

A Theoretical Analysis of Public Procurement for Innovation

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This paper provides a new theoretical rationale for public procurement for innovation (PPI), a unique policy encouraging public procurers to purchase innovative products. In contrast to existing studies that primarily emphasize the advantages of PPI, this paper takes a comprehensive approach, examining both the costs and risks associated with PPI, alongside its benefits. It finds a general condition under which PPI outperforms traditional public procurement. Under this condition, this paper demonstrates that PPI enhances social welfare by facilitating optimal risk-sharing between public procurers and the general economy. Additionally, it draws policy implications from a comparative analysis between the current PPI policy in Korea and an optimal PPI policy.

Key Word: Public Procurement for Innovation, Optimal Risk Sharing, State-Owned Enterprises

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I. Introduction

Public procurement refers to the procedure of purchasing goods or services within the public domain. It constitutes a substantial share of the national economy. As of 2021 in Korea, the aggregate amount of procurement contracts initiated by the public sector, including the central government, local governments, state-owned enterprises (SOEs), and educational administrative agencies, reached approximately 184 trillion won. This figure corresponds to 9% of the country's GDP.

The primary function of public procurement is to secure high-quality goods and services at competitive prices, with the overarching goal of maximizing the "value-for-money" concept. At present, public procurement is considered as a powerful means

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for governments to attain strategic objectives beyond cost efficiency. Particularly since the 2000s, the EU, the United States, and South Korea have utilized public procurement extensively to foster innovation, as documented in studies such as Edler and Georghiou (2007) and Hur and Park (2022). This specific approach is known as ‘public procurement for innovation’ (PPI).

Innovation is inherently challenging for several reasons. Firstly, firms must allocate substantial resources to develop novel but uncertain technologies. Secondly, the benefits of invention are not exclusively reaped by the inventor but are shared across society. Thirdly, buyers often exhibit hesitancy toward purchasing newly invented products due to the absence of a usage history. However, when governments and state-owned enterprises (SOEs) proactively engage in the procurement of newly invented products, they can facilitate innovation.

In Korea, SOEs are encouraged to boost their procurement of innovative products. In particular, when private suppliers invent new products that are officially recognized by relevant authorities as ‘innovative products’ and when these are subsequently procured by SOEs, public enterprises stand to attain higher scores on official management evaluations conducted by the central government. SOEs will receive more bonus payments from the government if they obtain higher scores. See Hur and Park (2022) for additional institutional details on this Korean practice.

However, the question remains as to whether and how PPI consistently contributes to social welfare overall. If the risks associated with innovation are high, the improvement in product quality may not be satisfactory or the production costs of new goods will significantly exceed those of existing goods, with innovation then deemed to be inefficient. Consequently, PPI can hardly be justified. Current literature predominantly focuses on benefits of PPI and innovation, often neglecting the associated risks and costs.

For instance, Kim and Kim (2019) and Guerzoni and Raiteri (2015) find that PPI leads to increased expenditure by suppliers on innovation, resulting in improved productivity. However, these studies do not explicitly consider whether the advancements in technology outweigh the concurrent increase in costs and the heightened level of risk. A comprehensive assessment of benefits, costs, and risks is necessary before unbiased policy implications can be derived.

The following key questions arise in this context: What constitutes an optimal approach by which to implement PPI? To what extent should bonus payments be contingent on PPI? Should such bonuses be linked to the quantity or quality of innovative goods? These considerations are crucial for developing detailed and effective policy recommendations.

To address this gap in the literature, this paper examines a theoretical model to analyze the rationale behind PPI. A micro-theoretical analysis is useful to scrutinize institutional intricacies, including the incentive and compensation structures of public procurers and their relationship with PPI. The primary findings here can be summarized as follows. Firstly, innovation is justifiable if the enhancement in quality resulting from innovation surpasses the associated rise in costs. Secondly, in such cases, PPI facilitates innovation by allowing for the overall economy and public procurers to share the risks associated with investments in product invention in an optimal manner. Thirdly, bonus payments contingent on PPI should lean more towards the quantity of procured innovative goods and less toward quality, given the

public procurer's risk aversion regarding the quality aspect. A comparative analysis between current PPI-related bonus schemes in Korea and the theoretically optimal scheme is also conducted here in an effort to draw policy implications and thus enhance the existing framework.

In the broader body of literature, PPI is acknowledged as a pivotal instrument for demand-driven innovation. According to the theoretical literature, PPI is justified for the following reasons (see Edler and Georghiou (2007), Park (2020)). Firstly, governments and other public entities can emerge as large-scale buyers, thereby mitigating the uncertainty of demand for nonstandard newly invented goods. This reduction in demand uncertainty is a key factor addressing the hesitation of private suppliers to invest in innovation. Secondly, PPI can mitigate market failures associated with the sharing of returns from innovation. Inventors cannot appropriate all; i.e., they enjoy only a fraction of, the social value an innovative product generates. PPI reduces this externality by enabling inventors to gain more returns from inventions. Thirdly, PPI offers a potential solution to the coordination problems inherent in R&D. To invent new goods, a number of different entities should closely coordinate and share knowledge, technology, human capital, and financial resources. As PPI results in the provision of consistent demands for invented goods, these diverse entities can better collaborate.

Unlike research thus far, this paper places emphasis on PPI-driven optimal risk-sharing between public procurers and the general economy as a primary mechanism for increasing social welfare.

Several theoretical studies explore the general equilibrium effects of PPI. Kim and Kim (2019) find that a 1% increase in the PPI-to-total public procurement ratio leads to a 0.2% increase in total factor productivity (TFP). Kim and Park (2019) also find a similar result, focusing on general public procurement from SMEs that are officially designated as innovative firms and revealing that a 1% increase in such procurement is associated with a 0.7% increase in TFP. Additionally, they find that procurement from innovative SMEs leads to increased outputs by not only the SMEs themselves but also by large corporations connected to these SMEs through supply chains.

However, these general equilibrium analyses simply consider TFP as an increasing function of R&D expenditure, which naturally increases with regard to the amount of PPI. They do not consider the institutional details of PPI, such as quantity-based subsidies or quality-based compensation for public procurers, risk-aversion by related parties, and/or the influence of SOE management evaluations of PPI compensation. By employing a detailed partial equilibrium model, this paper addresses these diverse policy variables meticulously, offering specific policy implications.

The empirical literature supports the effectiveness of PPI in promoting innovation. Guerzoni and Raiteri (2015) find that PPI contractors invest more in innovation than general contractors based on EU survey data. Similarly, Ghisetti (2017) observes by examining EU and US survey data that PPI contractors are more likely to adopt emission-reducing manufacturing technology than general contractors. Czarnitzki *et al.* (2020) examine German public procurement data and show that replacing general procurement with PPI without increasing government expenditure contributes to innovation. Related findings can be found in Aschhoff and Sofka (2009). Park (2020) examines the effect of PPI on an innovation performance indicator, in this case the number of respondent suppliers who reported that they have introduced novel goods

that remarkably improve upon existing goods, using Korean survey data. Their empirical study shows that PPI increases this performance indicator by 26%.

However, these empirical findings are relatively straightforward, if not obvious, as PPI inherently encourages investment in innovation. More intriguing questions revolve around the extent to which PPI enhances the quality of relevant goods by fostering innovation and whether the improvement outweighs the concurrent rise in production costs. The present study explicitly takes into account this consideration of quality improvement and cost differential, offering insights into the design of efficient procurement policies.

