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Contract Design, Supply Chain Complexity, and Accountability in Federal Contracts

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Panel 15. Connecting Contracting Strategy to Acquisition Outcomes

Thursday, May 5, 2016	
11:15 a.m. – 12:45 p.m.	**Chair: Major General Kirk F. Vollmecke, U.S. Army,** Program Executive Officer, PEO IEW&S ***Contract Design, Supply Chain Complexity, and Accountability in Federal Contracts*** Adam Eckerd, Assistant Professor, University of Tennessee Amanda Girth, Assistant Professor, The Ohio State University ***An Approach for Modeling Supplier Resilience*** Kash Barker, Associate Professor, University of Oklahoma Jose E. Ramirez-Marquez, Associate Professor, Stevens Institute of Technology Seyedmohsen Hosseini, PhD Candidate, School of Industrial and Systems Engineering, University of Oklahoma ***Antecedents and Consequences of Supplier Performance Evaluation Efficacy*** Timothy Hawkins, Lt Col, USAF (Ret.), Assistant Professor, Western Kentucky University Michael Gravier, Associate Professor, Bryant University

Contract Design, Supply Chain Complexity, and Accountability in Federal Contracts

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Abstract

In this manuscript, we argue that supply chain management choices are affected by both the extent to which there is a risk of disruption within the supply chain and external to the supply chain as well. We suggest that the formal governance mechanisms that are favored under different conditions of endogenous and exogenous supply chain risk reflect the risk management preferences of the supply chain partners. In this preliminary study of public sector supply chains, we found evidence suggesting that, as expected, when endogenous risk is low, suppliers tend to bear most of the disruption risk by agreeing to fixed price contracts. Conversely, when endogenous risk is high but exogenous risk is low, buyers (governments) are willing to bear most of the risk by agreeing to cost reimbursement or time and materials contracts. When both endogenous and exogenous risk is high, we found partial support of the proposition that buyers and suppliers are more likely to share risk by agreeing to incentive contracts.

Introduction

Supply chains are complex in at least two fundamental aspects—the complexity or complicatedness of the product, and the uncertainty of information exchange across different organizations (Vachon & Klassen, 2002). Gailbraith (1973, 1977) is credited as describing this complexity and elaborating on ways that organizations can manage uncertainty through better information processing. Flynn and Flynn (1999) apply these concepts to a manufacturing supply chain, noting six drivers of manufacturing environment complexity related to the diversity of management tasks in manufacturing, goals, processes, customers, suppliers, and labor, while Vachon and Klassen (2002) also note complexity in managing supply chains that cross international boundaries. 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.

For the most part, this research has focused on complications that reside within the supply chain. These mostly relate to aspects of market uncertainty, either in terms of the resources required in the manufacturing of a product or the stability of demand for the final good. However, there is also uncertainty that is exogenous to the supply chain and while “endogenous uncertainty can be decreased by actions of the firm” (Folta, 1998, p. 1010), “exogenous uncertainty is largely unaffected by firm actions” (Folta, 1998, p. 1011).

Exogenous uncertainty can come from a variety of different sources, such as geopolitical factors or natural disasters, but it ultimately relates to some sort of information that is missing which makes committing resources to production risky, particularly if those investments are highly specific to the product in question.

Firms deal with uncertainty through risk management. In general, when endogenous uncertainty is located in resource acquisition, downstream partners are willing to share risk with upstream partners, and conversely, when risk is in the demand market, upstream partners are willing to share risk with those closest to the market (Flynn & Flynn, 1999). Exogenous uncertainty is more difficult to prepare for and manage, and it may affect any portion of the supply chain (Trkman & McCormack, 2009). Since exogenous risks may not be as manageable, exchange partners will seek a common understanding of the terms of the exchange in order to reduce endogenous costs, namely the transaction costs of the exchange, so that the total costs of the exchange are low enough to deal with the exogenous uncertainty should any unforeseen shocks occur (Weber & Mayer, 2014). The complication is that these risks must be managed ex ante.

Our interest is in a domain where these risks, particularly exogenous risks, may be prevalent: public management. Public sector supply chains are subject to a variety of different exogenous factors associated with the political system, legal institutions, bureaucratic processes, and geopolitics, in addition to endogenous 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 in the supply chain or not. 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 like accounting services or janitorial work, may be relatively resilient to external events, while others, like aerospace or military procurement, may reside in highly turbulent environments (Peck, 2005).

