Dual Sourcing under Risky Public Procurement*

Vanessa Valéro†

June 1, 2012

Abstract

This paper examines the provision of a public service subject to a risk of disruption in a dynamic setting. To hedge against this risk, a public authority may use a dual sourcing policy. Instead of awarding the entire production to one supplier (sole sourcing), he may split it between two suppliers (dual sourcing). If the production of one supplier is disrupted, the other may take over. However, ensuring the continuity of production increases the procurement cost since a less efficient supplier may be awarded part of the production. The public authority thus faces a trade-off when deciding upon the procurement policy. We first examine the optimal choice between sole and dual sourcing. Then, we determine the optimal share of production awarded to each supplier in case of dual sourcing. We also consider how asymmetry of information on the secondary supplier's efficiency affects the optimal procurement policy since an informational rent is given up to this supplier. Finally, we extend our model to consider the influence of lobbying on the public authority's choice of procurement policy.

JEL classification: D81, D82, H41, H57.

Keywords: Public Procurement, Dual Sourcing, Risk of Disruption

1 Introduction

One of the major challenges in the provision of public services is the management of the risk of disruption through an appropriate public procurement policy. Disruption, defined as a major breakdown in production, may occur due to catastrophic events as natural disasters, terrorist attacks and political risks. In the aftermath of the March 2011 earthquake and tsunami in Japan, some nuclear power plants have been shut down which entailed a major regional disruption of electricity. The Fukushima disaster have brought

*I wish to thank Wilfried Sand-Zantman, Ruxanda Berlinschi, Jean-Christophe Poudou, Catherine Bobtcheff and Jerôme Pouyet for helpful discussions and suggestions.

†Corresponding author: vanessa.valero@tse-fr.eu, +33 (0)5 67 73 27 65, Toulouse School of Economics, Manufacture des Tabacs, 21 allées de Brienne, 31000 Toulouse, (GREMAQ and LAMETA).

new attention to how national energy systems are vulnerable to natural disasters. Terrorist attacks on centralised power production structures and supply restrictions resulting from political actions could also be a treat to security of energy supply.[1] To hedge against this risk is necessary for both developed and developing countries since important disruptions would cause serious economic upheaval. The threats to the actual energy systems bolster the rationale for deploying renewable energies such as solar, wind, hydro and geothermal energy. Opting for a secondary energy supply reduces vulnerability to a severe disruption at the national level. Such procurement policy refers to dual sourcing. Instead of awarding the entire production of a public service to one single supplier (sole sourcing), a public authority may split it between two suppliers (dual sourcing). If the production of one supplier is disrupted, i.e., the supplier is suddenly unable to produce the public service, a backup supplier may take over. However, the public authority faces a trade-off when deciding upon the optimal procurement policy: a backup supplier protects the production against disruptions, but it could also increase the procurement cost.

In this paper, we analyze the optimal procurement policy in presence of risk of disruption, which is characterized by two key decisions: the choice of the appropriate set of suppliers (sole versus dual sourcing) and the quantity to be produced by each selected supplier. In order to understand fundamental economic determinants of these decisions, we construct a two-period model of public procurement. Two potential suppliers can provide a public service on behalf of a public authority in each period. The primary supplier is unreliable in that her production is subject to random disruption at the second period. She may fail to deliver the public service for reasons out of her control, with a given publicly known probability. The secondary supplier is perfectly reliable, but more costly. Her production cost is private information contrary to the primary supplier, whose cost is known by the public authority. If the primary supplier is disrupted, the other may take over. The public authority may shift a part of the production to the secondary supplier which depends on her ability to increase her production at the second period. We assume that she may compensate for the default production without having previously produced.[2] The public authority has the choice to contract out production to the less costly, but less reliable primary supplier only or to both suppliers. To do so, he will trade-off between the cost due to supply disruption and the cost of contracting out a part of production to a more costly firm. While we discuss the choice between sole and dual sourcing, our paper is more focused on the choice of the split of production awarded to each supplier in case of dual sourcing, i.e., the relative use of the primary supplier and the secondary supplier once both have been selected.

[1] A large proportion of European or US energy supply originates from politically instable regions in the Middle east, the Caucasus and Central Asia.

[2] We abstract from the role of dual sourcing keeping the supplier alive to promote competition in later periods as it was suggested by Greer and Liao (1986) and Klotz and Chatterjee (1995). The secondary supplier can survive producing on the behalf of other publics authorities for example.

The ability of the secondary supplier to deliver the default production is one of the key determinants of the optimal procurement policy. We show that the public authority chooses dual sourcing when the marginal benefit of the default production ensured by the secondary firm is larger than the marginal cost of awarding to her a part of the production. The less the secondary supplier may compensate for the default production, the more valuable is dual sourcing. Indeed, when the part of the production that she may compensate decreases, the disruption cost increases and it becomes harder to ensure the continuity of the provision of the public service. The optimal split of production is then to rely more on the secondary supplier to ensure a backup production in case of disruption. However, when the public authority does not know the secondary supplier's cost, the latter can act strategically and take advantage of her private information. We show that asymmetry of information reduces the scope of dual sourcing and therefore reduces the share awarded to the secondary supplier. Indeed, optimal mechanisms for minimizing rents require reducing the productive efficiency.

We first extend the model to allow for the possibility that the probability of disruption depends on the suppliers' level of production. We then characterize the optimal procurement policy. Two situations can be distinguished when dual sourcing is preferred by the public authority. First, the higher the primary supplier's part of production, the lower her reliability. In this case, a decreased use of the primary supplier and an increased use of the secondary supplier is a better procurement strategy. In addition to ensure a backup production, dual sourcing may help reduce the probability of disruption. Second, the higher the primary supplier's part of production, the lower her probability of disruption. Therefore, to improve the primary supplier's reliability, the secondary supplier's part of production is downward distorted. The scope of dual sourcing is thus reduced. In this setting, the optimal split of the production is also determined by its impact on the probability of disruption.

We then examine the influence of lobbying on the public authority's choice of procurement policy. The assumption of benevolent public authority is relaxed, allowing him to value monetary transfers from lobbyists. We consider that the public authority is privately informed on the weight that she gives to these transfers with respect to social welfare. Only the secondary supplier, benefiting from rent due to her informational advantage over the public authority, attempts to influence procurement strategy in favor of dual sourcing. To do so, she will promise a monetary transfer in return for policy favors. In this part of the paper, we show how this transfer and therefore the procurement strategy, depends on the public authority's private information.

As discussed above, this paper aims to contribute to the literature that examines dual sourcing in procurement. Anton and Yao (1989, 1992) are two early contributions to the literature comparing the performance of sole sourcing and dual sourcing. Anton and

Yao (1989) consider the case in which the suppliers know each other's costs. They show that splitting production reduces the production costs when suppliers have strictly convex costs, but provides suppliers powerful incentives to collude. Anton and Yao (1992) extend their previous model to allow for asymmetric information among the suppliers about each other's cost. As collusion becomes harder to sustain, dual sourcing may lead to lower procurement costs than the sole sourcing. Our model differs in two ways from Anton and Yao's papers. First, we assume that returns to scale are constant. Second, we consider optimal mechanisms. From this point of view, our paper is close to Auriol and Laffont (1992), Dana and Spier (1994) and McGuire and Riordan (1995). They analyze the market structure, i.e., sole versus dual sourcing, under asymmetric information about firms' cost. McGuire and Riordan (1995) focus on the particular context in which firms produce differentiated products. We rather assume that products are perfectly substitutable as in Auriol and Laffont (1992) and Dana and Spier (1994). The key idea of these two papers is the role played by the duopolistic structure to reduce information cost. However, these papers restrict their analysis to a static setting. In this paper, we determine the optimal procurement strategy considering the dynamics of procurement as Klotz and Chatterjee (1995). Contrary to them, we do not consider dual sourcing as a means to maintain competition in later auctions. In our model, dual sourcing may be chosen by the public authority to hedge against the risk of disruption and therefore to ensure the continuity of the production.