The paper is structured as follows. Section 2 presents the micro-theoretical model, deriving the main theoretical results. Section 3 draws policy implications from these findings. Section 4 is the conclusion of the paper.

II. Model

A. Players

There are three players in the model economy: a government, a state-owned enterprise (SOE), and private suppliers. Firstly, the government chooses a procurement policy. Details pertaining to this government's choice problem are examined later in the paper.

Secondly, a representative SOE is a main economic player in this model. For a given procurement policy set forth by the government, the SOE decides on the contractors and amounts of objects to procure, such as goods or services. In the real world, the government not only selects a procurement policy but also procures objects to fulfill its own needs. For instance, the Ministry of Economy and Finance (MOEF) in Korea designs and implements a procurement policy based on which other ministries and SOEs procure objects. At the same time, however, the MOEF also procures objects by itself. Nevertheless, I assume that the government in the model economy as presented here chooses only a procurement policy without a loss of generality. It should also be noted that the theoretical framework is built on the standard principal-agent model. For expositional simplicity, I assume that the principal is the government and that the agent is an SOE. However, the main result still holds if readers view the principal as the general citizens of the national economy who maximize their total surplus by designing and implementing a procurement policy and the agent as any public procurement demand organization such as a central or local government or an SOE.

The last players in the model economy are private suppliers. They provide the procurement objects ordered by the SOE. They are classified into either 'general contractors' or 'innovative contractors.' General contractors provide standard objects for which there is no uncertainty in quality. These objects have long been provided for many SOEs and, hence, are standard in the sense that procurers are certain of their quality. In contrast, innovative contractors invent new products. These new 'innovative products' apparently outperform existing standard objects in terms of quality. However, because they are new, there is uncertainty with regard to the actual

quality. Despite the excellent appearance of some innovative products before use (i.e., ex-ante), SOEs can be disappointed with them after use (i.e., ex-post). Each supplier can choose its own type. If it invents a new product and the government determines that this invention is ‘innovative,’ the supplier is classified as an innovative contractor. If a supplier does not invent a new object but simply provides a standard one, it is classified as a general contractor. If a supplier invents a new object but the government determines that it is not innovative enough, the supplier fails to obtain the moniker ‘innovative contractor’ and, hence, is classified as a general contractor.

B. *Quality and cost of the procurement goods*

In actuality, SOEs procure goods and services. However, for simplicity and without a loss of generality, I assume that the SOE procures only goods. The total amount of goods that a representative SOE procures is normalized as 1. The SOE procures x units of the procurement goods from innovative contractors and the remaining $(1-x)$ units from general contractors.

The quality of procurement goods depends on the type of the private supplier. If a supplier is a general contractor, its good has quality of $m > 0$. This quality m is nonrandom and hence the SOE is certain of its level. Instead, if a supplier is an innovative contractor, it provides a procurement good with random quality y . Prior to procurement, the SOE has only an expectation of the quality of the product. After procurement, in contrast, by using the innovative good, the SOE realizes the true quality y , which is modeled as the following random variable:

$$(1) \quad y = m' + \varepsilon, \varepsilon \sim N(0, \sigma^2), \sigma > 0$$

Where m' is the expected quality. For a supplier to become an innovative contractor, it must submit a prototype of its newly invented good to a governmental body that assesses its innovativeness. This authority tests the invented good and determines whether or not it is innovative enough. The test result is summarized in a report or a certificate. The SOE can also test the prototype by itself or read the certificate. Based on this examination, it can form an expectation of the quality of the new good. Of course, the expected quality may differ from the true quality. This difference ε follows a normal distribution with a zero mean and variance of σ^2 . The higher the variance is, the larger the uncertainty of the quality of the new good becomes.

Assumption 1: $\Delta = (m' - m) > 0$

Let $\Delta \equiv (m' - m)$ denote the difference in the ex-ante quality between an innovative product and a standard product. Δ may be greater than zero, as a private supplier must pass a test to be designated as an innovative contractor. To pass the test, a supplier must demonstrate that a newly invented good outperforms existing standard

goods. Of course, the supplier cannot prove the true quality given that the true quality can be proven only after an SOE actually uses the product. However, the supplier can at least attempt to persuade the referees appointed by a governmental body in charge when the referees assess the innovativeness of their newly invented good. To persuade the referees, the new good must be clearly outstanding and should outperform existing standard goods at least in an experimental environment. For instance, the Ministry of SMEs and Startups in Korea designates a new good as an innovative product only if it satisfies the following three conditions of innovativeness: innovativeness of technology, marketability, and social value (see Table 1).

The SOE may regard an innovative product as a risky asset with a high return and high risk while considering a standard product as a risk-free asset. In this model, the production costs of a standard product and an innovative product are denoted by c and c' , respectively. The cost of an innovative product may be greater given that the invention of a new product that improves on an existing one is costly. The production cost of a standard product is lower than its quality (i.e., $c < m$), as otherwise production is meaningless. Similarly the production cost of an innovative product is lower than its expected quality (i.e., $c' < m'$).

Assumption 2: $\delta \equiv (c' - c) > 0$, $c < m$, and $c' < m'$

The procurement market for standard products is competitive. There are many private suppliers that are ready to provide standard products. The SOE can then buy

TABLE 1—CRITERIA FOR THE DESIGNATION OF INNOVATIVE PRODUCTS

	Criteria	Points
Innovativeness of technology	1. (Novelty) This criterion assesses whether the good is new, whether the good is an outcome of the convergence of old and new technologies, or whether the core technology is improved.	15
	2. (Superiority) This criterion assesses if the new technology embedded in the new good results in superior performance and benefits, such as efficiency or user-convenience.	15
Marketability	3. (Expected market size and share) This criterion assesses the market size if this new product creates a new market or the market share if this new product competes with standard products in the existing market.	15
	4. (Spillover) This criterion assesses whether the innovativeness and superiority of this new good are meaningful in other public sectors or industries. It also evaluates the scale and scope of such technology spillover.	15
Satisfaction of social needs	5. (Social value) This criterion assesses if the new good creates social value in the sense that it solves certain problems faced by society.	15
	6. (Importance and urgency) This criterion assesses if this new product is effective in solving an important and urgent problem.	15
	7. (Procurement needs) This criterion assesses if the social problem that this new product attempts to solve cannot be solved by private companies but only by public entities through procurement.	10
Total		100

Source: Guideline for Designating Excellent R&D Innovative Products by the Ministry of SMEs and Startups.

standard products by paying the production cost c per unit due to price competition. However, the market for innovative products is shallow. Only a few suppliers try to invent new products. Furthermore, very few of the newly invented products are innovative enough to be designated as ‘innovative products.’ Therefore, the SOE must pay more than the production cost. In particular, the SOE is assumed to pay $c' + p$, where c' is the production cost of an innovative product and $p > 0$ is the margin for an innovative contractor. This assumption is consistent with real-life procurement. In Korea, SOEs must hold auctions if they want to procure standard goods or services according to the relevant procurement laws. However, if a SOE considers buying an innovative product, it is allowed to trade with a contractor bilaterally without holding an auction. There are multiple competitors in an auction, while only a single competitor exists in bilateral contracting. Payments to contractors usually decrease with the degree of competition. For instance, Hwang and Lee (2020) empirically find that with more participating bidders in a procurement auction in Korea, the winning bidder makes a lower payment.