It is well accepted that managerial strategies are different when a supply chain is susceptible to endogenous risk (Manuj, Esper, & Stank, 2014). In this research, we argue that supply chains are also managed differently depending on the susceptibility of the supply chain to being affected by exogenous disruptions. In short, when the risk of disruption due to exogenous factors is high, we argue that risk will be shared between the exchange partners as a means of buffering the supply chain from external events. When exogenous risk is low, the risk management strategy will be determined by the nature of endogenous risk.

Supply Chain Risk

Endogenous

Endogenous risks are generally of two kinds: supply side, or resource-related risks, and demand side, or market-related risks. There are various points at which disruptions can occur in supply chains. Fluctuations in market demand can be expected, but there can be more volatility for certain final goods, and this volatility will affect the entire supply chain. There can be uncertainty in access to resources required for the production of the final good (both undersupply and oversupply), including fluctuations in natural resources, labor, technology, and access to capital for exchange partners. Coordination in the supply chain can be challenging due to the well-known bullwhip effect (Lee, Padmanabhan, & Whang, 1997) which occurs when each exchange partner makes ordering decisions in isolation, causing inefficient repercussions within the supply chain. Further, each of these effects becomes exacerbated as the complexity of the product increases and as more exchange partners are in the supply chain (Flynn & Flynn, 1999).

Exogenous

Exogenous risks exist beyond the focal supply chain, and thus the actors in the supply chain have little ability to control these events. Trkman and McCormack (2009) identify two types of exogenous uncertainty, discrete events and continuous risks, and suggest that different approaches may need to be taken to manage both types of uncertainty. Continuous risks are those that occur at a relatively stable rate and are generally more predictable than discrete risks, and while the exact timing of an occurrence is not known, the risk is more or less stable over time. Continuous risks may be events such as economic downturns, cross-cultural complications, or changing political environments due to election cycles or policymaker interest. Discrete risks are less predictable shocks to the external environment. These risks may include natural disasters, geopolitical events such as terrorism or international conflict, political or broad-based labor strife, or technological changes.

Managing Risk

There are many different specific strategies available for supply chain risk management (SCRM; Tang, 2006). Private sector firms have been shown to follow a few general approaches depending upon the nature of the supply chain risk. For endogenous supply risk, firms can hedge, that is attempt to secure resources from a variety of different suppliers, or they can assume and internalize the risk, by incurring production internally, for example. For endogenous demand risks, firms can postpone or delay production, or they can speculate and maintain inventory until demand stabilizes (Manuj, Esper, & Stank, 2014). Tang (2006) also notes that firms can adapt processes or products to deal with new circumstances or risks, or they can open information exchange to ensure that each partner in the supply chain has access to the same information. In short, the approach to managing endogenous risk is to mitigate the chances of disruption, to the extent possible, and implement strategies to minimize disruptions when they occur in order to ensure the efficient operation of the supply chain.

For exogenous risk, options for information sharing, hedging, postponing, or holding inventory may be much less effective. Hedging will be ineffective because an exogenous shock will be external to any particular supply chain, and it is likely that all or at least most suppliers will be affected by whatever the exogenous shock was. Regardless of the diversity of suppliers, the focal firm's supply chain will be impacted. Demand focused strategies will be risky because a shock may cause an unpredicted and fundamental shift in the nature of the demand for a product. In this scenario, postponing may lead to shortages because demand may recover, leaving the supply chain unable to meet demand. Conversely, holding inventory will be costly if demand never recovers. Finally, sharing information is unlikely to have an effect if the source of the disruption is external to the supply chain because the shock will be out of the control of any of the exchange partners and no firm is likely to have access to any more information than another.

The main strategy available for managing exogenous uncertainty is therefore to assume and internalize the risk within the supply chain. This can be done by ensuring that the parties to the exchange have a common understanding of the nature of both the exchange and the exogenous risks and coordinate activities to the extent that costs internal to the supply chain, namely the costs of the transaction, are as low as possible, leaving adequate resources to manage any exogenous shocks that occur and enabling the partners to internalize the potential costs of exogenous changes (Weber & Mayer, 2014). The key aspect in managing exogenous risk is thus not to take steps to avoid risky scenarios because exogenous risks cannot be avoided, but rather to take steps to ensure that the supply chain is resilient to the disruptions that do occur. There are a number of approaches

that can be taken to improve resilience, such as building flexibility into the contract in case one organization in the chain bears the brunt of the effects of the shock, discussing potential disruptions throughout the supply chain to ensure that there is a common understanding of the things that could potentially occur, and deriving contingency plans and processes in advance should disruptions occur (Brown, Potoski, & Van Slyke, 2015).

