critical, incentive contracts will be favored to share risk, but with the supplier taking on comparatively more risk than the buyer.

DATA AND METHOD

Data

We test our hypotheses using public-sector contracts data from federal agencies in the United States, derived from the Federal Procurement Data System-Next Generation (FPDS-NG), the only comprehensive source of unclassified federal contracts. The FAR requires that contract officers record in FPDS-NG contract actions exceeding $3,000 in value. Further, the Federal Funding Accountability and Transparency Act of 2006 requires federal contracts be catalogued in a searchable, publicly accessible website (usaspending.gov). As a result, this dataset offers an exclusive opportunity to study supply chain risk. The data provide unique insight into the contractual relationship between government purchasers and suppliers, containing data on contractual characteristics, the competiveness of the market, place of performance, and the like. Private-sector contracting data of this magnitude are unlikely as private firms have no obligations to publicly report data of this nature. The data setting is subject to accurate and complete data entry. The variables included in this analysis are among the most stable over time.

The unit of analysis in this study is the supply chain dyad of a buyer (the federal government) and a supplier. Because FPDS-NG captures all contract actions, including when the contract is initiated and subsequent modifications, we execute a process of aggregating the data for each individual contract action associated with a specific contract. For example, contract A is initiated and is subsequently modified three times. One modification might increase the initial value of the contract from $30,000 to $50,000. One modification might be a time extension of the contract from 12 months to 13. The final modification might deobligate funds associated with the contract by $5,000. As a result, the value of Contract A is ultimately $45,000 and the time duration is 13 months.

In this analysis, our data are comprised of 268,089 contracts from 22 service areas. Federal agencies purchase goods and services using two industry categorizations: North American Industry Classification System (NAICS) and the Product Services Code (PSC). Table 2 lists the contracts included in this analysis and their corresponding NAICS and PSC classification. All of the contracts selected in this sample are designated as procurements for services. The sample encompasses all completed unclassified contracts for these PSC/NAICS over a 15-year period from fiscal year 2000–2014.[1]

Measures

Dependent Variable. Our outcome of interest is a key aspect of how supply chain managers deal with risk: the dyadic choice of the type of formal contract that governs the relationship. The dependent variable *contract pricing type* is a nominal variable and is coded 1 if the contract is a fixed-price contract (specified in FPDS-NG as fixed-price redetermination, fixed-price level of effort, firm fixed-price, fixed price with economic price adjustment); 2 if the contract is an incentive contract (specified in FPDS-NG as fixed price

[1]We selected contracts on these criteria and initially captured 274,440 contracts in FPDS-NG from over 70 cabinet-level agencies and independent agencies. The number of contracts by agency during this time period ranged from 1 to 138,141. We eliminated contracts from all agencies with less than 1,000 contracts during this 15-year time period for the 22 services selected, resulting in 268,089 contracts in the sample.

TABLE 1

Dependent Variable: Contract Pricing Type

Contract Pricing Type			
Fixed Price	**Incentive**	**Cost Reimbursement**	**Time and Materials**
212,977	1,616	27,863	25,633
79.44%	.60%	10.39%	9.56%

incentive fee, fixed price award fee, cost plus incentive fee, cost plus award fee); 3 if the contract is a cost-reimbursement contract (specified in FPDS-NG as cost no fee, cost sharing, cost plus fixed fee); and 4 if the contract is a time and materials contract (specified in FPDS-NG as time and materials, labor hours). The variable is derived directly from FPDS-NG and was coded nominally (1–4) to represent the type of contract design. Table 1 reports the distribution of the dependent variable.