Private suppliers can specify their types. If a supplier chooses to be a general contractor, she will obtain a zero payoff, as the payment from the SOE and the corresponding production cost are equal. If instead a supplier chooses to be an innovative contractor, she has to pay a fixed cost k to invent a new product. If the newly invented product turns out to be sufficiently innovative such that the relevant authority designates it as an innovative product, she will get $c' + p$ as a payment from the SOE. However, if the new product fails to be designated as an innovative product, she does not receive any payment (nor does she incur the production cost, as she does not produce the good). Let θ denote the probability that a newly invented product is designated as an innovative product. Then, the expected utility of a supplier who pays the cost of invention k equals $\theta(c' + p - c' - k) + (1 - \theta)(-k - \rho)$, where $\rho > 0$ represents the magnitude of risk aversion of the supplier. If the invention is in the end a failure, the supplier suffers from disutility ρ . The more risk-averse a supplier is, the higher the disutility ρ becomes. A supplier chooses to be an innovative contractor if this expected utility is greater than or equal to the reservation payoff, which is zero. If this expected utility equals the reservation payoff, general contractors and innovative contractors receive the same zero payoff. Thus, the following condition must be met for the co-existence of both types of contractors in equilibrium.

$$(2) \quad \theta(p - k) + (1 - \theta)(-k - \rho) = 0$$

C. SOE's optimal choice

When the SOE procures a good of quality $q \in \{y, m\}$, its ex-post payoff (before-paying-the-price) is $\alpha q + \beta$, where $\alpha \in [\underline{\alpha}, 1)$, $\underline{\alpha} > 0$, denotes the quality-contingent payoff and β is the base payoff.

The quality-contingent payoff can have nonpecuniary and pecuniary components.

For instance, suppose that a power-generating SOE wants to procure a new gas turbine. If this gas turbine performs well and causes no problems, the employees in the gas-fired power plant feel a sense of reliability. This is a nonpecuniary benefit an SOE obtains from a high-quality procurement good.

In addition, this SOE can obtain some pecuniary compensation from the government if the quality of the gas turbine is high. The Ministry of Economy and Finance in Korea regularly evaluates the management performance of SOEs and pays SOE employees performance-based bonuses. Safety is an important component in these evaluations. If the high-quality gas turbine causes no accidents, the government may award a high score and hence the SOE will receive bonus payments.

The magnitude of the pecuniary component of the quality-contingent payoff is determined by the government and is hence an outcome of a government policy. In contrast, the nonpecuniary component affects the SOE employees' utilities directly and is hardly a choice variable of the government. In this regard, there is a lower bound $\underline{\alpha}$ for the size of quality-contingent payoff α . Later in this paper, we examine the government problem of considering α as a choice variable. However, the SOE considers α as a given rule. The base payoff β is non-contingent on the quality of the procurement good and is assumed to be set by the government. For instance, the government may provide some fixed payments to SOEs.

If the SOE procures x units of new products from innovative contractors, the government provides some benefits bx to the SOEs. Recently, the Ministry of Economy and Finance in Korea awarded bonus points to SOEs after evaluating their management performance if they purchased a large enough amount of innovative products from innovative contractors. These bonus points are useful for SOEs to obtain a higher final grade and hence receive more bonus payments. That is, the government subsidizes SOEs to encourage the procurement of innovative products. It should also be noted that bx depends on the ex-ante quantity of the innovative products, while αy depends on the ex-post quality of these products. That is, bx is independent of the ex-post quality. The government compensates the SOE for the mere purchase of the innovative products by giving a subsidy bx . In this sense, bx is quantity-dependent compensation while αy is quality-dependent compensation.

The price $c' + p$ paid by the SOE to an innovative contractor also depends on certain government choices. In particular, the margin p is a procurement policy outcome. In Korea, government forces SOEs to hold auctions if they want to procure an object. However, if the object is an innovative product, the SOE is allowed to conduct bilateral trading with the relevant innovative contractor. Rules and conditions for payment to contractors are more generous under bilateral trading than under auctions. This is why it is assumed here that the margin p is affected by the government's choice.

Given a procurement policy (α, β, b, p) , if the SOE purchases x units of procurement goods from innovative contractors and $(1-x)$ units from general contractors, it will receive the following ex-post payoff (after-paying-the-price) X .

$$(3) \quad X \equiv (\alpha y + \beta - (c + \delta + p))x + (\alpha m + \beta - c)(1-x) + bx$$

X is the ex-post payoff, which is realized only after the procurement is finalized and the SOE actually uses the procurement product. It is assumed here that the SOE is risk-averse. If the quality of an innovative product turns out to be disappointing, the SOE suffers. The SOE employees would also feel inconvenience as they then must exert efforts to fix related problems. If a failed product is a large piece of equipment, for instance, it could even cause safety issues. Furthermore, the SOE may face criticism from the media and the general public. For instance, Korea National Oil Corporation and Korea Gas Corporation purchased a number of oil fields, gas fields, and mining areas during a period in which oil prices were high in the early 2010, anticipating high profits. However, as oil price declined thereafter, these SOEs not only experienced significant financial losses but also faced substantial criticism from the media. Some employees in these SOEs were prosecuted for their failures in these procurement decisions. In this sense, I assume that the SOE is risk-averse with respect to procurement decisions.

Some may argue that SOEs are large corporations and hence are risk-neutral. If the SOE's payoff from procurement goods is only pecuniary, the costs from some procurements can be offset to some extent by the benefits from other procurements. However, the SOE also obtains a nonpecuniary payoff. The media criticizes failures but usually does not compliment successes to the same extent. A government auditor or a competent authority can penalize failures severely but gives minor rewards. For instance, some employees of Korea National Oil Corporation had to leave the company due to the unsuccessful purchases of oil fields, facing large cuts in their permanent income. However, even if they were successful, an equivalent amount of lifetime compensation would not be forthcoming.

Furthermore, most regular procurement decisions are made by procurement managers rather than senior management. Suppose that there are two procurement managers A and B. A decides to purchase good 1 and B purchases good 2. If it turns out that good 1's quality is poor while the good 2' quality is good, manager A is blamed and usually cannot share the good outcome manger B achieves. Therefore, from the point of view of the procurement manager, the quality risks associated with the procurement of goods is not fully diversified.

In this sense, the SOE's utility function $u(X)$ is assumed to be increasing and concave in X . In particular, for tractability, I consider the following exponential utility function with a measure of risk aversion, γ .

$$(4) \quad u(X) = -\exp(-\gamma X), \quad \gamma > 0$$

The SOE chooses the share of innovative products x during procurement to maximize the expected utility. The following lemma shows that this expected utility has a simple functional form.