Public Sector Supply Chains

Public sector supply chains offer a good context to understand SCRM due to their propensity to be affected by exogenous factors. A key reason why this is the case is that there is only one "consumer" for the end products, and it is a fickle consumer—the polity. In the U.S., the polity is represented in these exchanges by Congress and the President. With one buyer (the government broadly), there is no real market for the end goods, and owing to the non-excludable and non-rivalrous nature of public goods, pricing and, thus, demand are difficult or impossible to ascertain for many of the things that the government purchases. On the supply side, many products are idiosyncratic and involve highly technical or scarce materials, and policies often limit where those materials can come from and what sorts of vendors should be selected.

Internally, this means that there is often considerable endogenous risk owing to the high level of asset specificity that might be required of vendors to produce goods or services for the government, and the technical complicatedness of these goods and services may require numerous subcontractors and sources of supplies for the final product, with each relationship adding complexity to the management of the supply chain (Eriksson, 2015). Externally, public sector supply chains are subject to significant supply and demand uncertainty. Supplies can be disrupted by natural or manmade disasters that reduce the availability of needed resources or by having few potential vendors with the expertise to produce the good or service. Demand can be affected in numerous unexpected ways by disasters or other focusing events, but also due to changes in the political context via elections, interest group activity, or erratic shifts of interest from particular political authorities from either Congress or the Executive branch agencies.

It is typically left to public managers to deal with these risks and be prepared to respond to them. Public managers can take cues from private sector SCRM recommendations in cases where efficient supply chain operation is an overriding goal, but 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, efficiency is not always going to be the overriding goal. 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 (Kim & Brown, 2012; Eckerd & Snider, 2016).

This is not to say that the 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 in order to protect the organizations that are involved in the exchange. For some public products and services, efficiency and product/service quality are likely good buffering techniques in that they are producing a good or service that has wide political support and is in less danger of exogenous risk, but in other contexts, garnering the support of key political actors may be more important, while in others the goal might be to

stay “off the radar” as much as possible. Along these lines, Frumkin and Galaskiewicz (2004) find that public managers tend to be more externally focused in their management decisions than private managers do. Governmental organizations “[lack] a single stakeholder group to monitor the organization,” such as a board of directors or investors (Frumkin & Galaskiewicz, 2004, p. 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, p. 289). Along similar lines, managing exogenous risks may occupy more managerial capacity than dealing with internal issues.

SCRM in the public sector is thus likely more focused on the external environment and particularly focused on buffering the supply chain from those exogenous risks against which there may be some means to do so, at least under some circumstances. As we lay out in detail below, we expect public sector SCRM to have a more procedural than an outcome-oriented focus when exogenous exposure is high. However, we expect that when the key risks are low or endogenous, public sector supply chains will behave similarly to private sector supply chains. This is because when endogenous risk is low, the product or service is likely not particularly complex, so the assets needed for production will not be specific. In these situations, there are likely multiple potential suppliers, and public organizations (like their private sector counterparts) can therefore hedge and be prepared to solicit offers from a variety of different vendors. When products are more complex but exogenous risk relatively low, internalization of risk is more likely. Governments can opt to produce these goods or services internally or when they are procured through a supply chain to internalize the risk to ensure the stability of the supply chain as much as possible (Brown & Potoski, 2003). That is, with low exogenous risk, public managers may be more willing to bear the burden of risk, assured that the external environment is stable for them, and allow their supply chain partners to be buffered from risk as much as possible, or the production process can be managed strictly internally.

However, these strategies are likely to be altered by the extent to which the supply chain is susceptible to exogenous risk. In short, we argue that the more that the supply chain is subject to external risk, the more that the supply process requires buffering and sharing of risk across the supply chain, potentially in ways that are contrary to what we might expect given the endogenous risks of disruption. Before developing our argument of exogenous risk, we first explain risk management techniques as they relate to the public sector.

One of the key ways to manage risk is though 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 contract 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 is with respect to the design of the formal contract which better represents an ex ante risk management strategy. In public sector contracting, there are three 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 cost, incentive, 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 vendors to provide

the good or service. Fixed price contracts are often short term in nature and place relatively few constraints on vendors. Under *cost reimbursement* contracts, the government will propose a good, service, or task and solicit bids, reimbursing the vendor for the costs incurred in delivering the product. *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 vendor exceeds that minimum, then the vendor receives additional money (or conversely, if the vendor fails to meet expectations, there may be sanctions). Time and materials contracts are another commonly used type of contract, but are considered a form of cost reimbursement contracts (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).