Managing the risk of disruption is a growing element of concern in supply chains. Berger et al. (2004) are among the first to incorporate supplier risk into the selection of the optimal number of suppliers. Furthermore, Ruiz-Torres and Mahmoodi (2006) not only examine the supplier selection problem, but also the corresponding volume allocation for each selected supplier. Yu et al. (2009) propose a method to opt for single or dual sourcing based on the disruption probability, where both suppliers have similar characteristics in terms of reliability and cost as in our paper. Unlike these papers, we do not examine the risk of disruption affecting supply chain design and management. Our paper restricts the analysis to public service in a dynamic framework.

Finally, our paper is related to the lobbying literature such as Grossman and Helpman (1994). Indeed, our model considers the possibility for a supplier to make monetary contributions in order to influence the incumbent public authority's choice of procurement policy. As Le Breton and Salanié (2003), we consider an environment where decision makers are privately informed on the weight that they give to social welfare with respect the value of the lobbyists' contributions. However, contrary to them, we do not consider the competition between two special interest groups to influence the decision maker. In our model, only one supplier is tempted to buy the favor of the public authority.

The paper is organized as follows. Section 2 describes the model of dual sourcing.

In Section 3, we present the benchmark case in which the probability of disruption is exogenous. The optimal procurement policy under complete and incomplete information is characterized. In Section 4, we examine the implications of the probability of disruption being endogenous. Section 5 analyzes the influence of the political process (i.e., lobbying) on the procurement policy. Section 6 concludes.

2 The Model of Dual Sourcing

We consider a two-period model of public procurement. A public authority, also called the principal, must procure one unit of a perfectly divisible service at each period. The service can be produced by two potential risk neutral suppliers (either by supplier A, by supplier B or by both). Supplier A (resp. supplier B) is awarded a perfectly substitutable part $(1-\alpha)$ (resp. α) of the production of the service, where $\alpha \in [0,1]$. We focus on the full spectrum of sourcing strategies from the sole sourcing to the dual sourcing. In sole sourcing, the principal orders from only one of the two suppliers, which has sufficient capacity to produce the entire service. In dual sourcing, the principal simultaneously sources from both suppliers.[3] These two sourcing strategies represent a long-term relationship, in which the principal commits to allocate the same part of the production to the suppliers for both periods. The cost for supplier A (resp. supplier B) of producing $(1-\alpha)$ (resp. α) is given by $\theta_A(1-\alpha)$ (resp. $\theta_B\alpha$).[4] The cost parameter θ_k, $k = A, B$, denotes their respective constant marginal cost, fixed over time. Contrary to the marginal cost θ_A which is known by supplier A and the principal, the marginal cost θ_B is privately observed by supplier B (asymmetry of information). The cost θ_B can take only two values $\underline{\theta}$ and $\overline{\theta}$ with respective probabilities v and $1-v$. We denote $\Delta\theta = \overline{\theta} - \underline{\theta}$, the spread of the uncertainty. This cost θ_k is linked to the technology used which is subject to a random disruption. A disruption may occur at the beginning of the second period with a publicly known probability p_k. The supplier is modeled as either on (available) or off (disrupted). We make the following assumptions about the suppliers' marginal cost and their probability to be disrupted.

Assumption 1 : Supplier A has a cost advantage: $\theta_A < \underline{\theta} < \overline{\theta}$.

Assumption 2 : Supplier A has a higher probability to suffer from disruption: $p_A > p_B$. For the sake of simplicity, we consider that supplier B is perfectly reliable, i.e., the probability to be disrupted p_B is equal to zero. Then, we denote $p_A \equiv p$.

Assumption 3 : If supplier A's technology is disrupted, supplier B may compensate for

[3] The cost of managing two different suppliers is neglected, but could be added on top of our model without changing the internal mechanics.

[4] We ignore the fixed costs which play no other role than justifying the existence of a single supplier.

some portion of the default production $(1-\alpha)$ without additional search or negotiation costs. With probability p, supplier B's part of the production at the second period $\widehat{\alpha}$ depends on the first period split of the production such as:

$$\widehat{\alpha}(\alpha) = \alpha + a(1-\alpha).$$

We have introduced a system of compensation among suppliers by means of the "production flexibility" parameter, a, where $a \in [0, 1)$. "Production flexibility" represents the ability of supplier B to increase her production at the second period. We assume that supplier B's ability to compensate is limited; she cannot deliver the entire default production. In case of sole sourcing, supplier B will only deliver the part a of the production. It means that she may survive at the second period without producing at the first period.[5]

For concreteness, we may interpret supplier A as a centralized energy systems such as nuclear or fossil fuel (coal, gas powered) and supplier B as renewable energies such as solar, wind, hydro and geothermal energy. The two suppliers are heterogeneous differing in their marginal costs of production and their likelihoods of disruption. Renewable energies are considered more costly but more reliable.[6] Indeed, their decentralised nature contributes to the resistance of the energy system to central shocks. As this technology is newly established, the cost is not yet perfectly publicly known.

The value for the risk neutral public authority of this unit of service, denoted S, is common knowledge. The marginal value of the service is positive and strictly decreasing with the part of the production of the service bought by the principal, $S(.)' > 0$ and $S(.)'' < 0$, and satisfies the Inada condition $S(0) = 0$. With probability $(1-p)$, both suppliers are available, so the entire service is provided. In this case, we let the principal's surplus be denoted such that: $S(1) \equiv S$. With probability p, supplier A is not available at the second period, so the service is only partially provided by supplier B. The surplus is henceforth denoted $S(\widehat{\alpha})$.

To ensure the suppliers' participation, the production of the good must yield as least as much utility as the outside option level, normalized to zero. Supplier A must be compensated only for the reimbursement of her cost $\theta_A(1-\alpha)$ at each period to accept working for the public authority. As her marginal cost θ_A is common knowledge, the principal (who has all the bargaining power by assumption) is able to maintain supplier A at zero utility level. For the sake of clarity, we do not explicit her utility level in the rest of the paper, its value being null. Contrarily, the public authority must pay a net monetary transfer t to supplier B encompassing the reimbursement of her cost. This

[5] To contract only with the supplier A at the first period doesn't mean that the supplier B won't be available if it might need it at the second period, except for $a = 0$.

[6] The nuclear energy is less costly if we consider its marginal cost of production. If we take in consideration the cost of building the infrastructure and therefore the long run incremental cost, this assumption is not so obvious.

transfer depends on the supplier's marginal cost and her part of the production. With probability $(1-p)$, supplier B's utility level is then $U(\theta_B, \alpha) = t(\theta_B, \alpha) - \theta_B \alpha$ at each period in dual sourcing. With probability p, her utility level becomes, at the second period, $U(\theta_B, \widehat{\alpha}) = t(\theta_B, \widehat{\alpha}) - \theta_B \widehat{\alpha}$ in dual sourcing or $U(\theta_B, a) = t(\theta_B, a) - \theta_B a$ in sole sourcing.

For notational simplicity, we denote the transfer such that: $\underline{t} \equiv t(\underline{\theta}, \underline{\alpha})$, $\widehat{\underline{t}} \equiv t(\underline{\theta}, \widehat{\underline{\alpha}})$, $\underline{t}(a) \equiv t(\underline{\theta}, a)$, $\overline{t} \equiv t(\overline{\theta}, \overline{\alpha})$, $\widehat{\overline{t}} \equiv t(\overline{\theta}, \widehat{\overline{\alpha}})$ and $\overline{t}(a) \equiv t(\overline{\theta}, a)$. The public authority designs the procurement contract on the observables t and the part of production produced by supplier B equals to α, $\widehat{\alpha}$ or a. It specifies a transfer-part of production pair for each type of supplier B, namely: $\{(\underline{\alpha}, \underline{t}), (\widehat{\underline{\alpha}}, \widehat{\underline{t}}), (a, \underline{t}(a))\}$ for supplier $\underline{\theta}$ and $\{(\overline{\alpha}, \overline{t}), (\widehat{\overline{\alpha}}, \widehat{\overline{t}}), (a, \overline{t}(a))\}$ for supplier $\overline{\theta}$.