Explanatory Variables. We examine *service complexity* using complexity measures developed by Kim, Roberts and Brown (2016). We use the results of their survey of federal acquisition professionals, which determined ease of measurement and specialized investment ratings. Their combined factors are reported in a product/*service complexity* rating in Table 2, which corresponds to our service complexity measure across 22 services.[2]

We operationalize *mission criticality* by capturing the potential interest and saliency of the supply chain with political representatives as contract value. As mission criticality increases, public purchasers will be driven to contract pricing types that share or redistribute risk to ensure stable flow of services for functions that are viewed as critical for the organizational mission. *Mission criticality* is the logged value of total dollars obligated to the contract. This is measured in real dollars with 2014 as the base year. Although we acknowledge that contract value is not a perfect measure of mission criticality, it is a clear proxy for political interest; higher dollar value contracts are subject to additional oversight, particularly during times of tight budgets, and are more likely to be managed at higher levels of the bureaucracy (Eckerd & Snider, 2017). Although the perception of mission criticality is likely to be idiosyncratic and with thousands of different contracts and hundreds of different agencies, there is unlikely to be one clear way to measure this important variable. Nevertheless, we expect greater political interest and attention to the contract as contract value increases, which may result in selecting different contract pricing types. To illustrate, as acquisition costs of a Department of Defense contract increase, so do the requirements for decision authority within the agency. Statutorily required Congressional reporting is also triggered by heightened acquisition costs per the Defense Federal Acquisition Regulation Supplement to the FAR.

Control Variables. We control for several factors that can influence the relationship between supply chain risk and contract pricing type. Market factors, such as the number of qualified suppliers, are perceived as a source of supply chain risk (Zsidisin, 2003). Contract type can also be affected by the competitiveness of the market (Gopal, Sivaramakrishnan, Krishnan & Mukhopadhyay, 2003). We measure competition in three ways. First, we capture the *number of bidders* on the contract. *Number of bidders* is the logged value of the total number of offers received for the contract recorded in FPDS-NG. Second, we control for whether the contract is categorized as a *set-aside*. *Set-aside* is coded 1 if the contract is a set-aside (e.g., small business, economically disadvantaged business owned by women or veterans, disabled veteran owned, and HUB zone) or 0 if the contract was not designated as a set-aside contract. Set-aside contracts are contract design tools aimed at leveling the competitive environment for otherwise disadvantaged firms, yet they also restrict the supplier market. Each contract in FPDS-NG is designated as a set-aside or not, and a particular type of set-aside is assigned (as noted above). For purposes of this analysis, we aggregated set-asides into one category to compare them against non-set-aside contracts. Third, we include a control for *solicitation type* to measure whether the contract was bid as full and open competition or restricted. FPDS-NG contains the type solicitation for each contract. We coded 1 if unrestricted and 0 if restricted. The most common type of restricted

[2]Kim et al. (2016). surveyed members of the National Contract Management Association, which is a membership organization for public procurement officials. Respondents rated service complexity by assessing ease of measurement and specialized investment, both on a 5-point scale (5 = high, 1 = low). The combined mean of these two measures was used to derive the service complexity score. The measures of product characteristics used to create the service complexity scale are well established in the extant literature (e.g., Brown & Potoski, 2005; Hefetz & Warner, 2012; Levin & Tadelis, 2010).

TABLE 2

Product Categories and Complexity Scores

Product Category	PSC	NAICS	Number of Contracts	Service Complexity
Solid waste collection	S205	562111	17,804	3.08
Landscaping	S208	561730	37,609	3.16
Laundry and dry cleaning	S209	812320	8,008	3.26
Janitorial service	S201	561720	46,634	3.30
Court reporting	R606	561492	18,914	3.51
Warehousing and storage	S215	493110	2,034	3.61
Security guard and patrol	S206	561612	25,303	3.77
Advertising	R701	541810	5,306	4.43
Auditing	R704	541211	2,149	4.77
Legal service	R418	541110	8,480	4.97
Professional and management training	U008	611430	12,118	5.02
Equipment maintenance and repair	J099	811310	5,924	5.22
Program management and support	R408	541611	11,496	5.62
Logistics support	R706	541614	3,113	5.63
Program review and development	R409	541611	615	5.87
Engineering	R425	541330	55,365	6.76
Computer system development	D302	541512	4,038	7.58
Weapons—basic research	AC51	541710	565	7.60
Defense aircraft—basic research	AC11	541710	880	7.94
Defense aircraft—engineering development	AC14	541330	122	8.46
Weapons—applied R&D	AC52	541710	659	8.60
Defense aircraft—applied R&D	AC12	541710	990	8.66

solicitation is one that is sole sourced. While these three constructs are related, they are distinct measures of competition. Statistical correlations among the three variables range from .17 to .39, the latter represents the correlation between the solicitation type and the log of the number of offers received.