The contract that is chosen offers a view of the SCRM strategy. A fixed price contract can be viewed as a hedging strategy and is most likely useful with low complexity products. Simple products or services are likely to have more actual or potential suppliers, enabling the government to dictate the market and put 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 vendor 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. We expect that when a supply chain is not especially prone to endogenous risk, fixed price contracts will be favored, particularly when the supply chain is also not especially prone to exogenous risk. This is because the products in question are likely not complex, the assets are likely not specific, and with a low chance of risk and a buyer's market, the supplier will bear risk.

In situations where endogenous risk is higher, for example when a product or service is complex and buyers are limited, options for hedging are likely to be limited due to a smaller set of potential suppliers, so risk will need to be internalized by the buyer. This can be done by using a cost reimbursement contract, which places the risk on the buyer which is the government in this case. By internalizing risk this way, governments can enable suppliers' willingness 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. Thus, when endogenous risk is high, we expect cost reimbursement contracts to be favored.

However, these considerations may be changed when a supply chain is susceptible to high levels of exogenous risk, such as projects that are very salient with political authorities. We can conceive of exogenous risks in a variety of different ways, but the public management context offers a relatively clear way to assess one aspect of exogenous risk: the interest that the political system has on the product or service in question (Epstein & Segal, 2000). If a particular project has little salience with the public, then it likely has little salience with Congress, and is therefore less exposed to potential political disruption than a program that is well known. While this may not be the only type of exogenous risk that a public sector supply chain would be exposed to, it is one of the more continuous types of risk for which a strategy may be devised to manage it (in contrast to dynamic risks like natural disasters that can be planned for but are less predictable).

The choice of which contract type is selected can provide an indication of the risk management strategy and it can also send a signal to the external political environment. We expect that one of the main intentions of public managers is using the contract selection as a means through which to buffer the supply chain from unexpected political interest. For salient products that the polity and policymakers focus on, or those situations where

exogenous risks are higher, cost reimbursement contracts might be favored if endogenous risks are high, but these contract types may look like “backroom deals” and might garner unwanted attention from the external environment. In other words, the seemingly appropriate contract for the internal dynamics might not be preferred because of the external environment. Therefore, in cases where both endogenous and exogenous risks are high, we suggest that risks can be internalized through an incentive contract, in which the supplier takes on risk by agreeing to some minimum threshold at a fixed cost, while the government takes on risk by agreeing to pay additional costs for any production beyond this threshold. Firms “will charge a premium” for taking on risk, and risk sharing between partners becomes more efficient as uncertainty increases (Jensen & Stonecash, 2005, p. 777), but they are willing to do so because an incentive contract should better buffer the supply chain from exogenous shocks from the political system (Lawther & Martin, 2005). For products that are subject to high exogenous risk but low endogenous risk, we can see two potential strategies. First, if a product is not complex, it is likely that the costs can be estimated well, suggesting that a fixed price contract that keeps government costs low may be the best approach to buffer the supply chain. On the other hand, if the product in question is mission critical, then the government bears some risk in a fixed price contract if the contractor fails to deliver. Although there will be legal recourse to recoup costs, this might matter less than the timely delivery of some important product, and thus incentive or cost reimbursement contracts may be favored. Our expectations are laid out in Table 1.

- *Hypothesis 1: Fixed price contracts will be favored over other contract types when both endogenous risk and exogenous risk are low.*
- *Hypothesis 2: Cost reimbursement contracts will be favored over other contract types when endogenous risk is high and exogenous risk is low.*
- *Hypothesis 3: Incentive contracts will be favored over other contract types when both endogenous risk and exogenous risk are high.*

Table 1. Supply Chain Risk and Contract Design Choice

	Low exogenous risk	**High exogenous risk**
Low endogenous risk	Fixed price	Idiosyncratic to product
High endogenous risk	Cost reimbursement	Incentive

Data and Method

Data

We test our hypotheses of endogenous and exogenous supply chain risk using public sector contracts data from federal agencies in the U.S. Contracts data is derived from the Federal Procurement Data System-Next Generation (FPDS-NG), the only comprehensive source of unclassified federal contracts. The Federal Acquisition Regulation (FAR) requires that contract officers record in FPDS-NG contract actions exceeding $3,000 in value. As a result, this data set offers an exclusive opportunity to study supply chain risk.

The unit of analysis in this study is the federal contract. Because the 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 preliminary analysis, our data is comprised of 274,440 contracts from 22 product areas. Federal agencies purchase goods and services using two industry categorizations: the 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. The sample encompasses all completed unclassified contracts for these PSC/NAICS from FY2000–2014.