Lemma 1: $E[u(X)]$ equals

$$-\exp\left[-\gamma\left\{(\alpha\Delta - \delta - p + b)x + (\alpha m + \beta - c) - \frac{\gamma\alpha^2\sigma^2}{2}x^2\right\}\right]$$

Proof: Using identity (3), the ex-post payoff X can be rewritten and simplified as follows:

$$X = (\alpha\Delta - \delta - p + b)x + (\alpha m + \beta - c) + \alpha\epsilon x$$

Then, the expected utility is given by

$$\begin{aligned} E[u(X)] &= E[-\exp[-\gamma\{X\}]] \\ &= E[-\exp[-\gamma\{(\alpha\Delta - \delta - p + b)x + (\alpha m + \beta - c)\}]] \times E[-\exp[-\gamma\alpha\epsilon x]] \\ &= -\exp[-\gamma\{(\alpha\Delta - \delta - p + b)x + (\alpha m + \beta - c)\}] \times -\exp\left[\frac{\gamma^2\alpha^2\sigma^2}{2}x^2\right] \\ &= -\exp\left[-\gamma\left\{(\alpha\Delta - \delta - p + b)x + (\alpha m + \beta - c) - \frac{\gamma\alpha^2\sigma^2}{2}x^2\right\}\right], \end{aligned}$$

where the third inequality above is derived by using the mathematical property that $E[-\exp[A\epsilon]] = -\exp\left[\frac{A^2\sigma^2}{2}\right]$ for any real number A . ■

Let x^* denote the optimal choice of innovative goods. Given that the expected utility function in Lemma 1 is a monotonic increasing function of $W \equiv (\alpha\Delta - \delta - p + b)x + (\alpha m + \beta - c) - \frac{\gamma\alpha^2\sigma^2}{2}x^2$, the optimal choice is characterized by the following first-order condition with respect to the function W .¹

$$(5) \quad x^* = \frac{\alpha\Delta - \delta - p + b}{\gamma\alpha^2\sigma^2} \text{ if } 0 < \alpha\Delta - \delta - p + b < \gamma\alpha^2\sigma^2$$

Equation (5) shows what determines the optimal choice of innovative goods. It should be noted here that x^* is the value-to-risk ratio. The numerator is the ‘value’ of procurement from innovative contractors as opposed to general contractors. Innovative goods are superior to standard goods in terms of the expected quality as much as Δ .

¹The second-order condition is satisfied if and only if $\gamma\alpha^2\sigma^2 > 0$, which is true given that $\gamma > 0$, $\alpha \geq \underline{\alpha} > 0$, and $\sigma > 0$.

The SOE enjoys only α fraction of this improvement in quality through quality-dependent compensation $\alpha\Delta$. Therefore, if there is no ex-ante quantity-dependent compensation (i.e., if $b = 0$), the SOE will choose a positive amount of innovative goods only if the ‘effective quality improvement’ $\alpha\Delta$ outweighs the sum of ‘added cost’ δ and ‘added payment’ p . However, if the government introduces a quantity-dependent subsidy bx , the SOE obtains additional value b from innovative goods. In sum, the value of procurement from innovative contractors equals $\alpha\Delta - \delta - p + b$.

The denominator is the ‘risk’ of procurement from innovative contractors. As noted above, buying an innovative good is similar to purchasing a risky asset. If the realized quality of an innovative good is lower than the expected quality, the outcome is detrimental to the SOE. If the SOE is more risk-averse (i.e., if γ is high), it suffers more. If the underlying uncertainty is the larger (i.e., σ^2 is large), the SOE is hurt more. Note that the SOE is responsible for quality only to the extent of α . Thus, higher levels of risk arise if the compensation depends more on performance (i.e., if α is large). As a result, the risk of procurement from innovative contractors equals $\gamma\alpha^2\sigma^2$.

Note that the ex-post quality-dependent compensation factor α affects both the value and risk associated with the procurement of innovative goods. As this factor determines the performance-based payment $\alpha\Delta$, both the value and risk are increasing in α for a given b . That is, an increase in α provides both an incentive and a disincentive to procure innovative goods. However, this is not the case when the procurement policy (α, β, b, p) is endogenously set by the government. I show that the value is independent of α , while the risk remains dependent on α by solving the government’s policy choice problem below.

In addition, if the value exceeds the risk, x^* should equal 1 because it cannot be greater than 1 by definition. Thus, in this case, we have the following corner solution:

$$(6) \quad x^* = 1 \text{ if } \alpha\Delta - \delta - p + b \geq \gamma\alpha^2\sigma^2$$

Hitherto, I focus on the case where the value of procurement from innovative contractors is positive. However, some contractors may invent only marginally superior goods at high additional costs. In such cases, the new goods are not innovative enough and, hence, the SOE wants to buy nothing from these contractors. However, the government can still push the SOE to purchase from these contractors by raising the ex-ante subsidy b . Therefore, the optimal choice of innovative goods is zero if the quality improvement or the ex-ante subsidy is small enough:

$$(7) \quad x^* = 0 \text{ if } \alpha\Delta - \delta - p + b \leq 0$$

The following proposition summarizes these optimal procurement choices.

Proposition 1: Suppose Assumptions 1 and 2 hold. Given a procurement policy (α, β, b, p) , the optimal procurement choice x^* is characterized by (5), (6), and (7).

Proof: Omitted.

D. Government's optimal choice

The SOE chooses an optimal procurement from innovative contractor x^* considering the procurement policy (α, β, b, p) as given. Below, I solve the government's policy choice problem. I consider a benevolent government who wants to maximize social welfare. Although I use the term 'government,' this actually refers to a virtual economic agent that maximizes the social welfare of the whole economy. In this sense, this economic agent, or the government, can also be understood as general citizens. Because general citizens constitute the whole national economy, with an enormous size, it would be reasonable to assume that general citizens can diversify risks in the sizable national economy and that they are hence risk-neutral. Let V denote the objective function of the government, which is expressed as

$$(8) \quad V \equiv E[(y - \alpha y - \beta)x + (m - \alpha m - \beta)(1 - x) - bx].$$

The higher the quality of a procurement good (i.e., y or m), the greater the social welfare. Also, I assume that the larger the payment to the SOE is, the weaker the social welfare is. Some readers may argue that the SOE is a constituent of the broader government and hence that the payment to the SOE should not be subtracted from the government's objective function. However, this payment could be used for other social purposes if it were not paid to the SOE. Therefore, given the scarcity of resources, the payment to the SOE should be considered as an opportunistic cost.

Basically, this model is an example of the principal-agent framework, where the principals are general citizens (or the benevolent government) and the agents are SOEs and private suppliers. In the standard principal-agent framework, the principal's own utility is the objective function that should be maximized. The agent's utility does not always need to be added into the objective function. However, the agent's utility should be considered as a constraint. In the standard principal-agent framework, the principal maximizes its own utility but at the same time must make the agent participate (by satisfying the participation constraints) and must ensure that the agent behaves in the manner desired by the principal (by satisfying the incentive-compatibility constraints). All of these participation and incentive-compatibility constraints are explicitly considered in this model (see equations (2), (5), (6), (7), and (9)). The production costs of private suppliers are also considered explicitly in this model through the private suppliers' participation constraints (see equation (2)).

The government can set the policy variables (α, β, b, p) but cannot set the procurement variable x . Although x is a one-dimensional real variable in this model, it is a metaphor of a much more complicated real world in which hundreds of SOEs procure millions or more of different products and services. Furthermore, each product or service must be procured at different times. The government has to incur prohibitively high costs of calculating and planning what products and services

to be procured for which SOE at what time. In addition, management and ownership of SOEs are legally separated in many countries, including Korea; hence, the government cannot dictate to SOEs the exact details of their daily operations, including their procurements. Although government payments to SOEs depend on the amount of innovative goods, this dependence is usually on the aggregate amount rather than on individual amounts of each of many different types of innovative goods. Considering these realities, I assume that the government cannot choose x but can implement a x -dependent procurement policy. For instance, in Korea, SOEs choose the amounts and types of procurement objects by themselves, while the government evaluates the management performance of SOEs and correspondingly pays bonuses based on the aggregate amount of procurement objects.