We allow the public authority to be able to commit on contracts relative to the whole duration of the relationship. At the beginning of the first period (but after the supplier has learned her marginal cost), the principal can offer a contract settling all future exchanges which cannot be reneged on. The public authority and the suppliers use a common discount factor, $\delta > 0$.

To describe the dynamic of the relationship between the public authority and the suppliers, let us detail the timing of the contracting game as follows.

At the first period: Supplier B discovers her marginal cost for both periods. The public authority chooses the optimal sourcing strategy and offers a contract to the suppliers. The suppliers accept or refuse the contract (if they refuse, they get their reservation utility). The first part of the contract is implemented.

At the second period: The nature draws the state of the nature: (a) with a probability $(1-p)$, supplier A is available, the same split of the production than the first period is provided by both suppliers ; (b) with a probability p, supplier A is disrupted and supplier B may compensate only for some portion of the production. The latter thus provides the production a in case of sole sourcing or $\widehat{\alpha}$ in case of dual sourcing. The second part of the contract is implemented.

3 Procurement Policy under Exogenous Probability of Disruption

In this section, we assume that the probability of disruption is exogenous. Disruptions of the provision of the public service may occur due, for example, to natural disasters, political risks and acts of terrorism. We characterize the public authority's procurement policy for both complete and incomplete information cases.

3.1 Complete Information

Under complete information, the public authority observes supplier B's marginal cost. He would thus maximize social welfare under supplier B's participation constraint such that:[7]

$$\underset{\{t,\alpha\}}{Max}\{S-\theta_A(1-\alpha)-\theta_B\alpha-U(\theta_B,\alpha)$$
$$+\delta[(1-p)[S-\theta_A(1-\alpha)-\theta_B\alpha-U(\theta_B,\alpha)]+p[S(\widehat{\alpha}(\alpha))-\theta_B\widehat{\alpha}(\alpha)-U(\theta_B,\widehat{\alpha})]]\}$$

subject to $U(\theta_B,\alpha)+\delta[(1-p)U(\theta_B,\alpha)+pU(\theta_B,\widehat{\alpha})]\geq 0$.[8]

Social welfare encompasses the full spectrum of procurement strategies from the sole sourcing (if $\alpha = 0$ or $\alpha = 1$) to the dual sourcing (if $1 > \alpha > 0$). Instead of awarding the entire production to supplier A, the public authority may decide to award the part α of the production to supplier B to ensure the continuity of the production and then obtain $\widehat{\alpha}(\alpha)$ in case of disruption at the second period. Indeed, supplier B is a more costly but, does not suffer from disruption. To better understand the role of dual soucing in the public service provision, the social welfare can be rewritten explicitly both in terms of investment I in dual sourcing and its return R. The program of maximization (P1) is such as:

$$\underset{\{t,\alpha\}}{Max}\{S-\theta_A-I+\delta[(1-p)(S-\theta_A)+p[S(a)-\theta_Ba-U(\theta_B,a)+R]]\}$$

subject to $U(\theta_B,\alpha)+\delta[(1-p)U(\theta_B,\alpha)+pU(\theta_B,\widehat{\alpha})]\geq 0$ and $U(\theta_B,a)\geq 0$.

Supplier B' s ability to compensate for some portion of the default production without producing at the first period appears more clearly in this expression of social welfare. If the principal decides to use sole sourcing at the first period, supplier B will thus provide the production a at the cost $\theta_B a$ and will receive the rent $U(\theta_B,a)$. Such backup production will thus depend on her ability to increase her production at the second period, as we will discuss later.

The investment I corresponds to the cost that the public authority incurs using dual sourcing. It is defined as:

$$I=[(\theta_B-\theta_A)\alpha+U(\theta_B,\alpha)](1+\delta). \tag{1}$$

Contracting with supplier B for the part α of the production instead of allocating to supplier A is costly for the principal. In addition, the public authority has to give the

[7] Social welfare corresponds to social value of trade minus the rent of the suppliers. The public authority is only concerned about consumers' surplus, not about supplier's profit.

[8] To obtain supplier B's participation, the public authority must ensure that her utility level is non-negative. In this setting, only the participation constraint matters for the principal since the supplier can be forced to reveal her type and then to produce the corresponding share of production.

information rent to supplier B $U(\theta_B, \alpha)$. Furthermore, once dual sourcing is adopted at the first period, the public authority cannot choose to abandon the backup supplier B even if supplier A has not been disrupted. So, the investment is paid for both periods.

The return on investment R of dual sourcing is:

$$R = [S(\widehat{\alpha}(\alpha)) - \theta_B \widehat{\alpha}(\alpha) - U(\theta_B, \widehat{\alpha})] - [S(a) - \theta_B a - U(\theta_B, a)] + [(\theta_B - \theta_A)\alpha + U(\theta_B, \alpha)]. \quad (2)$$

The first terms in brackets, in equation (2), corresponds to the social welfare of splitting the provision of the public service between two suppliers in case of disruption. If the provision from supplier A is disrupted, the public authority can shift partially his outsourcing to supplier B in addition to her previous production. The latter will thus provide the production $\widehat{\alpha}(\alpha)$ at the cost $\theta_B \widehat{\alpha}(\alpha)$ and will receive the rent $U(\theta_B, \widehat{\alpha})$. However, to obtain the return on investment R, we have to subtract the second bracketed term. It refers to social welfare from the backup production a ensured by supplier B even if she does not produce at the first period. Finally, the return encompasses the reimbursement of second part of the investment, which is partially reversible in case of disruption.[9] It is represented by the bracketed term on the right-hand side of equation (2).

Under complete information, supplier B's rent being socially costly, the public authority maintains the supplier at her status quo utility level fixed at zero. The participation constraints are binding at the optimum in case of dual sourcing:

$$U(\theta_B, \alpha) + \delta[(1-p)U(\theta_B, \alpha) + pU(\theta_B, \widehat{\alpha})] = 0 \quad (3)$$

and in case of sole sourcing:

$$U(\theta_B, a) = 0.$$

Then, by substituting α into $\widehat{\alpha}$, the principal maximizes expected social welfare with respect to α and we obtain the first-best part of production α^{FB}. The next proposition summarizes the solution of the public authority's problem (P1).

Proposition 1 *: Under complete information, the optimal procurement policy entails:*

- *For $S'(a) > \theta_B + (\theta_B - \theta_A)\frac{1+\delta(1-p)}{\delta p(1-a)}$, dual sourcing is the optimal procurement policy. The first-best part of the production awarded to the secondary supplier α^{FB} is given by:*

$$S'(\widehat{\alpha}(\alpha^{FB})) = \theta_B + (\theta_B - \theta_A)\frac{1+\delta(1-p)}{\delta p(1-a)}. \quad (4)$$

- *Otherwise, sole sourcing is optimal and α^{FB} is null.*

[9] The initial cost of investment is sunk at the first period through dual sourcing, but if the supplier A is disrupted at the second period, sourcing from both suppliers is not anymore possible.

We denote $\underline{\alpha}^{FB}$ (resp. $\overline{\alpha}^{FB}$) the solutions corresponding to $\theta_B = \underline{\theta}$ (resp. $\theta_B = \overline{\theta}$). The proof is straightforward and omitted.

The public authority chooses dual sourcing when the marginal benefit of the backup production a is larger than the marginal cost of splitting the production between both suppliers. Increasing the backup production beyond a implies that the principal has to give up a part of the production to supplier B at the first period such as $\alpha^{FB} > 0$. Furthermore, we see that the less the supplier may compensate for the default production, the more valuable is dual sourcing. When the benefit to increase the production beyond a is lower than its marginal cost, the public authority prefers opting for sole sourcing. In this case, he benefits only from the production a. While we have discussed the choice between sole and dual sourcing, we focus more on the optimal of the split of production awarded to each supplier in case of dual sourcing, i.e., the relative use of supplier A and supplier B once both have been selected.