Measures

Dependent variable. Our outcome of interest is a key aspect of how supply chain managers deal with risk: 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 the 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 the FPDS-NG as fixed price 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 the 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 the FPDS-NG as time and materials, labor hours). Table 2 reports the distribution of the dependent variable for both products.

Table 2. Dependent Variable: Contract Pricing Type

Contract pricing type			
1 Fixed price	**2 Incentive**	**3 Cost reimbursement**	**4 Time and material**
218,120 79.48%	1,642 0.60%	27,968 10.19%	26,710 9.73%

Put simply, fixed price contracts shift risk primarily to the supplier because the supplier receives a fixed amount regardless of any extenuating circumstances. Cost reimbursement and time and materials contracts are unique contract types, but are similar in that the risk is borne primarily by the government because the government reimburses the supplier for relevant costs regardless of the actual amount of a service received. Both of these contract types are used when requirements are unable to be properly specified. Incentive contracts, which allow suppliers to earn an additional fee based on meeting specified performance objectives, are characterized as a risk-sharing position.

Explanatory variables. We are interested in testing the effects of both endogenous and exogenous risks to the supply chain. We examine endogenous risk—related to complexity in the supply chain—by analyzing *product complexity*. We operationalize endogenous risk using product complexity measures developed by Kim, Roberts, and Brown (forthcoming). The authors surveyed federal acquisition professionals to determine their assessment of ease of measurement and specialized investment ratings. They then combine these factors into a product complexity rating as reported in Table 3. We use their findings to study contracts from 22 product areas, allowing us to assess both endogenous and exogenous risk in our analysis.

Table 3. Product Categories and Complexity Scores

Product Category	PSC	NAICS	Number of Contracts	Product complexity
Solid waste collection	S205	562111	17,907	3.08
Landscaping	S208	561730	37,774	3.16
Laundry and dry cleaning	S209	812320	8,051	3.26
Janitorial service	S201	561720	47,058	3.30
Court reporting	R606	561492	19,940	3.51
Warehousing and storage	S215	493110	2,104	3.61
Security guard and patrol	S206	561612	25,522	3.77
Advertising	R701	541810	5,445	4.43
Auditing	R704	541211	2,682	4.77
Legal service	R418	541110	9,732	4.97
Professional and management training	U008	611430	12,816	5.02
Equipment maintenance and repair	J099	811310	5,971	5.22
Program management and support	R408	541611	12,401	5.62
Logistics support	R706	541614	3,175	5.63
Program review and development	R409	541611	615	5.87
Engineering	R425	541330	55,822	6.76
Computer system development	D302	541512	4,196	7.58
Weapons-basic research	AC51	541710	578	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

Exogenous risks—those factors that affect the supply chain but are external to the organizations involved in the exchange, and that the actors have little ability to control—are operationalized using three variables all intended to capture aspects of the potential interest and saliency of the supply chain with political representatives: *contract value*, *market competition*, and *competitive limitations*. Taken together, we expect that heightened exogenous risks will decrease the use of fixed price contracts and drive public purchasers to other contract pricing types in order to share or redistribute risk.

- *Contract value* is the logged value of total dollars obligated to the contract. This is measured in real dollars with 2014 as the base year. Contract value is a clear proxy for political interest, particularly during times of tight budgets (Eckerd & Snider, 2016). While the size of the procurement budget is not necessarily indicative of politically contentious programs, with all else equal, it seems reasonable to assume that larger acquisition projects will draw more political attention. That is, we expect greater political interest and attention to the contract as contract value increases, which may result in selecting different contract pricing types. Specifically, we see two different responses to high value contracts depending on the nature of the endogenous supply chain risk. When endogenous risk is low, we expect that high value contracts will tend to be fixed price. When endogenous risk is higher, we expect more risk sharing in the form of incentive contracts.
- *Market competition* is the logged value of the total number of offers received for the contract. This variable is a proxy for the level of market competition for

the particular product. While this is not a direct measure of political salience, when markets are highly competitive, exogenous attention may be more likely to identify perceived waste or exorbitant costs. An older example of this logic is the infamous Packard Commission's 1986 report identifying the Department of Defense's $435 hammer and $600 toilet seat (Blue Ribbon Commission on Defense Management, 1986). More recently, consider the scrutiny received over the ultimate cost of a fuel station in Iraq (Davenport, 2015). Thus in circumstances where there is much market competition but endogenous risk is low, a situation of high exogenous risk, we expect to see greater use of fixed price contracts that place more risk on the supplier. This is, in part, due to the lower costs of switching suppliers if contract performance is unsatisfactory. However, as with contract value, we expect a different response if there is high endogenous risk. We expect that when market competition is low, but endogenous risk high, cost reimbursement contracts may be preferred to ensure program continuity (thus buffering exogenous interest), but when both competition and endogenous risk are high, we expect incentive contracts to be favored as a mechanism to share risk across the supply chain.