Therefore, the government must set a procurement policy under which SOEs and private suppliers find it optimal to participate (i.e., participation constraints). Also, the government needs to induce SOEs to choose the proper amounts and types that the government renders desirable (i.e., incentive-compatibility constraint). Let \bar{W} denote the ex-post reservation payoff to be received by the SOE if it does not participate. I normalize \bar{W} to zero. The SOE's participation constraint is then given by

$$(9) \quad W \equiv (\alpha\Delta - \delta - p + b)x + (\alpha m + \beta - c) - \frac{\gamma\sigma^2}{2}x^2 \geq 0.$$

Recall that condition (2) is the participation constraint for private suppliers. The incentive-compatibility constraints are expressed as (5), (6), and (7). Thus, the government faces the following problem:

$$\max_{\alpha, \beta, b, p} V = E[(y - \alpha y - \beta)x + (m - \alpha m - \beta)(1 - x) - bx] \text{ subject to} \\ (2), (5), (6), (7), \text{ and } (9)$$

The procurement choice x is the share of innovative goods relative to the total amount of goods. Hence, there are potentially two corner solutions, i.e., $x = 0$ and $x = 1$. The first corner solution arises when the SOE chooses all goods from general contractors. This could be a realistic scenario, as many (but not all) SOEs procure only from general contractors in Korea. However, the second corner solution may be unrealistic given that no real-life SOEs procure all products and services entirely from innovative contractors. If the government provides decent compensation, SOEs may procure more from innovative contractors. Nevertheless, they hardly purchase all of their goods and services from nonstandard suppliers. Therefore, I use the following assumption, which rules out the second corner solution. This assumption is used only for simplicity and tractability. The main messages with regard to procurement policies do not change if the assumption is relaxed.

Assumption 3: $\alpha > \sqrt{\frac{\Delta - \delta}{\gamma\sigma^2}}$

The following proposition 2 is the main result of this paper. It states the optimal procurement policy of the government and the optimal procurement choice by the SOE given the optimal policy.

Proposition 2: Suppose Assumptions 1, 2 and 3 hold. The optimal procurement policy $(\alpha^*, \beta^*, b^*, p^*)$, the optimal procurement choice x^* , and the social welfare at the optimum V^* are characterized as follow:

(i) Suppose that $\Delta > \delta + \frac{k}{\theta} + \frac{1-\theta}{\theta} \rho$. Then,

$$p^* = \frac{k}{\theta} + \frac{1-\theta}{\theta} \rho,$$

$$\alpha^* = \underline{\alpha},$$

$$\beta^* = -\frac{\Delta - \delta - p^*}{2} - \underline{\alpha}m + c,$$

$$b^* = (1 - \underline{\alpha})\Delta,$$

$$x^* = \frac{\Delta - \delta - p^*}{\gamma \underline{\alpha}^2 \sigma^2}, \text{ and}$$

$$V^* = \frac{[\Delta - \delta - p^*]^2}{2\gamma \underline{\alpha}^2 \sigma^2} + m - c.$$

(ii) Suppose that $\Delta \leq \delta + \frac{k}{\theta} + \frac{1-\theta}{\theta} \rho$. Then, $x^* = 0$, and $V^* = m - c$.

Proof: The government's objective function V can be rewritten as

$$(10) \quad V = [(1 - \alpha)\Delta - b]x + [(1 - \alpha)m - \beta].$$

The SOE's participation constraint is always binding. Suppose that it is nonbinding to reach a contradiction. Then, by reducing β slightly, the government becomes better off, as V increases while the incentive constraints (5), (6), and (7) are unaffected and the participation constraint is still satisfied, which is a contradiction.

The private suppliers' participation constraint (2) is satisfied if and only if the margin p equals p^* , defined as shown below.

$$(11) \quad p^* = \frac{k}{\theta} + \frac{1-\theta}{\theta} \rho$$

Proof of (i): I shall prove this by using a guess-and-verify method. Guess that $0 < \alpha^* \Delta + b^* - \delta - p^* < \gamma(\alpha^*)^2 \sigma^2$. Then, the optimal procurement choice x^* is characterized by equation (5). By substituting for x in (10) with x^* in (5), the government's objective function becomes

$$(12) \quad V = \frac{[(1-\alpha)\Delta - b][\alpha\Delta - \delta - p^* + b]}{\gamma\alpha^2\sigma^2} + [(1-\alpha)m - \beta].$$

Recall that the SOE's participation constraint (9) is binding. Accordingly, by replacing x in the participation constraint (9) with x^* in (5), the constraint can be rewritten as shown below.

$$\begin{aligned} 0 &= (\alpha\Delta - \delta - p^* + b) \frac{\alpha\Delta - \delta - p^* + b}{\gamma\alpha^2\sigma^2} + (\alpha m + \beta - c) - \frac{\gamma\alpha^2\sigma^2}{2} \frac{[\alpha\Delta - \delta - p^* + b]^2}{\gamma^2\alpha^4\sigma^4} \\ &= \frac{[\alpha\Delta - \delta - p^* + b]^2}{2\gamma\alpha^2\sigma^2} + (\alpha m + \beta - c) \end{aligned}$$

By rewriting the equality above, the following expression for β can be obtained:

$$(13) \quad \beta = -\frac{[\alpha\Delta - \delta - p^* + b]^2}{2\gamma\alpha^2\sigma^2} - \alpha m + c$$

By replacing β in (12) using equation (13), the government's objective function is rewritten as

$$(14) \quad V = V(\alpha, b) \equiv \frac{[(2-\alpha)\Delta - \delta - p^* - b][\alpha\Delta - \delta - p^* + b]}{2\gamma\alpha^2\sigma^2} + m - c.$$

In this way, the government's problem is reduced to maximize $V(\alpha, b)$ in (14) without any constraint. The first-order condition with respect to b implies that

$$(15) \quad b = b(\alpha) \equiv (1-\alpha)\Delta.$$

It can easily be shown that the second-order condition is satisfied. Under this optimal bonus scheme, equation (5) implies that the optimal procurement choice equals

$$(16) \quad x^* = x(\alpha) \equiv \frac{\Delta - \delta - p^*}{\gamma\alpha^2\sigma^2}.$$

These two equations (15) and (16) imply that the government's objective function equals

$$(17) \quad V = V(\alpha) = \frac{[\Delta - \delta - p^*]^2}{2\gamma\alpha^2\sigma^2} + m - c = \frac{\Delta - \delta - p^*}{2} x(\alpha) + m - c.$$

Because $\Delta > \delta + p^*$, the government's objective function is maximized if $x(\alpha)$ is maximal. As $x(\alpha)$ is decreasing in α , the optimal quality-dependent compensation factor equals $\alpha^* = \underline{\alpha}$. Equations (13), (15), (16), and (17) imply that $\beta^* = -\frac{\Delta - \delta - p^*}{2} - \underline{\alpha}m + c$, $b^* = (1 - \underline{\alpha})\Delta$, $x^* = \frac{\Delta - \delta - p^*}{\gamma\underline{\alpha}^2\sigma^2}$, and $V^* = \frac{[\Delta - \delta - p^*]^2}{2\gamma\underline{\alpha}^2\sigma^2} + m - c$. Note that $\alpha^*\Delta + b^* - \delta - p^*$ equals $\Delta - \delta - p^*$, which is greater than zero and less than $\gamma\underline{\alpha}^2\sigma^2$ according to Assumption 3. That is, the guess is verified.