We control for *contract length*, which is measured as the total length of the contract in years. Presumably, a longer term contract provides the opportunity for the relational contract to develop more fully, which could affect the choice of the formal, written contract (Provan & Gassenheimer, 1994). We also include a control for *supplier contract count*. That is, we control for the supplier's number of contracts within these 22 service markets and this subset of agencies as a proxy for supplier experience. This variable is measured as the logged value of the number of contracts the supplier had the prior year as reported in FPDS-NG. The variable is lagged one year to account for the potential for contract type to be influenced by contract activity in the previous fiscal year.

We include *year* dummy variables to correspond to the fiscal year of the earliest contract action associated with each contract. This is typically the year the first agreement was signed, which is also when the contract pricing type is established. This allows us to control for unobserved policy and/or political changes that might affect contract pricing type. We also include *agency* dummy variables for each of the agencies included in the model. These include: the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security, Interior, Justice, Labor, State, Transportation, Treasury, Veterans Affairs, and the Environmental Protection Agency, Office of Personnel Management, Social Security Administration, General Services Administration, and National Aeronautics and Space Agency.

Table 3 provides descriptive statistics for each of the independent variables.

Method

Given the nonordinal categorical nature of our dependent variable, *contract pricing type*, we use a multinomial logistical regression model to test our hypotheses. We estimate preferences for incentive contracts compared to fixed-price contracts, cost-reimbursement contracts compared to fixed-price contracts,

TABLE 3

Independent Variables: Descriptive Statistics

Independent Variable	Mean	Std Dev	Min	Max
Service complexity	4.509	1.510	3.08	8.66
Mission criticality	8.309	4.787	0	21.376
Number of bidders	1.177	.792	0	6.908
Set-aside	.330	.470	0	1
Solicitation type	.700	.458	0	1
Contract length	1.817	1.629	1	16
Supplier contract count	2.196	1.790	0	7.131

and time and materials contracts compared to fixed-price contracts. Relative-risk ratios are reported for ease of interpretation. Relative-risk ratios and standard errors are generated using a clustering technique to obtain robust standard errors. Standard errors are clustered at the broader independent delivery vehicle (IDV) level (or the unique contract level if the contract is not part of an IDV). Numerous delivery or task orders, each a unique contract, often fall under one broader IDV. Examples of IDVs include blanket purchase agreements, federal supply schedules, and task and delivery order contracts that are government-wide or multi-agency agency contracts. Although these contracts are unique purchases, they are acquired using the same guidelines and pricing associated with the IDV. Because these contracts are similarly structured, we need to account for the similarities among these unique, but associated contracts. As a result, standard errors are clustered at the IDV level. Approximately 10% of contracts were missing set-aside data; the model is ultimately restricted to 241,600 contracts.

While we utilize data for contracts from 2000 to 2014, the dataset does not have a panel or time series structure. Each contract is discrete, and while a contract may undergo modifications during the period of study, the data do not track contract performance over time. With each contract being discrete, we cannot conceptually organize the data in a panel format, as doing so would require aggregation to a higher unit of analysis, such as the IDV-year or agency-year level. With a discrete choice of contract type for each dyadic contract mechanism, there is no meaningful way to aggregate up to the IDV or agency level. The dataset is thus best thought of a pooled cross section of contracts. We ran several variations of the models, including fixing effects at both the year and agency level, with postestimation results indicating that controlling for year of contract initiation was necessary.[3]