In intuitive terms, the first-best part of the production awarded to supplier B, α^{FB} may be described by the following first-order condition:

$$\frac{\partial I}{\partial \alpha} = \delta p \frac{\partial R}{\partial \alpha}$$

Such optimal split of the production is obtained by equating the marginal investment in dual sourcing defined as:

$$(\theta_B - \theta_A)(1 + \delta)$$

and its marginal return weighted by the discount factor δ and the probability of disruption p such as:

$$\delta p[S'(\widehat{\alpha}(\alpha^{FB}))(1 - a) + (\theta_B - \theta_A)]$$

From equation (4), we see that the first-best part of the production is such that the marginal benefit of ensuring a backup production $\widehat{\alpha}(\alpha)$ in case of disruption is just equal to the marginal disutility of doing so. Such disutility, described by the right-hand side of the equation (4) is composed of two terms. The first term corresponds to supplier B's marginal cost. The second one represents the cost related to sourcing a part α^{FB} of production from the secondary supplier instead of allocating to less costly supplier A. This expression takes into account that such cost is reversible in case of disruption.

In this case, instead of awarding the entire production to one supplier (sole sourcing), the public authority splits award production among both suppliers (dual sourcing). Contracting only with cheapest supplier A for all of the production process costs less, but by doing so, the public authority is accepting the risk of disruption. The cost of disruption corresponds to the loss incurred by the public authority when supplier A fails to provide the allocated part of the production due to the occurrence of catastrophic events disruption. Due to such possibly loss, the public authority finds it valuable to make a contracting arrangement with supplier B in order to secure the production of the public service. Dual sourcing is an attractive option to manage the risk of disruption by using a secondary source in public procurement.

From (4), the comparative static analysis shows that the ability of supplier B to compensate for the default production is one of the key determinants of the procurement strategy. As the surplus S is concave, the higher the "production flexibility" parameter a, the lower supplier B's part of the production, $\partial\alpha^{FB}/\partial a < 0$. Contrarily, when a decreases, the disruption cost increases, and the best sourcing strategy is to rely more on supplier B to ensure a backup production at the second period in case of disruption. The optimal procurement strategy depends also on the intensity of the risk and the discount factor. When p increases, supplier A is more likely to default and the public authority calls relatively more on supplier B. It is also the case when the public authority does not discount the future. The higher the discount factor δ, the more valuable the use of supplier B. Finally, the suppliers' allocation of the production depends on their respective marginal cost. The scope of dual sourcing is more important when supplier A's marginal cost θ_A increases and when supplier B's marginal cost θ_B decreases. Furthermore, dual sourcing is increasingly favored by the principal as the supplier cost heterogeneity $(\theta_B - \theta_A)$ decreases.

3.2 Incomplete Information

We suppose now that the public authority cannot observe supplier B's marginal cost. From the Revelation Principle, there is no loss of generality in restricting the analysis to direct revelation mechanisms which specify for each message from supplier B, $\widetilde{\theta}_B = \underline{\theta}$ or $\widetilde{\theta}_B = \overline{\theta}$, a part of the production to achieve and a net transfer from the public authority. The direct revelation mechanism must be truthful, i.e., must satisfy the following incentive constraints under dual sourcing:

$$\begin{aligned}
\underline{t} - \underline{\theta\alpha} + \delta[(1-p)(\underline{t} - \underline{\theta\alpha}) + p(\widehat{\underline{t}} - \underline{\theta\widehat{\alpha}})] &\geq \bar{t} - \underline{\theta}\overline{\alpha} + \delta[(1-p)(\bar{t} - \underline{\theta}\overline{\alpha}) + p(\widehat{\bar{t}} - \underline{\theta}\widehat{\overline{\alpha}})] \\
\bar{t} - \overline{\theta}\overline{\alpha} + \delta[(1-p)(\bar{t} - \overline{\theta}\overline{\alpha}) + p(\widehat{\bar{t}} - \overline{\theta}\widehat{\overline{\alpha}})] &\geq \underline{t} - \underline{\theta\alpha} + \delta[(1-p)(\underline{t} - \underline{\theta\alpha}) + p(\widehat{\underline{t}} - \underline{\theta\widehat{\alpha}})]
\end{aligned}$$

and under sole sourcing:

$$\begin{aligned}
\underline{t} - \underline{\theta}a &\geq \bar{t} - \underline{\theta}a \\
\bar{t} - \overline{\theta}a &\geq \underline{t} - \underline{\theta}a
\end{aligned}$$

We denote the utilities for simplicity as: $\underline{U} \equiv U(\underline{\theta}, \underline{\alpha})$, $\overline{U} \equiv U(\overline{\theta}, \overline{\alpha})$, $\widehat{\underline{U}} \equiv U(\underline{\theta}, \widehat{\underline{\alpha}})$, $\widehat{\overline{U}} \equiv U(\overline{\theta}, \widehat{\overline{\alpha}})$, $\underline{U}(a) \equiv U(\underline{\theta}, a)$ and $\overline{U}(a) \equiv U(\overline{\theta}, a)$. Under dual sourcing, the incentive constraints are written in terms of information rents as follows:

$$\begin{aligned}
\underline{U}+\delta[(1-p)\underline{U}+p\widehat{\underline{U}}] &\geq \overline{U}+\delta[(1-p)\overline{U}+p\widehat{\overline{U}}]+\Delta\theta\overline{\alpha}+\delta[(1-p)\Delta\theta\overline{\alpha}+\Delta\theta\widehat{\overline{\alpha}}] \quad (5)\\
\overline{U}+\delta[(1-p)\overline{U}+p\widehat{\overline{U}}] &\geq \underline{U}+\delta[(1-p)\underline{U}+p\widehat{\underline{U}}]-\Delta\theta\underline{\alpha}-\delta[(1-p)\Delta\theta\underline{\alpha}+\Delta\theta\widehat{\underline{\alpha}}] \quad (6)
\end{aligned}$$

and under sole sourcing as:

$$\begin{aligned}
\underline{U}(a) &\geq \overline{U}(a)+\Delta\theta a \quad (7)\\
\overline{U}(a) &\geq \underline{U}(a)-\Delta\theta a \quad (8)
\end{aligned}$$

Supplier B is given incentives to reveal her marginal cost at the first period.[10]

To obtain supplier B's participation, her utility level must yield at least the outside option level. The following participation constraints must be satisfied:

$$\begin{aligned}
\underline{U}+\delta[(1-p)\underline{U}+p\widehat{\underline{U}}] &\geq 0 \text{ and } \overline{U}+\delta[(1-p)\overline{U}+p\widehat{\overline{U}}]\geq 0 \quad (9)\\
\underline{U}(a) &\geq 0 \text{ and } \overline{U}(a)\geq 0 \quad (10)
\end{aligned}$$

The principal's problem is then to choose a pair of split of production $\underline{\alpha}$ and $\overline{\alpha}$ which maximize the expected welfare. The maximization program (P2) writes as:

$$\underset{\{(\underline{t},\underline{\alpha}),(\overline{t},\overline{\alpha})\}}{Max} E_{\theta^B}\{S-\theta_A-I+\delta[(1-p)(S-\theta_A)+p[S(a)-\theta_B a-U(\theta_B,a)+R]]\}$$

subject to (5), (6), (7), (8), (9) and (10).