Guess instead that $\alpha\Delta + b - \delta - p^* \leq 0$. Then, according to equation (7), $x^* = 0$, which means $\beta = -\alpha m + c$ given the binding participation constraint (see equation (9)). The government's objective function in equation (10) then becomes $V = m - c$, which is strictly less than $\frac{[\Delta - \delta - p^*]^2}{2\gamma\underline{\alpha}^2\sigma^2} + m - c$. As the government can further increase its welfare by choosing a different procurement policy $(\alpha^*, \beta^*, b^*, p^*)$, we reach a contradiction.

Guess that $\alpha\Delta + b - \delta - p^* \geq \gamma(\alpha)^2\sigma^2$ at the optimum. Then, according to equation (6), $x^* = 1$, which means $\beta = -(\alpha\Delta + b - \delta - p^*) + \frac{\gamma(\alpha)^2\sigma^2}{2} - \alpha m + c$ due to the binding participation constraint. In this case, the government's objective function in the equation (10) becomes $V = (\Delta - \delta - p^*) - \frac{\gamma(\alpha)^2\sigma^2}{2} + m - c$. Because V is decreasing in α , it must be that $\alpha = \underline{\alpha}$. Then, V equals $(\Delta - \delta - p^*) - \frac{\gamma\underline{\alpha}^2\sigma^2}{2} + m - c$. This is smaller than $\frac{[\Delta - \delta - p^*]^2}{2\gamma\underline{\alpha}^2\sigma^2} + m - c$ as the function $(\Delta - \delta - p^*)x - \frac{\gamma\underline{\alpha}^2\sigma^2}{2}x^2$ is maximized at $x = \frac{\Delta - \delta - p^*}{\gamma\underline{\alpha}^2\sigma^2}$. Note that $x = \frac{\Delta - \delta - p^*}{\gamma\underline{\alpha}^2\sigma^2}$ is less than 1 according to Assumption 3. Note also that the function $(\Delta - \delta - p^*)x - \frac{\gamma\underline{\alpha}^2\sigma^2}{2}x^2$ equals $\frac{[\Delta - \delta - p^*]^2}{2\gamma\underline{\alpha}^2\sigma^2}$ at the maximum $x = \frac{\Delta - \delta - p^*}{\gamma\underline{\alpha}^2\sigma^2}$, while it equals $(\Delta - \delta - p^*) - \frac{\gamma\underline{\alpha}^2\sigma^2}{2}$ at the suboptimum $x = 1$. As the government can further increase its welfare by choosing a different procurement policy $(\alpha^*, \beta^*, b^*, p^*)$, we reach a contradiction.

Proof of (ii): According to the SOE's binding participation constraint, it follows that

$$(18) \quad \beta = -\alpha m + c - (\alpha\Delta + b - \delta - p^*)x + \frac{\gamma\alpha^2\sigma^2}{2}x^2.$$

By plugging β in equation (18) into the government's objective function in (10), it follows that

$$(19) \quad V = (\Delta - \delta - p^*)x - \frac{\gamma\alpha^2\sigma^2}{2}x^2 + m - c.$$

Given that $\Delta \leq \delta + p^*$, the government must induce $x = 0$ to maximize the objective function. To this end, given the incentive-compatibility constraint (6), it must set low levels of α and b so that $\alpha^*\Delta + b^* - \delta + p^* \leq 0$. Then, $x^* = 0$ and $V^* = m - c$. ■

Below, I provide an intuition of Proposition 2. Firstly, consider the case where $\Delta \leq \delta + p^*$. In this case, newly invented goods are not innovative enough such that the improvement in quality Δ is less than the added cost δ and added payment p^* . The risk-neutral government (which behaves in the best interest of the general public) then finds it optimal to procure only from general contractors, (i.e., $x^* = 0$). Therefore, the government must discourage the procurement of innovative goods by providing low or zero benefits such that the SOE perceives zero or negative value from procuring innovative goods (i.e., $\alpha^*\Delta + b^* - \delta - p^* \leq 0$). In this case, the SOE purchases all goods from general contractors and, hence, the social welfare equals the quality of a standard good minus the cost of its production (i.e., $V^* = m - c$).

Secondly, consider a more interesting case where $\Delta > \delta + p^*$. The newly invented goods are sufficiently innovative such that the improvement in quality outweighs the added cost and the margin. The risk-neutral government (and the general public) then wants to maximize the amount of procurement from innovative contractors. However, the SOE is risk-averse and considers not just the improvement in quality but also the associated risk. Consequently, it is reluctant to purchase innovative goods. To solve this agency problem, the government must align the SOE's perceived value of innovative goods (i.e., $\alpha\Delta + b - \delta - p^*$) with the social value (i.e., $\Delta - \delta - p^*$) and minimize the perceived risk (i.e., $\gamma\alpha^2\sigma^2$). There are two ways to adjust the SOE's perceived value: through a quality-dependent payment and with a quantity-dependent payment. If the ex-post quality-dependent payment increases (i.e., α increases), both the perceived value and risk increase. In contrast, if the ex-ante quantity-dependent payment increases (i.e., b increases), the risk does not change while the value increases. Therefore, it is optimal for the government to minimize the power of the quality-dependent payment (i.e., $\alpha^* = \underline{\alpha}$) while raising the power of the quantity-dependent payment (i.e., $b^* = (1 - \underline{\alpha})\Delta$) so that the SOE's perceived value agrees with the social value (i.e., $\alpha^*\Delta + b^* - \delta - p^* = \Delta - \delta - p^*$).

Consequently, the SOE chooses $x^* = \frac{\Delta - \delta - p^*}{\gamma\underline{\alpha}^2\sigma^2} > 0$ and the social welfare becomes

$V^* = \frac{\Delta - \delta - p^*}{2}x^* + m - c$. Finally, the procurement of innovative goods contributes to

social welfare as much as $\frac{\Delta - \delta - p^*}{2} x^*$.

III. Policy Implications

The theoretical analysis shows that procurement of innovative products with outstanding expected quality is socially efficient. SOEs are passive in purchasing innovative goods because they may be audited, disciplined, and evaluated unfavorably in the government-led management evaluation if the innovative goods' quality is in the end unsatisfactory ex-post. On the other hand, at the national economy level, it is desirable actively to purchase innovative products with excellent expected quality levels, as quality risks can be diversified throughout the economy. Therefore, an optimal procurement policy is to transfer the quality risk from SOEs to the national economy by devising an optimal incentive mechanism.

What is an optimal incentive mechanism? There are two methods by which to incentivize the procurement of innovative products. Firstly, ex-ante quantity-based compensation provides more subsidies if SOEs buy more innovative products. Secondly, ex-post quality-based compensation rewards or penalizes SOEs conditional on the realization of the quality. Between these two compensation methods, the theoretical analysis shows that ex-ante quantity-based compensation is preferable. Because this compensation is independent of quality, the SOE is not exposed to the risk of quality and, hence, the national economy and the SOE can reach an optimal risk-sharing arrangement. That is, all risks are transferred from the risk-averse SOE to the risk-neutral government. In Korea, SOEs can gain higher scores on their management evaluations if they increase the quantity of the innovative products they procure. This type of quantity-based compensation is justifiable according to the theoretical analysis.