FINDINGS

We expect a high level of supply chain risk to be indicated by high mission criticality and high service complexity. In this instance we expect to see cost-reimbursement contracts favored (H2). When service complexity is high but mission criticality is low, we expect to see incentive contracts favored, sharing supply chain risk (H4). When service complexity and mission criticality are low, we expect fixed-price contracts to be favored (H1). When service complexity is low and mission criticality is high, we expect time and materials contracts to be favored (H3). We therefore compare each of the other contract types to fixed-price contracts, which are the most prevalent type of contract selected by far, with nearly 80% of the contracts in our data being fixed price. The results of the multinomial regression analysis are reported in Table 4.

Incentive Contracts

As expected, when *service complexity* is high, incentive contracts are favored over fixed-price contracts. That is, contracts for procurements with high *service complexity* are 2.52 times as likely to be incentive contracts than fixed-price contracts. *Mission criticality* is also statistically significant, suggesting that as contract value increases so too does the preference for incentive contracts over fixed-price contracts; however, the effect is much smaller. When *mission criticality* is high, incentive contracts are 1.12 times as likely as fixed-price contracts. We also compare incentive contracts to cost-reimbursement and time and materials contracts. To do this, we compute relative-risk ratios with varying base categories for the two explanatory variables: *mission criticality* and *service complexity*. Results are reported in Table 5. We find evidence that incentive contracts are favored over other contract types when

[3]While we contend that the multinomial model best fits our conceptual argument, to assess the sensitivity of the model, we tested our outcomes in two different ways. We assessed an ordered logit model to test the conceptual argument and coded the dependent variable contract type, by level of risk, as: 1 = fixed price, 2 = incentive, 3 = time and materials, and 4 = cost reimbursement. We found that as complexity and mission criticality increase, risk bearing also increases, consistent with the results of our multinomial model. We also wanted to test for potential time trends. Second, to account for time and agency trends, we collapsed the data into a panel, by agency-year, and the mean ordinal contract type dependent variable, as a proxy for the agency's willingness to take on risk during a given year. The results are also consistent with our multinomial model.

TABLE 4

Multinomial Logit Analysis

	Fixed-Price Contract Versus					
	Incentive Contract		Cost-Reimbursement Contract		Time and Materials Contract	
Independent Variable	RRR	Rob Std Err[a]	RRR	Rob Std Err[a]	RRR	Rob Std Err[a]
Explanatory variables						
Service complexity	2.516***	.222	4.607***	.287	2.453***	.082
Mission criticality	1.118***	.046	1.055***	.007	1.052***	.007
Control variables						
Number of bidders	.977	.086	.654***	.060	1.109**	.050
Set-aside	.801	.254	.831	.139	.648***	.074
Solicitation type	2.141***	.550	1.956***	.268	1.015	.087
Contract length	1.217***	.045	1.116***	.022	1.146***	.019
Supplier contract count	1.192**	.100	1.544***	.063	1.398***	.040
Constant	.000***	.000	.000***	.000	.000***	.000

N = 241,600; χ^2 = 217,291.25***; Pseudo-R^2 = .42; *p < .10, **p < .05, ***p < .01; two-tailed tests. [a]108,951 clusters at the IDV-PIID level. Year and agency dummies not shown.

TABLE 5

Relative-Risk Ratios

	Contract Pricing Types			
Risk Factors	Incentive Rather than Fixed-Price Contract	Incentive Rather than Cost-Reimbursement Contract	Incentive Rather than Time And Materials Contract	Cost-Reimbursement Rather than Time And Materials Contract
Service complexity	2.516	.546	1.026	1.878
Mission criticality	1.118	1.124	1.127	1.003

mission criticality is high. When *mission criticality* is high, incentive contracts are 1.12 times as likely as cost-reimbursement contracts, and 1.3 times as likely than time and materials contracts. We also see that when *service complexity* is high, incentive contracts are favored over time and materials and fixed-price contracts; however, cost-reimbursement contracts are preferred for the most complex services. When *service complexity* is high, incentive contracts are 1.03 times as likely as time and materials contracts, and 45 percent less likely than cost-reimbursement contracts. We only find partial support for hypothesis 4—consistent with *service complexity* but not *mission criticality*. We find *solicitation type* is more likely to be full and open compared to fixed-price contracts. We find a statistically positive relationship between *contract length* and incentive contracts compared to fixed-price contracts. We also find that suppliers with incentive contracts are more likely to have a higher *contract count* than those with fixed-price contracts.