The standard simplification in the number of constraints leaves us with four relevant constraints, $\underline{\theta}$-supplier B's incentive constraints (5) and (7) and $\overline{\theta}$-supplier B's participation constraints described in equations (9) and (10), which are binding.[11] In case of dual sourcing, we thus have:

$$\underline{U}+\delta[(1-p)\underline{U}+p\widehat{\underline{U}}]=\Delta\theta\overline{\alpha}+\delta[(1-p)\Delta\theta\overline{\alpha}+\Delta\theta\widehat{\overline{\alpha}}] \text{ and } \overline{U}+\delta[(1-p)\overline{U}+p\widehat{\overline{U}}]=0 \quad (11)$$

It results that $\overline{\theta}$-supplier B obtains no rent. Contrarily, $\underline{\theta}$-supplier B benefits from an information rent, generated by her informational advantage over the principal. This rent depends on the part of production allocated to $\overline{\theta}$-supplier B. So, the principal has to give up a positive rent to $\underline{\theta}$-supplier B as long as he allocates a certain level of the production to $\overline{\theta}$-supplier B. In case of sole sourcing when supplier A is disrupted, we obtain:

$$\underline{U}(a)=\Delta\theta a \text{ and } \overline{U}(a)=0 \quad (12)$$

[10]The principal wants to discriminate among types to leave as small a rent as possible to supplier B.

[11]Note that the neglected $\overline{\theta}$-supplier B's incentive constraints (6), (8) and $\underline{\theta}$-supplier B's participation constraint (9) are satisfied by the solution.

While $\overline{\theta}$-supplier B gets no rent, $\underline{\theta}$-supplier B earns a rent depending on her ability to compensate for the default production. Contrary to the previous case, her production a is not beyond the principal's control. The public authority's optimization is thus altered by asymmetric information, compared with the complete information framework, due to the subtraction of the expected rent given up to $\underline{\theta}$-supplier B.

The maximization of expected social welfare with respect to $(\underline{\alpha}, \overline{\alpha})$ subject to (11) and (12) can rewritten in terms of investment and return, as:

$$\begin{aligned} &\underset{\{\underline{\alpha},\overline{\alpha}\}}{Max} \ \{ \ v \ [S - \theta_A - \underline{I} + \delta[(1-p)(S-\theta_A) + p[S(a) - \underline{\theta}a - \Delta\theta a + \underline{R}]] \\ &+(1-v) \ [S - \theta_A - \overline{I} + \delta[(1-p)(S-\theta_A) + p[S(a) - \overline{\theta}a + \overline{R}]]\} \end{aligned}$$

In incomplete information, the investment $\overline{I}$ and the return $\overline{R}$ of dual sourcing are the same than in complete information with $\theta_B = \overline{\theta}$. Contrarily, the investment $\underline{I}$ and the return $\underline{R}$ when $\theta_B = \underline{\theta}$ include information rents. Inserting (11) and (12) into equations (1) and (2), we obtain:

$$\begin{aligned} \underline{I} &= (1+\delta)[(\underline{\theta} - \theta_A)\underline{\alpha} + \Delta\theta\overline{\alpha}], \\ \underline{R} &= S(\widehat{\underline{\alpha}}) - \underline{\theta}\widehat{\underline{\alpha}} - \Delta\theta\widehat{\overline{\alpha}} - [S(a) - \underline{\theta}a - \Delta\theta a \ ] + (\underline{\theta} - \theta_A)\underline{\alpha} + \Delta\theta\overline{\alpha}. \end{aligned}$$

By substituting $(\underline{\alpha}, \overline{\alpha})$ into $(\widehat{\underline{\alpha}}, \widehat{\overline{\alpha}})$, we maximize expected social welfare with respect to $(\underline{\alpha}, \overline{\alpha})$ and obtain the following proposition 2.

Proposition 2 *Under incomplete information, the optimal procurement policy is as follows:*

- For $S'(a) > S'(\widehat{\alpha}(\overline{\alpha}^{FB})) + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap)}{\delta p(1-a)}$, dual sourcing is optimal. The optimal menu of contracts entails no distortion of the second-best part of the production $\underline{\alpha}^{SB}$ from the first-best and a downward distortion of the second-best part of the production $\overline{\alpha}^{SB}$, determined by:

$$S'(\widehat{\alpha}(\overline{\alpha}^{SB})) = S'(\widehat{\alpha}(\overline{\alpha}^{FB})) + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap)}{\delta p(1-a)}$$

- *Otherwise, sole sourcing is the optimal procurement policy and the second-best parts of the production* $\underline{\alpha}^{SB}$ *and* $\overline{\alpha}^{SB}$ *are null.*

The proof of proposition 2 and all later results are presented in the Appendix. In what follows, we focus our attention on settings in which dual sourcing is optimal.

As previously, the optimal production split is obtained by equating the marginal cost of dual sourcing and its marginal benefit, under incomplete information. The second-best split of the production when supplier B's marginal cost is $\underline{\theta}$ is not distorted away from the first-best level, $\underline{\alpha}^{SB} = \underline{\alpha}^{FB}$. Contrarily, when supplier B's marginal cost is $\overline{\theta}$, the existence of information rents leads the principal to distort downwards the level of production $\overline{\alpha}^{SB}$ away from the first-best level, such as $\overline{\alpha}^{SB} < \overline{\alpha}^{FB}$. To reduce the cost of sourcing from both suppliers which depends on the rent left to $\underline{\theta}$-supplier B, $\overline{\theta}$-supplier B level of production $\overline{\alpha}^{SB}$ is downward distorted. Even if a part of the rent, $\underline{U}$, is reversible at the second period if supplier A is disrupted, the principal distorts the second-best split of production level away from its first-best value to reduce the cost of the rent $\widehat{\underline{U}}$. To sum up, reducing $\overline{\theta}$-supplier B part of the production reduces $\underline{\theta}$-supplier B's information rent, whatever the probability of disruption. The principal stops decreasing the split of the service production $\overline{\alpha}^{SB}$, until a further decrease would have a higher cost than the benefit in reducing the information rent it would bring about.

We derive simple comparative statics analysis of the effect of the informational rent on the optimal contract. As in the "classical" contract theory literature, following Baron and Myerson (1982), Laffont and Tirole (1993) or more recently Laffont and Martimort (2002), we find that the higher the probability v that the is efficient, the lower $\overline{\theta}$-supplier's part of the production. It also the case as the spread of the uncertainty $\Delta\theta$ increases. Indeed, an infinitesimal increase in $\overline{\theta}$-supplier B level of production also increases $\underline{\theta}$-supplier B's information rent and the principal's expected payoff is diminished. On the reverse, a lower value of a, leading to a lower value of the rent $\widehat{\underline{U}}$, decreases the distortion from the first-best of $\overline{\theta}$-supplier B level of production. Furthermore, when the intensity of the risk p and the discount factor δ increase, the downward distortion of the level of production $\overline{\alpha}^{SB}$ due to the informational rent given up to supplier B is diminished.

In incomplete information, the principal designs a contract menu without knowing supplier B's marginal cost, who can act strategically and take advantage of her private information. Consequently, asymmetric information makes supplier B's backup production less valuable for the principal. The latter may still opt for dual sourcing, but we find that the cost of doing so is higher under asymmetric information due to supplier B' incentives to misrepresent her marginal costs. As a result, when the probability of disruption is exogenous, asymmetric information about supplier B's marginal cost reduces the scope of using dual sourcing and pushes the public authority towards a lower use of the backup supplier.

4 Procurement Policy under Endogenous Probability of Disruption

We now consider that the probability of disruption is endogenously determined by supplier A's part of production. Indeed, we may consider that her reliability depends on her part of production. Two cases can be distinguished. First, the probability of disruption increases as supplier A produces more. Second, the supplier A is less likely to be disrupted as her part of production increases. Variations of the probability of disruption p with respect to the suppliers' part of the production α will be part of the discussion below.

4.1 Complete Information

Under complete information, supplier B's marginal cost is common knowledge. In this case, the public authority's problem is to choose a split of production which maximizes the social welfare considering now the probability of disruption as endogenous. Therefore, he wishes to solve the problem (P3) below:

$$\underset{\{t,\alpha\}}{Max}\{S-\theta_A-I+\delta[(1-p(\alpha))(S-\theta_A)+p(\alpha)[S(a)-\theta_A a-U(\theta_B,a)+R]]\}$$

subject to $U(\theta_B,\alpha)+\delta[(1-p)U(\theta_B,\alpha)+pU(\theta_B,\widehat{\alpha})]\geq 0$ and $U(\theta_B,a)\geq 0$.