The optimality of the aforementioned incentive mechanism relies on the basic premise that the newly invented products are sufficiently innovative. In particular, the improvement in expected quality Δ must exceed the sum of the increase in cost δ and the increase in payment p^* . If a newly invented product demonstrates higher (ex-ante) quality than comparable standard products, but only at an even higher cost of production, this new product cannot be considered as innovative. If the improvement in quality exceeds the increase in cost, but if the inventor requires too much additional payment from an SOE, this new product is still not socially valuable. Therefore, the relevant authority should assess the improvement in quality accurately and determine properly whether it outweighs the sum of the increased cost and increased payment.

However, the Korean procurement authority appears to consider only the magnitude of the quality improvement and not the added cost and/or added payment. For instance, the Ministry of SMEs and Startups officially designates newly invented products as innovative if they fulfill the criteria set forth by the Guideline for Designating Excellent R&D Innovative Products (see Table 1). These criteria mainly assess the extent to which new products enhance existing ones. However, the criteria do not

require evaluators to compare the degree of enhancement with the cost and payment increases. In order to produce a better product, a contractor typically incurs a higher cost. To purchase this better product, a buyer usually pays a higher price. Therefore, the current rules for designating innovative products may need to be revised such that the improvement in quality is compared to the cost and payment increases.

The theoretical analysis derives the optimal margin p^* . If this margin is too small, private suppliers would not bear the burden and risk associated with inventing in innovation. However, if this margin is too large, the public sector can find room for economizing on its own procurement expense. The optimal margin $p^* = \frac{k}{\theta} + \frac{1-\theta}{\theta} \rho$ is the outcome of balancing this tradeoff. This optimal margin p^* turns out to increase with the invention cost k and risk-aversion ρ , whereas it decreases with the probability θ that the invention is successful. Because there are many different SOEs, they want to buy a range of different types of innovative products. Some innovative products are easy to invent, whereas others are very difficult. Because SOEs know better than the government regarding each of these different products, SOEs must exert some discretion over how much of a margin to pay for each different innovative product. Currently, the Ministry of Economy and Finance in Korea allows SOEs to conduct bilateral trading with innovative contractors if they want to procure products that are officially designated as innovative, whereas they can rely only on standard auction mechanisms if they want to buy standard products. Given that SOEs can exercise more autonomy with bilateral trading than with auctions, this exceptional rule for the procurement of innovative products is justified by the current theoretical analysis. Nevertheless, SOEs must put more effort into improving cost of invention evaluations, their degree of risk-aversion, and the probability of success in an invention. Consequently, they can better encourage private suppliers' inventions by paying the lowest possible margin.

The theoretical analysis shows that the ex-ante quantity-based subsidy is effective for optimal risk sharing. Note that the size of the incentive provided by the quality-based pay and the quantity-based subsidy scheme equals $\alpha^* \Delta$ and $b^* = (1 - \alpha^*) \Delta$, respectively. Thus, the total incentives from these two schemes should match the size of the improvement in quality Δ . Because pay-for-performance is only a small fraction of the total compensation for employees in many real-life SOEs, one can expect that quality-based pay α^* will be scant.² However, in this case the quantity-based subsidy b^* must be large.

Nonetheless, the current procurement policy in Korea appears to provide few subsidies with inaccurate measurements. Among the many criteria used during SOE management evaluations, Table 2 shows two criteria that relate to the procurement of nonstandard products. There are two types of nonstandard products. The first is an innovative product and the second is a standard product that is however produced

²For instance, Korea Electric Power Corporation (KEPCO), the biggest Korean SOE, reported that the five-year (2018-2022) average pay-for-performance amount based on the government-led management evaluation is 8.52% of total employee compensation (see <https://alio.go.kr/search/searchTabPage.do?word=%ED%95%9C%EA%B5%AD%EC%A0%84%EB%A0%A5%EA%B3%B5%EC%82%AC&apbnm=&sortType=LAT-EST&tab=jeoggi>, 2023.09.19).

TABLE 2—SOE MANAGEMENT EVALUATION CRITERIA THAT RELATED TO THE PROCUREMENT OF NONSTANDARD PRODUCTS

Objective	Criteria	Points
Win-win Cooperation and Regional Development	1. Quantitative Evaluation:	2
	(1) SMEs' Product Purchases	0.5
	(2) SMEs' R&D Product Purchases	0.2
	(3) Co-operatives' Product Purchases	0.2
	(4) Traditional Market's Product Purchases	0.3
	(5) Female-owned Firms' Product Purchases	0.2
	(6) Disabled Persons' Product Purchases	0.4
	(7) Admired Veterans' Product Purchases	0.2
	2. Qualitative Evaluation:	2
	(1) Efforts and achievements for the development and implementation of programs for community participation and revitalization of the local economy	0.5
(2) Efforts and achievements to establish fair economic terms and conditions, such as timely payments for SME contractors	0.5	
(3) Efforts and achievements of technical and/or institutional support to strengthen the competitiveness of SMEs and small business owners <i>* Procurement from innovative contractors is one of many activities related to this criterion.</i>	0.5	
(4) Efforts and achievements to support social enterprises, cooperatives, or self-support enterprises, etc.	0.5	
Total		4

Source: Guideline for the SOE Management Evaluation, Ministry of Economy and Finance, 2022.

by a minority group. The guideline of SOE management evaluation favors the procurement of these nonstandard products.³ There are several points worth noting with regard to these criteria.

Firstly, the procurement of innovative products is evaluated mostly qualitatively.⁴ According to the first criterion, 'Quantitative Evaluation,' SOEs are rewarded if they purchase products that are produced by SMEs, co-operatives, female-owned small enterprises, or by disabled people or other minorities in society. However, this criterion does not reward the procurement of innovative products. Because procurements of innovative products are evaluated only qualitatively, SOEs cannot calculate the exact amount of the subsidy per unit of purchase of innovative products. In some cases, they can receive relatively few points even if they purchased a great many goods from innovative contractors. However, in other cases, they can receive many points even when they purchase a small amount of innovative products. Due to this uncertainty, SOEs are exposed to a new risk, i.e., the risk of evaluation, on top of the existing risk of quality. This additional risk causes SOEs to be reluctant to purchase innovative products, which is socially inefficient. In addition, the current

³Coate and Lury (1993) show theoretically that affirmative-action policies for those who are socially disadvantaged, such as African-Americans, introduced in the United States to give the disadvantaged a fair opportunity, rather solidifies the prejudice that the performance of disadvantaged people would be low. Thus, such policies have the adverse effect of reducing the affected group's incentive to work diligently.

⁴In Korea, there are a number of different evaluation programs managed by different ministries, including the Ministry of Economy and Finance and the Ministry of SME and Startups. Some of these evaluation programs evaluate the amount of PPI quantitatively. However, the most prestigious evaluation program is the SOE management evaluation conducted by the Ministry of Economy and Finance, and this program does not explicitly evaluate the PPI performance quantitatively.

qualitative evaluation does not explicitly consider the magnitude of quality improvement Δ . The theoretical analysis shows that an optimal subsidy increases in Δ . However, the guideline does not explicitly require evaluators to award more points for the procurement of innovative products of better ex-ante quality.

Secondly, SOEs can obtain too few points by procuring innovative products. Even in a case in which the total number of points is 100, only 0.5 is assigned for procurement from innovative contractors. To see this, note that the second criterion, 'Qualitative Evaluation,' consists of four specific subcategories. Each subcategory is equally important. Because 2 point is assigned to this criterion, each subcategory is worth more or less 0.5 points. Of these subcategories, only subcategory (3) is related to the procurement of innovative products. However, this subcategory (3) considers other factors as well. Therefore, SOEs can acquire at most 0.5 points regardless of how excellent are their efforts and achievements during their procurement of innovative products is. It appears that 0.5 points is too few to assign to an SOE with a sufficient incentive to purchase innovative products.