Time and Materials Contracts

When *service complexity* is high, time and materials contracts are preferred over fixed-price contracts. Indeed, time and materials are used for the least complex contracts, second only to fixed-price contracts. When *service complexity* is high, time and materials contracts are 2.45 times as likely as fixed-price contracts. Time and materials contracts are favored over fixed-price contracts when *mission criticality* is high, as hypothesized. When *mission criticality* is high, time and materials contracts are 1.05 times as likely as fixed-price contracts. Time and materials contracts do not appear to be utilized for the most *mission-critical* contracts, as hypothesized. As such, our results only partially support hypothesis 3. We also see that all *set-*

aside and *number of bidders* reach levels of statistical significance. Set-asides are less likely for time and materials contracts and these contracts have higher numbers of bidders compared to fixed-price contracts. We find a statistically positive relationship between *contract length* and *supplier contract count* for time and materials contracts compared to fixed-price contracts.

Cost-Reimbursement Contracts

Again, as expected, when *service complexity* is high, contracts are more likely to be cost-reimbursement than fixed-price contracts, and more likely than all other contract types. When *service complexity* is high, cost-reimbursement contracts are 4.61 times as likely as fixed-price contracts. They are also 1.88 times as likely as time and materials contracts when *service complexity* is high. Cost-reimbursement contracts also have a higher *mission criticality* than fixed-price contracts; however, not as high as incentive contracts, only partially supporting hypothesis 2. When *mission criticality* is high, cost-reimbursement contracts are 1.05 times as likely as fixed-price contracts. Compared to fixed-price contracts, cost-reimbursement contracts are favored in situations with lower *number of bidders*, *solicitation type* that is full and open, when there is a higher *supplier contract count* and when *contract length* is longer.

Fixed-Price Contracts

Fixed-price contracts are preferred when both *service complexity* and *mission criticality* are lowest. The results support hypothesis 1.

DISCUSSION

Risk is one of the hidden costs of outsourcing (Sanders, Locke, Moore & Autry, 2007). Buyers and suppliers make supply chain management choices to mitigate and elucidate risk based upon the extent to which risk disruption exists within and external to the supply chain. In this research, we argued that the characteristics of supply chain risk would, in part, predict the preferences regarding the nature of the formal contract that governed buyer–supplier relationships in the public sector. We find some support for these hypotheses, but some results are also mixed.

Our study suggests that contract design is used to anticipate and manage disruptions to the supply chain based on the complexity of the procured services. That is, in all cases, our hypotheses related to service complexity were supported. Our evidence is less clear on risk management strategies associated with mission criticality. Among the least complex services, fixed-price contracts are used. We hypothesized that incentive contracts would be more likely when mission criticality was low and that cost-reimbursement contracts were more likely when mission criticality was high, and yet our findings suggest that incentive contracts are used most often when mission criticality is high, contrary to our expectations.

There appears to be a preference for risk sharing when the procured service is among the most mission critical. We do note that this result could reflect another consideration when contracts are high dollar value. Managers may attempt to buffer the supply chain from external political scrutiny by structuring it as an incentive contract rather than cost reimbursement. That is, it seems plausible that Congress may focus more attention on the potential for problems arising in cost-reimbursement scenarios than incentive scenarios, and our indicator variable simply measures whether or not an incentive contract is selected, not the nature or structure of that incentive.