- *Competitive limitations* 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. These political tools can introduce exogenous risk into the supply chain by restricting the supplier market and also potentially drawing interest from political actors who designed the set aside not to meet supply chain efficiency goals, but rather to meet broader social/public policy goals of inclusion and equity (Eckerd & Eckerd, 2016). When endogenous risk is low, we expect that contracts with competitive limitations will be fixed price. When endogenous risk is higher, we expect that incentive contracts will be favored when there are competitive limitations in order to share risk.

Control variables. We control for several factors that can influence the relationship between supply chain risk (whether endogenous or exogenous) and contract pricing type. We control for *contract length*, which is measured as the total length of the contract in years. We include a control for *unrestricted competition* to measure whether the contract was bid with unrestricted competition (e.g., full and open) or restricted competition (e.g., sole source), coded 1 if unrestricted and 0 if restricted. This can affect the number of bidders on a contract. The *Department of Defense (DoD)* accounts for approximately two-thirds of federal contracts. Because the DoD has more experience with contracting in general, we expect that they are more likely to use more diverse contract pricing types. The DoD is coded 1 if the contract agency is the DoD, and 0 otherwise. We also include *year* dummy variables to correspond to the fiscal year 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 the exogenous risk to the supply chain.

Table 4 provides descriptive statistics for each of the independent variables.

Table 4. Independent Variables: Descriptive Statistics

Independent Variable	Mean	Std dev	Min	Max
Product complexity	4.509	1.502	3.08	8.66
Contract value	8.292	4.788	0	21.376
Market competition	1.171	0.791	0	6.908
Competitive limitation	0.327	0.496	0	1
Unrestricted competition	0.697	0.459	0	1
Contract length	1.816	1.627	1	16
DOD	0.503	0.499	0	1

Method

Given the non-ordinal categorical nature of our dependent variable, contract 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, 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 amongst 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. As a result, the model is restricted to 246,362 contracts.

Findings

The results of multinomial regression are reported in Table 5. We expect a high level of exogenous risk to be indicated by a combination of a high contract dollar value, low levels of market competition when endogenous risk is high and high levels of market competition when endogenous risk is low, and the presence of competitive limitations. High levels of product complexity are evidence of endogenous risk. When these risk factors are low, we expect fixed price contracts to be favored. 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.

Incentive contracts compared to fixed price contracts. As expected, when endogenous risk is high, incentive contracts are favored over fixed price contracts. Only one exogenous factor, contract value, is statistically significant, suggesting that as contract value increases, so too does the preference for incentive contracts over fixed price contracts. Both findings are consistent with hypothesis 3. We find *competitive limitations* (set asides) are less likely with incentive contracts 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 compared to civilian agencies, the DoD is more likely to use incentive contracts than fixed price contracts when endogenous risk is low.

Cost reimbursement contracts compared to fixed price contracts. Again, as expected, when endogenous risk measured by product complexity is high, contracts are more likely to be cost reimbursement than fixed price contracts. All three exogenous factors, *competitive limitations*, *market competition*, and *contract value*, reach levels of statistical significance. Cost reimbursement contracts are favored in situations with fewer *competitive limitations*, less *market competition*, and higher *contract value* than fixed price contracts, which provide mixed evidence for hypothesis 2. The value of the contract and market competition is consistent with our expectations, but competitive limitations is not. We find that cost reimbursement contracts are likely to be longer than fixed price contracts, less likely to be competed with restrictions, and more likely to be DoD contracts compared to fixed price contracts.

Time *and materials contracts compared to fixed price contracts*. When endogenous risk, *product complexity*, is high, time and materials contracts are preferred over fixed price contracts. We also see that all three exogenous factors, *competitive limitations*, *market competition*, and *contract value* reach levels of statistical significance. Time and materials contracts are favored in situations with fewer *competitive limitations*, greater *market competition*, and greater *contract value* than fixed price contracts, which again provides mixed evidence for hypothesis 1. We find a statistically positive relationship between contract length and time and materials contracts compared to fixed price contracts. Time and materials contracts are more likely to be competed with restrictions compared to fixed price contracts. We also find that compared to civilian agencies, the DoD is less likely to use time and materials contracts than fixed price contracts.