The participation constraints are binding at the optimum as in section 3.1. Supplier B's rents are thus defined as follows in dual sourcing:

$$U(\theta_B,\alpha)+\delta[(1-p)U(\theta_B,\alpha)+pU(\theta_B,\widehat{\alpha})]=0$$

and in sole sourcing:

$$U(\theta_B,a)=0.$$

Then, we solve the public authority's problem (P3) and obtain the following proposition characterizing the optimal split of the production α^*.

Proposition 3 : *Under complete information, the optimal procurement policy entails:*

- *For $S'(a)>S'(\widehat{\alpha}(\alpha^{FB}))+\frac{\partial p(\alpha)}{\partial\alpha}\frac{1}{p(\alpha)(1-a)}[S-\theta_A-S(\widehat{\alpha}(\alpha))+\theta^B\widehat{\alpha}(\alpha)]$, dual sourcing is optimal. When the probability of disruption decreases (resp. increases) with the part awarded to the backup supplier, the first-best part of the production allocated to the backup supplier α^* is higher (resp. lower) than in the exogenous probability of disruption case. The part α^* is defined, at $p=p(\alpha)$, by:*

$$S'(\widehat{\alpha}(\alpha^*))=S'(\widehat{\alpha}(\alpha^{FB}))+\frac{\partial p(\alpha)}{\partial\alpha}\,|_{\alpha=\alpha^*}\;\frac{1}{p(\alpha^*)(1-a)}[S-\theta_A-S(\widehat{\alpha}(\alpha^*))+\theta_B\widehat{\alpha}(\alpha^*)] \quad (13)$$

- *Otherwise, sole sourcing is the optimal procurement policy and the first-best part of the production α^* is null.*

We denote $\underline{\alpha}^*$ the solution corresponding to $\theta_B = \underline{\theta}$ and $\overline{\alpha}^*$ to $\theta_B = \overline{\theta}$.

The benefit of dual sourcing depends on the last term in the equation (13) representing the impact of the split of the production on the probability to be disrupted. We distinguish two different cases. First, the higher supplier A's part of production $(1-\alpha)$, the higher her probability to be disrupted. So, increasing the scope of dual sourcing reduces the risk of disruption, $\partial p(\alpha)/\partial\alpha < 0$. The marginal benefit of dual sourcing is greater than the benchmark case described in proposition 1. Reducing the probability of disruption implies a higher backup production at the second period, i.e. relying more on supplier B such that $\alpha^* > \alpha^{FB}$. Second, increasing supplier A's part of production improves her reliability. In other words, reducing the scope of dual sourcing decreases the risk of disruption, $\partial p(\alpha)/\partial\alpha > 0$. The marginal benefit of dual sourcing decreases. The part of the production awarded to supplier B decreases such that: $\alpha^* < \alpha^{FB}$. To lower the probability of disruption, the principal uses less the backup supplier with respect to the benchmark case.

We study the sustainability of such a split of production in a setting suffering from asymmetry of information on supplier B's efficiency.

4.2 Incomplete Information

We assume that supplier B is privately informed about her marginal cost of production. Following similar procedures to what we have done so far in section 3.2, only $\underline{\theta}$-supplier B's incentive constraints and $\overline{\theta}$-supplier B's participation constraints are binding such as:

$$\begin{aligned}\underline{U} + \delta[(1-p)\underline{U} + p\widehat{\underline{U}}] &= \Delta\theta\overline{\alpha} \text{ and } \overline{U} + \delta[(1-p)\overline{U} + p\widehat{\overline{U}}] = 0 \\ \underline{U}(a) &= \Delta\theta a \text{ and } \overline{U}(a) = 0\end{aligned}$$

We insert those expressions into the public authority's objective function:

$$\underset{\{\underline{\alpha},\overline{\alpha}\}}{Max} \;\; E_{\theta^B}\{S - \theta_A - I + \delta[(1-p(\alpha))(S-\theta_A) + p(\alpha)[S(a) - \theta_A a - U(\theta_B, a) + R]\}$$

The next proposition summarizes the solution of this program (P4).

Proposition 4 *Under incomplete information, the optimal procurement policy is as follows:*

- *For* $S'(a) > S'(\widehat{\alpha}(\overline{\alpha}^*)) + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap(\overline{\alpha}^{**}))}{\delta p(\overline{\alpha}^{**})(1-a)}$, *dual sourcing is optimal. The optimal menu of contracts entails no distortion of the second-best part of the production* $\underline{\alpha}^{**}$, *and a downward distortion of the second-best part of the production* $\overline{\alpha}^{**}$ *from the first-best, determined as:*

$$S'(\widehat{\alpha}(\overline{\alpha}^{**})) = S'(\widehat{\alpha}(\overline{\alpha}^{*})) + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap(\overline{\alpha}^{**}))}{\delta p(\overline{\alpha}^{**})(1-a)}$$

- *Otherwise, sole sourcing is the optimal procurement policy and the second-best parts of the production* $\underline{\alpha}^{**}$ *and* $\overline{\alpha}^{**}$ *are null.*

As in the previous section, the optimal split of the production depends on its impact on the probability of disruption. In the first case, the provision from supplier A is more likely to disrupt as her part of production increases. So, the public authority finds it more valuable to rely more on supplier B in order to hedge the risk of disruption. In the second case, p lowers as supplier A's part increases. The optimal procurement policy is thus to rely more on supplier A. However, the complete information optimal contracts can no longer be implemented under incomplete information. At the optimal (second-best) contract, the public authority trades-off the benefit to reach allocative efficiency against the cost coming from the information rent given up to efficient supplier B. Indeed, the rent information cost adds up to the cost of dual sourcing and then justifies downward distortions from the first-best of the split of the production achieved under asymmetric information.

To sum up, the optimal procurement policy depends on the impact of the split of production on the probability of disruption. The public authority calls more (resp. less) on the backup supplier when it decreases (resp. increases) the probability of disruption. However, in incomplete information, the scope of using dual sourcing is reduced. The information rents make supplier B's backup production less valuable for the principal.

5 Procurement Policy under Lobbying

We consider the exogenous probability framework to evaluate the impact of lobbying on the procurement policy (sole sourcing versus dual sourcing) in the incomplete information case described at the section 3.2.

5.1 The Model of Lobbying

In this section, we relax the pure benevolence assumption allowing the public authority to value monetary transfers from lobbyists. So, we assume that there is a self-interested public authority and rent-seeking lobbyists. Suppliers may make monetary contributions in order to influence the incumbent public authority's choice of procurement policy at the beginning of the contracting game.[12]

The public authority must choose between two procurement strategies, sole sourcing

[12] We allow supplier B to lobby the public authority only before to know her type, to avoid problem of information signalling. Otherwise, we have to deal with ratchet effect.

a_{SS} and dual sourcing a_{DS}. Supplier A is indifferent between both strategies. Indeed, she receives no rent, $E_{\theta_A}[U(\theta_A, (1-\alpha))] = 0$, in both cases. Only supplier B attempts to influence decision made by the public authority, in favor of dual sourcing. While she obtains the following payoff V_{SS} in case of sole sourcing:

$$V_{SS} = \delta p E_{\theta_B}[U(\theta_B, a)],$$

her payoff V_{DS} in dual sourcing is such as:

$$V_{DS} = E_{\theta^B}[U(\theta_B, \alpha) + \delta[(1-p)U(\theta_B, \alpha) + pU(\theta_B, \widehat{\alpha})]].$$

So, supplier B receives a larger payoff if a_{DS} is chosen versus a_{SS}:

$$V_{DS} > V_{SS}$$

$$\Leftrightarrow v\Delta\theta[(1+\delta(1-p))\overline{\alpha} + \delta p\widehat{\overline{\alpha}}] > \delta p v \Delta\theta a$$
$$\Leftrightarrow v\Delta\theta\overline{\alpha}[1+\delta(1-ap)] > 0$$

We denote W_i, $i = SS, DS$, the social welfare if the strategy a_i is chosen. Without loss of generality, we assume that the following condition defined in proposition 2 holds,

$$S'(a) \leq S'(\widehat{\alpha}(\overline{\alpha}^{FB})) + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap)}{\delta p(1-a)}$$

which implies that:

$$W_{SS} > W_{DS}$$

Therefore the efficient decision is a_{SS}. So, supplier B attempts to influence the procurement policy in favor of a_{DS} by promising to make a non negative monetary transfer T to the public authority conditionally on dual sourcing being adopted such as:

$$V_{DS} - T \geq V_{SS}$$

$$\Leftrightarrow v\Delta\theta\overline{\alpha}[1+\delta(1-ap)] \geq T$$

The transfer T does not depend on the supplier's marginal cost due to the fact that it is promised before she discovers it.