We also see evidence that these considerations might be affected by the nature of the relationship between the contracting partners. In all cases, when contract lengths are longer, all contract types are favored over fixed-price contracts, suggesting that the longer the contract the more willing the government is to shoulder risk. Although length of time is an insufficient proxy, this may indicate that like other types of supply chains, as contracting partners work together longer, the relational contract is able to strengthen, mitigating the need to specify risk in the formal contract (Eckerd & Eckerd, 2016). We also find evidence that the greater number of contracts that suppliers have, the more likely they are to have contract types that shift risk onto the government. That is, as suppliers' contract count increases, the likelihood that they will have incentive, cost-reimbursement, or time and materials contracts also increases. This might indicate that past contract experience with the agency and/or for particular services strengthens the relational contract between supply chain partners and the government is more willing to bear risk.

Policy and Managerial Implications

Our study shows that mission-critical services are most likely to be procured using risk-sharing contractual approaches. While we expected that government would bear risk (via cost-reimbursement contracts) in these scenarios, this assumed that cost was the primary risk factor. Given the higher level of oversight and scrutiny for mission-critical contracts, the practice of designing contracts to share risk, whether the onus of risk is on the government or the supplier, likely demonstrates supply manager sensitivity to heightened political attention. Further, when objectives are not solely driven by efficiency, risk-sharing schemes prevail. This supports prior research that public-sector managers are more likely to be externally focused than their private-sector counterparts (Frumkin & Galaskiewicz, 2004). Policymakers may want to consider the ways in which mission-critical services are

procured and the nature of the incentives that are being used in the contractual requirements.

Our study has implications for public- and private-sector supply chain managers. From the supplier side of public-sector supply chains, managers may want to consider not only the immediate cost implications of procuring government contracts, but also the political risk potential. For mission-critical items, suppliers could be taking on more risk than necessary by agreeing to incentive contracts, when, if our argument is correct, the government might be willing to agree to cost-reimbursement contracts. From the government side, managers might consider their more powerful position. If, even in mission-critical circumstances, suppliers are willing to agree to incentive contracts, it may not be necessary to utilize either time and materials or cost-reimbursement contracts. We also see implications for managers within private-sector supply chains, particularly those producing highly complex products, particularly when there are few buyers for those products. Contract design can be an effective tool to manage supply chain risk for both buyers and suppliers in this situation. Supply chain managers may benefit from building in risk sharing or shifting arrangements via incentive and cost-reimbursement contracts for the acquisition of highly complex products.

Limitations

We acknowledge some limitations of this study. We have only examined 22 product categories and their respective complexity ratings in this analysis, which does not cover the vast array of products and services purchased by the federal government. We also acknowledge that our risk measures are incomplete. Although our measures represent aspects of risk as they relate to the political process, we recognize the need to develop a more complete picture of risk management that takes into account characteristics that more specifically gauge mission criticality.

Nevertheless, we believe that this analysis offers a proof of concept suggesting that there are meaningful relationships between supply chain susceptibility to risk disruption and the choices that are made regarding the formal governance arrangements in public-sector supply chains. In short, we argue that the selection of contract type presents public-sector managers with an opportunity to manage risks.

CONCLUSION

In this study, we argued that supply chain management choices are affected by the extent to which supply chain disruptions are anticipated ex ante. We claimed that contract design is a predominant strategy to set contractual expectations among supply chain partners to manage risk. We hypothesized that variation in contract design was a function of both the mission criticality and complexity of the procured service. In this preliminary study, we found evidence suggesting that, as expected, when both mission criticality and service complexity are low, suppliers tend to bear most of the disruption risk by agreeing to fixed-price contracts. When mission criticality is high, we found government shared risk by agreeing to incentive contracts. Finally, when service complexity is high, we found that cost-reimbursement and incentive contract were preferred, as expected.

Our study contributes to a broader understanding of supply chain risk management by analyzing public-sector supply chains, an understudied area of supply chain literature. The study provides evidence of how mission-driven organizations might make risk management decisions when factors other than financial efficiency prevail. We build upon research of contract design and pricing types to better understand contract choice as a risk management strategy.

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