Table 5. Multinomial Logit Analysis

	Fixed price contract versus					
Independent Variable	Incentive contract		Cost reimbursement contract		Time and materials contract	
	RRR	*Rob std err*[a]	*RRR*	*Rob std err*[a]	*RRR*	*Rob std err*[a]
Product complexity	2.348***	.185	4.19***	0.227	1.992***	0.050
Contract value	1.196***	0.023	1.070***	0.007	1.055***	0.006
Market competition	.0975	0.083	0.651***	0.051	1.3077**	0.039
Competitive limitation	0.743	0.246	0.668***	0.109	0.432***	0.043
Unrestricted competition	2.196***	0.629	2.570***	0.339	1.034	0.087
Contract length	1.149***	0.045	1.071***	0.019	1.060***	0.019
DOD	1.479*	0.357	6.996***	1.212	0.461***	0.042
Constant	1.51^{e-06}***	1.26^{e-06}	5.26^{e-06}***	3.17^{e-06}	0.001***	0.001

N = 246,354
Chi^2 = 5050.254***
Pseudo R^2 = 0.35
*p<.10 **p<.05 ***p<.01; two-tailed tests
[a]112,249 clusters at the IDVPIID level
Year dummies not shown

In order to fully test hypothesis 3, 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 that reach statistical significance across all contract types: *contract value* and *product characteristics*. Results are reported in Table 6. We find evidence that incentive contracts are favored over other contract types when *contract value* and *product characteristics* are high, substantiating H3.

Table 6. 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
Endogenous: Product complexity	2.348	0.5604	1.1788
Exogenous: Contract value	1.196	1.118	1.133

Discussion

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. First, we expected that, in general, fixed price contracts would be favored when endogenous risk was low, as compared to situations when endogenous risk was high. We expected that fixed price contracts would be especially favored when exogenous risk was also low, and we see some support for this; however, the results are mixed. This may indicate that there are different considerations about managing supply chain risk depending on the nature of the exogenous risk. If exogenous risk is thought of as the potential for political attention (as operationalized by the dollar value of the contract), then our results fit with our expectations in hypothesis 1. If exogenous risk is conceived in other terms, mangers may be following more idiosyncratic approaches to risk management. When endogenous and exogenous risk is high (as measured by market competition and contract value) cost reimbursement contracts are favored over fixed price contracts, generally supporting hypothesis 2.

We find partial support for hypothesis 3. We purported that when both exogenous and endogenous risk is high, incentive contracts would be favored over other contract types. The results show that for the most costly of government contracts, risk sharing between supplier and government purchaser is preferable and incentive contracts are favored.

In no case did we find *competitive limitation*, or use of a set aside, affecting contract choices as we expected. For both cost reimbursement and time and materials contracts, the measure was statistically significant and negative, noting that managers are less inclined to restrict competition through set asides for contracts, wherein the buyer assumes greater risk than the supplier. This might mean that buyers are willing to amplify risk when that risk is shifted to the supplier in fixed price contracts, but are less likely to increase risk through set aside provisions when the risk is borne or partially borne by the government.

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).

Limitations

We acknowledge some limitations of this preliminary 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 measures of exogenous risk are incomplete. While each of our measures represent aspects of exogenous risk as they relate to the political process, we recognize the need to develop a more complete picture of exogenous risk that takes into account characteristics that more specifically gauge political salience in addition to susceptibility to natural and or manmade disruptions.

Nevertheless, we believe that this preliminary analysis offers a proof of concept suggesting that there are meaningful relationships between the levels of endogenous and exogenous risk 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 contract managers with an opportunity to manage risks.

Conclusion

In this manuscript, we argued that supply chain management choices are affected by both the extent to which there is a risk of disruption within the supply chain and external to the supply chain as well. We argued that public sector supply chains are subject to considerable exogenous risk and that studying supply chain management decisions in the public sector offers a unique opportunity to understand how supply chain managers deal with both endogenous and exogenous risk situations. In this preliminary study, we found evidence suggesting that, as expected, when endogenous risk is low, suppliers tend to bear most of the disruption risk by agreeing to fixed price contracts. Conversely, when endogenous risk is high, we find partial support that government purchasers are willing to bear most of the risk by agreeing to cost reimbursement or time and materials contracts. We also find partial support of our proposition that when both endogenous and exogenous risk is high, governments are more likely share the risk with suppliers by favoring incentive contracts.

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Contract Design, Supply Chain Complexity, and Accountability in Federal Contracts

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Purpose

- Supply chains are fundamentally complex (Vachon and Klassen, 2002; Galbraith 1973)

- Are supply chains managed differently based upon the susceptibility of the supply chain to
  - Endogenous disruptions?
  - Exogenous disruptions?