In sum, this paper suggests that the current subsidization policy should be reformed in the following ways. Firstly, the procurement of innovative products should be evaluated not merely qualitatively but also quantitatively. Secondly, the size of the subsidy should be proportional to the size of the improvement in quality an innovative contractor accomplishes. Third, a sufficient number of points should be assigned so that SOEs have sufficient incentives to increase their procurements from innovative contractors.

IV. Concluding Remarks

Recently, public procurement has arisen as a pivotal tool for encouraging innovation. This type of public procurement is known as 'public procurement for innovation (PPI)'. In general, innovations are challenging to take on for a number of reasons, including risks and uncertainty with respect to investments in new technologies, externalities stemming from inventors' only partial appropriation of the returns from their innovations, and buyers' reluctance to purchase goods with no history of usage. However, innovation can be facilitated if governments and public enterprises proactively purchase newly invented products. In Korea, state-owned enterprises (SOEs) are rewarded if they purchase new products officially designated as 'innovative products' by relevant authorities.

However, it is unclear as to whether PPI is always beneficial to social welfare. If the risks associated with innovation are high, the quality improvement due to innovation is insufficient, or the increased production costs due to invention are substantial, then innovation may not be efficient. Consequently, PPI cannot be justified. The literature mostly focuses on the benefits of PPI and innovation and but not on the associated risks and costs. This paper presents and tests a theoretical model to analyze the rationale behind PPI through a comprehensive analysis of the benefits, costs, and risks of innovation.

The main results are as follows. Firstly, innovation is justified if the improvement in quality due to the innovation outweighs the sum of the associated increase in costs

and the increased payments to suppliers. Secondly, in this case, PPI facilitates innovation by enabling the overall economy and public procurers to share risks optimally. Thirdly, bonus payments for encouraging PPI should depend more on the quantity of the procured innovative goods and less on the quality. Also, I compare current PPI-related bonus schemes in Korea with the theoretically optimal scheme and suggest a number of improvements.

The principal-agent framework proposed in this paper captures certain key interactions related to public procurement among key players such as a benevolent government (i.e., general citizens), SOEs, and private suppliers. This framework is employed to deliver general and theoretical implications. However, as most microeconomic theory does, my theory is also limited in its ability to capture every detail of reality.

First, I argued that too few points are assigned for PPI in the SOE management evaluations conducted by the Korean government. However, even if few points are assigned for PPI, these points could become in some circumstances crucial in determining the final grades of SOEs. For instance, if there are two SOEs with the same scores in all areas except for PPI, one SOE can beat the other by earning a few more points for PPI.

Second, although there are many different standards when designating ‘innovative products,’ I primarily consider the standard set forth by the Ministry of SME and Startups (i.e., MOSS). The policy implications drawn from this paper are based on a comparison between the theoretical optimum and the standard of MOSS. Therefore, policy implications can change if other standards that differ significantly from those of MOSS are considered. However, I suspect that ministries have similar standards of designation of innovative products because real-life ministries usually observe other ministries’ standards—in particular, the standard of MOSS given that MOSS is the primary ministry in charge of SME-related policies—and create make similar ones, if not copy them outright.

Third, I consider the risk-aversion of SOEs with respect to their decision to purchase a newly invented product as exogenous. However, the government can implement policies that affect the degree of this risk-aversion. For instance, the government sometimes grants procurement managers of SOEs with the right of immunity; hence, the government cannot punish such procurement managers even if their decisions to buy newly invented products turn out to be poor. Nevertheless, the main result still holds unless risk-aversion by SOEs disappears completely due to certain policies that reduce it, as PPI remains as an optimal risk-sharing device whenever general citizens are risk-neutral and SOEs are risk-averse, regardless of how low their risk-aversion is.

In sum, I believe that the qualitative aspect of the main result of this paper does not entirely change even if I explicitly consider the aforementioned details of real-life procurement policies in the model, though the materiality of the main result could be weakened. The policy implications drawn from this paper should be understood within the context of these details.

REFERENCES

- Aschhoff, Birgit and Wolfgang Sofka.** 2009. "Innovation on Demand: Can Public Procurement Drive Market Success of Innovations?" *Research Policy*, 38, pp. 1235-1247.
- Coate and Lury.** 1993. "Will Affirmative-Action Policies Eliminate Negative Stereotypes?" *American Economic Review*, 83(5), pp. 1220-1240.
- Czarnitzki, Dirk, Paul Hunermund, and Nima Moshgbar.** 2020. "Public Procurement of Innovation: Evidence from a German Legislative Reform," *International Journal of Industrial Organization*, 71.
- Edler, Jakob and Luke Georghiou.** 2007. "Public Procurement and Innovation: Resurrecting the Demand Side," *Research Policy*, 36, pp. 949-963.
- Ghisetti, Claudia.** 2017. "Demand-Pull and Environmental Innovations: Estimating the Effects of Innovative Public Procurement," *Technological Forecasting & Social Change*, 125, pp. 178-187.
- Guerzoni, Marco and Emilio Raiteri.** 2015. "Demand-Side vs. Supply-Side Technology Policies: Hidden Treatment and New Empirical Evidence on the Policy Mix," *Research Policy*, 44, pp. 726-747.
- Hur, Rayoon and Inhwan Park.** 2022. "Public Procurement for Innovation: The Current Status and Ways to Improvement," *NARS Current Issues and Analysis*, 253, National Assembly Research Service. (in Korean)
- Hwang, Sunjoo and Hwa Ryung Lee.** 2020. "Analysis of Public Procurement Contracts: Effectiveness of the Average Price Auction with Screening (APAS)," *KDI Monograph 2020-03*. (in Korean)
- Kim, Jaehyun and Byuonggeon Kim.** 2019. "An Economic Effect on the Increasing Share of Technological Innovation-Oriented Public Procurement," *Journal of Science and Technology Policy*, 2(2), pp.247-270. (in Korean)
- Kim, Jaehyun and Sungbok Park.** 2019. "Macroeconomic Impact of Public Procurement Support for Technology Based Innovative SMEs," *Journal of SME Policy*, pp. 37-70. (in Korean)
- Park, Jeongho.** (2020). "Effect of Public Procurement of Innovation (PPI) on Firms' Innovation as Outcome," *Journal of Science and Technology Policy*, 3(1), pp. 5-32. (in Korean)

LITERATURE IN KOREAN

- 김재현, 김병건. 2019. 『혁신지향 공공조달 비중 확대에 따른 경제적 파급효과』, 과학기술정책, 2(2), pp.247-270.
- 김재현, 박성복. 2019. 『기술혁신 중소기업 공공조달 지원의 거시경제 파급효과』, 중소기업정책연구, pp.37-70.
- 박경호. 2020. 『기업의 혁신성과에 대한 혁신공공구매(PPI)의 효과』, 과학기술정책, 3(1), pp. 5-32.
- 허라운, 박인환. 2022. 『혁신조달의 현황과 개선과제』, NARS 현안분석, 제253호, 국회입법조사처
- 황순주, 이화령. 2020. 『공공부문 조달계약에 관한 연구: 종합심사낙찰제의 효과성을 중심으로』, 한국개발연구원 연구보고서.