As Grossman and Helpman (1994), we consider that the incumbent public authority values social welfare because it cares to be re-elected but also monetary transfers because it can be used to finance campaign spending. Then, the public authority chooses the procurement strategy which maximizes a weighted sum of social welfare and monetary transfer, defined as:

$$\gamma W + T.$$

The parameter γ denotes the weight on social welfare in the public authority's payoff. The public authority is privately informed on γ with γ in $\Gamma = [\underline{\gamma}, \overline{\gamma}]$, with a cumulative distribution function $F(\gamma)$ and a density function $f(\gamma)$, both positive on $[\underline{\gamma}, \overline{\gamma}]$. Furthermore, to ensure that first order conditions are necessary and sufficient, we assume that monotone hazard rate property $(\frac{F(\gamma)}{f(\gamma)})' \geq 0$ holds.

The timing of the contracting game including lobbying unfolds as follows.

At the first period: Supplier B promises a monetary offer T to the public authority that she commits to pay if strategy a_{DS} is chosen. Supplier B discovers her marginal cost. The public authority chooses the optimal procurement strategy between sole sourcing and dual sourcing and offers a contract to the suppliers. The suppliers accept or refuse the contract (if they refuse, they get their reservation utility). The first part of the contract is implemented.

At the second period: The second part of the timing is described in section 2.

5.2 Complete Information on the Weight on Social Welfare

As a benchmark case, let us first assume that the weight on social welfare γ is common knowledge. In this case, the public authority selects the inefficient strategy a_{DS} if:

$$\gamma W_{SS} \leq \gamma W_{DS} + T$$

$$\Leftrightarrow T \geq \gamma (W_{SS} - W_{DS})$$

As supplier B's utility decreases in the level of lobbying T, the constraint above is binding. Then, the supplier's transfer is defined as:

$$T^C = \{ \begin{array}{cl} \gamma(W_{SS} - W_{DS}) & \text{if } V_{DS} - T^C \geq V_{SS} \\ 0 & \text{otherwise} \end{array}$$

As we have seen, supplier B attempts to influence the procurement policy in favor of a_{DS} only when the transfer is lower than the difference of rents she stands to get in dual sourcing rather in sole sourcing. In this case, we find that supplier B will lobby to defeat sole sourcing more vigorously the greater the weight on social welfare γ. In other words, the less the public authority values transfer, the higher are the latter. Similarly, the higher the social welfare difference $(W_{SS} - W_{DS})$, the higher the transfer. Indeed, as the welfare difference increases, supplier B has to lobby more strongly. Once the supplier decides the amount of the transfer, the public authority chooses the procurement policy which maximizes his payoff.

5.3 Incomplete Information on the Weight on Social Welfare

Now, we assume that the weight γ is a private information of the public authority. So, supplier B lacks information on how costly it is to influence the procurement strategy. In this case, the public authority selects the inefficient strategy a_{DS} if γ is below some threshold γ_0:

$$\gamma < \frac{T}{W_{SS} - W_{DS}} \equiv \gamma_0.$$

We suppose that $\underline{\gamma} < \gamma_0 < \overline{\gamma}$. Supplier B's payoff corresponds to:

$$\begin{aligned} V_{DS} - T \text{ if } \gamma &< \gamma_0 \\ V_{SS} \text{ if } \gamma &\geq \gamma_0 \end{aligned}$$

To determine the optimal level of transfer T, the firm is willing to maximize her ex ante payoff such as:

$$\underset{\{T\}}{Max}\{[V_{DS} - T]F(\gamma_0) + V_{SS}(1 - F(\gamma_0))\}$$

The next proposition summarizes the solution of the supplier's problem. The assumption of monotone hazard rate ensures that the second-order condition is satisfied.

Proposition 5 *Under uncertainty on the public authority's preferences, the optimal transfer is characterized by the following first-order condition:*

$$T^{IC} + \frac{F(\gamma_0)}{f(\gamma_0)}(W_{SS} - W_{DS}) = V_{DS} - V_{SS}$$

For simplicity and in order to highlight comparative statics, we assume that γ is drawn from the uniform distribution on [0,1]. It results that the lobbist should pay, to influence the choice of procurement policy in favor of dual sourcing, the following monetary transfer:

$$T^{IC} = \frac{V_{DS} - V_{SS}}{2}$$

$$\Leftrightarrow T^{IC} = \frac{v\Delta\theta\overline{\alpha}[1 + \delta(1 - ap)]}{2}$$

The ability of supplier B to increase her production at the second period is one of the determinants of the transfer. The lower the "production flexibility" parameter a, the higher the level of the transfer. As a decreases, the probability of dual sourcing (without any lobbying) increases so there is less scope for lobbying. It is also the case as the risk of disruption p increases and as the discount factor δ decreases. On the contrary, the higher the probability v that supplier B is efficient, the higher the level of transfer. Similarly, the larger the suppliers heterogeneity $\Delta\theta$ and the greater $\overline{\theta}$-supplier B level of production $\overline{\alpha}$, the higher the level of transfer. Indeed, these three variables are component of supplier B's information rent. So, supplier B lobbies to defeat sole sourcing more vigorously the greater the rent she stands to obtain.

In this section, we examined the lobbying as an essential element of the procurement strategy. We conclude that monetary contributions may influence the public authority in favor of the inefficient strategy. Surprinsigly, the lobbyist is not the incumbent supplier A to save her dominant position as cheapest supplier, but the entrant supplier B. Contrary to supplier A whose cost may be revealed over time, supplier B benefits from her informational advantage over the public authority. So, the latter has interest to influence the choice of procurement policy in favor of dual sourcing.

6 Conclusion

Suppliers around the world may experience severe disasters causing major supply disruptions. The Fukushima nuclear accident shows the importance of energy source diversification and justifies the use of secondary source in public procurement. The choice of the optimal procurement policy, particularly in regard of the number of simultaneous suppliers for the same service, is strategically important in risky environments. Sole sourcing can increase the provision of service's exposure to the risk of disruption (i.e., supplier's default), but, at the same time, dual sourcing presents greater procurement costs using a more costly secondary supplier. In this paper, we show that the optimal procurement policy depends mainly on the secondary supplier's ability to compensate for the default production. This policy is characterized by two key decisions: the choice between sole sourcing and dual sourcing and the relative use of the primary supplier and the secondary supplier once both have been selected. First, we find that dual sourcing is more (resp. less) likely to be optimal as the secondary supplier's compensation for the default production decreases (resp. increases). Second, we determine the optimal split of production awarded to each supplier in case of dual sourcing. When the production flexibility diminishes, the disruption cost increases and it becomes harder to ensure the continuity of the provision the service. The best sourcing strategy is then to rely more on the secondary supplier to ensure a backup production in case of disruption. We also find that whatever the determination of the probability of disruption (exogenously or endogenously), asymmetric information about the secondary supplier's cost reduces the scope of dual sourcing. Contrary to the widespread view that dual sourcing has specific incentive properties, we show that the information advantage of suppliers prevents the public authority from achieving the efficient allocation of production between both suppliers. Finally, we conclude that the public authority may choose an inefficient procurement policy if he receives from the secondary supplier a monetary transfer.

References

[1] Anton, J. J. and D. A. Yao, (1989), "Split awards, procurement and innovation," RAND Journal of Economics 20, 538-552.