- Contract design as a risk management strategy

Supply Chain Risk

- Endogenous
  - Supply risks
    - Resource related
  - Demand risks
    - Market related
  - Complexity of the product, number of exchange partners exacerbates risk (Flynn and Flynn 1999)
  - Might be decreased by the firm (Folta 1998)
- Exogenous
  - Discrete events (Trkman and Mccormack 2009)
    - Unpredictable shocks
  - Continuous risks
    - More stable e.g., political environment
  - Largely unaffected by firm actions (Folta 1998)

Risk Management Strategies

- Endogenous risk management
  - *Supply risks:* Hedge (multiple suppliers), internally produce
  - *Demand risks:* Postpose production, maintain inventory (Manuj, Esper, and Stank 2014)
  - Share information with SC partners

- Exogenous risk management
  - Assume and internalize risk
  - Mutual understanding of risks among partners to lower transaction costs as much as possible (Weber and Mayer 2014)
  - Flexibility in contract, contingency plans (Brown, et al 2015)

Public Sector Supply Chains

- Public managers tend to be more externally focused (Frumkin and Galaskiewicz 2004)
- Inefficient SC can thrive if valued by/benefit powerful actors (Kim and Brown 2010; Eckerd and Snider 2016)
- Public sector SC behave more/less like private sector depending upon exogenous disruption
- Contract design as a risk management strategy

	Low exogenous risk	**High exogenous risk**
Low endogenous risk	Fixed price	Idiosyncratic to product
High endogenous risk	Cost reimbursement	Incentive/award fee

Hypotheses

1) Fixed price contracts will be favored over other contract types when both *endogenous risk and exogenous risk are low*.

2) Cost reimbursement contracts will be favored over other contract types when *endogenous risk is high and exogenous risk is low*.

3) Award/incentive fee contracts will be favored over other contract types when both *endogenous risk and exogenous risk are high*.

Data

Source: FPDS-NG

22 product/service contracts FY2000-2014

Sample size: 274,440 contracts

Product Category	PSC	NAICS	Number of Contracts	Product complexity
Solid waste collection	S205	562111	17,907	3.08
Landscaping	S208	561730	37,774	3.16
Laundry and dry cleaning	S209	812320	8,051	3.26
Janitorial service	S201	561720	47,058	3.30
Court reporting	R606	561492	19,940	3.51
Warehousing and storage	S215	493110	2,104	3.61
Security guard and patrol	S206	561612	25,522	3.77
Advertising	R701	541810	5,445	4.43
Auditing	R704	541211	2,682	4.77
Legal service	R418	541110	9,732	4.97
Professional and management training	U008	611430	12,816	5.02
Equipment maintenance and repair	J099	811310	5,971	5.22
Program management and support	R408	541611	12,401	5.62
Logistics support	R706	541614	3,175	5.63
Program review and development	R409	541611	615	5.87
Engineering	R425	541330	55,822	6.76
Computer system development	D302	541512	4,196	7.58
Weapons-basic research	AC51	541710	578	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

Source: Kim, Roberts, and Brown 2016

Measures and Method

Dependent variable

- *Contract pricing type:* 1 Fixed price, 2 Incentive/award fee, 3 Cost reimbursement, 4 Time and material

Explanatory variables

- *Endogenous risk:*
  - *Product complexity*
- *Exogenous risk:*
  - *Contract value*: total dollars obligated (log)
  - *Market competition*: number of offers received (log)
  - *Competitive limitation*: coded 1 if the contract is a set aside

Control variables

- *Contract length*: total length of contract in years
- *Unrestricted competition:* coded 1 if full and open
- *DOD*
- *FY dummies*

Method

- Multinomial logistical regression, robust SE, clustered at IDV level

Results

Hypotheses	Findings
H1: Fixed price contracts will be favored over other contract types when both *endogenous risk and exogenous risk are low.*	Partial Yes Complexity (-) Contract value (-)
H2: Cost reimbursement contracts will be favored over other contract types when *endogenous risk is high and exogenous risk is low.*	Partial Yes *Complexity (+)* Contract value (+FP/-AI)
H3: Award/incentive fee contracts will be favored over other contract types when both *endogenous risk and exogenous risk are high.*	Partial Yes Complexity (+FP/-CR) *Contract value (+)*

Discussion

- Endogenous risk
  - Fixed price more likely for less complex products/services
  - Cost reimbursement more likely for most complex products/services
- Exogenous risk
  - If characterize high dollar value as a proxy for political attention, then incentive/award fee most likely
  - If characterize market strength as a proxy for political attention, then results are not clear
- Findings suggest relationship between varying types of SC risk and contract design choices

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