[2] Anton, J. J. and D. A. Yao, (1992), "Coordination in Split Award Auctions," Quarterly Journal of Economics, 107, pp. 681–707.

[3] Auriol, E. and J.J. Laffont, (1992), "Regulation by duopoly," Journal of Economics and Management Strategy 1, 507-533.

[4] Baron, D. and R. Myerson, (1982), "Regulating a Monopolist with Unknown Costs," Econometrica, 50, 911-930.

[5] Berger, P. D., A.Gerstenfeld and A.Z. Zeng, (2004), "How many suppliers are best? A decision analysis approach," Omega 32 (1), 9-15.

[6] Burnett, W. and W. Kovacic, (1989), "Reform of United States Weapons Acquisition Policy: Competition, Teaming Agreements, and Dual Sourcing," Yale Journal of Regulation, 6, 249-317.

[7] Crocker, K. J. and K. J. Reynolds, (1993), "The Efficiency of Incomplete Contracts: An Empirical Analysis of Air Force Engine Procurement," RAND Journal of Economics, 24, pp. 126–146.

[8] Dana, J. D. an K. E. Spier, (1994), "Designing a Private Industry. Government Auctions with Endogenous Market Structure," Journal of Public Economics, Vol. 53, pp. 127-147.

[9] Demski, J., D. Sappington, and P. Spiller, (1985), "Managing Supplier Switching," Rand Journal of Economics, Vol 18, 77-97.

[10] Greer W. and S. Liao, (1986), "An analysis of risk and return in the defense market-its impact on weapon system competition," Management Science. 32, 1259-1273.

[11] Grossman, G.M., and E. Helpman, (1994), "Protection for Sale," A.E.R., 84: 833–50.

[12] Grossman, G.M., and E. Helpman, (1996), "Electoral Competition and Special Interest Politics," Review of Economic Studies, April 1996, 63(2), pp. 265-86.

[13] Klotz, D.E. and K. Chatterjee (1995), \Dual Sourcing in Repeated Procurement Competitions", Management Science, vol. 48, n0 8, 1317-127.

[14] Laffont, J. J., (1995), "Regulation, Moral Hazard and Insurance of Environmental Risks," Journal of Public Economics, 58: 319-336.

[15] Laffont, J. J. and D. Martimort, (2002), "The Theory of Incentives," Princeton Univ. Press, Princeton.

[16] Laffont, J. J. and J. Tirole, (1993), "A theory of incentives in procurement and regulation," Cambridge, Mass:MIT Press.

[17] Lebreton, M. and F. Salanié, (2003), "Lobbying under Political Uncertainty," Journal of Public Economics, 87, 2589-2610.

[18] McGuire, T. and M. H. Riordan, (1995), "Incomplete Information and Optimal Market Structure: Public Purchases from Private Providers," Journal of Public Economics, 56, pp. 125–141.

[19] Ruiz-Torres, A. J. and F. Mahmoodi, (2006), "A supplier allocation model considering delivery failure, maintenance and supplier cycle costs," International Journal of Production Economics 103 (2), 755-766

[20] Yu, H., A. Zeng and L. Zhao, (2009), "Single or dual sourcing: decision-making in the presence of supply chain disruption risks," Omega, 37 (4), 788–800.

Appendix

Proof. Proposition 2: The public authority solves the maximization program (P2) and we obtain for the inefficient $\overline{\theta}$-supplier B:

$$\frac{\partial \overline{I}}{\partial \overline{\alpha}} + \frac{v}{1-v}\Delta\theta(1+\delta) = \delta p[\frac{\partial \overline{R}}{\partial \overline{\alpha}} + \frac{v}{1-v}\Delta\theta a] \tag{14}$$

Inserting the derivatives of investment and returns into equation (14), we must have $\overline{\alpha}^{SB}$ such as:

$$S'(\widehat{\alpha}(\overline{\alpha}^{SB})) = \theta_B + (\theta_B - \theta_A)\frac{1+\delta(1-p)}{\delta p(1-a)} + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap)}{\delta p(1-a)}$$

that can be written as:

$$S'(\widehat{\alpha}(\overline{\alpha}^{SB})) = S'(\widehat{\alpha}(\overline{\alpha}^{FB})) + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap)}{\delta p(1-a)}$$

This new expression shows clearly that the marginal benefit of dual sourcing in incomplete information depends on its expression in the complete information. ■

Proof. Proposition 3: The maximization program (P3) yields:

$$\frac{\partial I}{\partial \alpha} = \delta[p(\alpha)\frac{\partial R}{\partial \alpha} - \frac{\partial p(\alpha)}{\partial \alpha}\frac{1}{p(\alpha)(1-a)}(S - \theta_A - S(a) + \theta_B a + U(\theta_B, a) - R)] \tag{15}$$

Replacing the derivatives of investment and returns into equation (15), the split of production is defined by:

$$S'(\widehat{\alpha}(\alpha^*)) = \theta_B + (\theta_B - \theta_A)\frac{1+\delta(1-p(\alpha^*))}{\delta p(\alpha^*)(1-a)} + \frac{\partial p(\alpha)}{\partial \alpha}\,|_{\alpha=\alpha^*}\ \frac{1}{p(\alpha^*)(1-a)}[S - \theta_A - S(\widehat{\alpha}(\alpha^*)) + \theta_B\widehat{\alpha}(\alpha^*)]$$

This yields the following expression at $p = p(\alpha)$:

$$S'(\widehat{\alpha}(\alpha^*)) = S'(\widehat{\alpha}(\alpha^{FB})) + \frac{\partial p(\alpha)}{\partial \alpha}\,|_{\alpha=\alpha^*}\ \frac{1}{p(\alpha^*)(1-a)}[S - \theta_A - S(\widehat{\alpha}(\alpha^*)) + \theta_B\widehat{\alpha}(\alpha^*)]$$

Under complete information, the marginal benefit of splitting the provision of the public good between both suppliers when the probability of disruption is endogeneous depends on its expression when such probability is exogeneous. ■

Proof. Proposition 4: The public authority solves the maximization program (P4) and we get for the inefficient $\overline{\theta}$-supplier B:

$$\frac{\partial \overline{I}}{\partial \overline{\alpha}} + \frac{v}{1-v}\Delta\theta(1+\delta) = \delta[p(\overline{\alpha})\frac{\partial \overline{R}}{\partial \overline{\alpha}} - \frac{\partial p(\overline{\alpha})}{\partial \overline{\alpha}}(S - \theta_A - S(a) + \overline{\theta}a + U(\overline{\theta}, a) - \overline{R}) + \frac{v}{1-v}p(\underline{\alpha})\Delta\theta a]$$

Substituting the derivatives of investment and returns in the previous equation, the maximization yields now:

$$\begin{aligned} S'(\widehat{\alpha}(\overline{\alpha}^{**})) &= \theta_B + (\theta_B - \theta_A)\frac{1+\delta(1-p)}{\delta p(1-a)} \\ +\frac{\partial p(\overline{\alpha})}{\partial \overline{\alpha}} &\mid_{\overline{\alpha}=\overline{\alpha}^{**}} \frac{1}{p(\overline{\alpha}^{**})(1-a)}[S - \theta_A - S(\widehat{\alpha}(\overline{\alpha}^{**})) + \theta_B\widehat{\alpha}(\overline{\alpha}^{**})] + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap(\overline{\alpha}^{**}))}{\delta p(\overline{\alpha}^{**})(1-a)} \end{aligned}$$

We immediately obtain the following expression:

$$S'(\widehat{\alpha}(\overline{\alpha}^{**})) = S'(\widehat{\alpha}(\overline{\alpha}^{*})) + \frac{v}{1-v}\Delta\theta\frac{1+\delta(1-ap(\overline{\alpha}^{**}))}{\delta p(\overline{\alpha}^{**})(1-a)}$$

Under the endogenous probability of disruption, the marginal benefit of dual sourcing in incomplete information depends on its expression in the complete information. ■