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Effects of Stockholders’ Secondary Tax Liability on Corporate Investment†

By JANGWOOK LEE*

This study analyzes the impact of secondary tax liability borne by stockholders, an exception to the principle of limited liability, on corporate investment. The paper constructs a model of a firm to examine the effect of this secondary tax liability, finding that the violation of limited liability increases firms’ expected bankruptcy costs, thereby reducing investments. By means of an empirical analysis, the paper examines whether firms with the largest shareholder stake exceeding 50%, the condition under which secondary tax liability is incurred, decrease their investments. The results show that firm investment is highly concentrated in observations of cases in which the largest shareholder stake does not exceed 50%. Investments decrease sharply in cases where the largest shareholder stake exceeds 50%. The results here provide implications pertaining to how exceptions of the limited liability principle, existing only in Korea, affect corporate investments.

Key Words: Secondary Tax Liability, Principle of Limited Liability, Corporate Investment

JEL Codes: G30, G38

I. Introduction

The principle of shareholder limited liability refers to the principle that shareholders are responsible for the company up to the amount of stock they purchase. Requiring only limited liability from stockholders of a firm is significant in that it facilitates stock trading and accumulation of capital by the firm. If a firm goes bankrupt and stockholders are responsible for amounts greater than those invested, the incentive for stock buyers to purchase is significantly reduced. The stock company system based on the principle

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* Received: 2024. 3. 3
* Referee Process Started: 2024. 3. 13
* Referee Reports Completed: 2024. 4. 22
† This paper is based on a study by Jangwook Lee, “The effects of the exception to limited liability on firm’s investment”, KDI, 2021 (in Korean). I am grateful to Shiyun Roh for her outstanding assistance and to two anonymous referees for their valuable comments. All remaining errors are mine.
of limited liability has played a significant role in the birth and development of numerous companies by facilitating the financing and dispersal of risks in risky businesses.

In Korea, there are exceptions to the principle of limited liability for shareholders. There are cases where investors must bear the company’s liability in excess of the invested amounts. The principle of limited liability is adhered to in debt relationships between companies and other private economic entities (companies and individuals). However, in Korea, there are exceptions to the principle of limited liability in relation to debt relationships between companies and the government, especially with regard to delinquent national taxes. This secondary tax liability of stockholders is an exception to the principle of limited liability. The secondary tax liability requires oligopolistic shareholders to bear the unpaid amount of national taxes when a firm is liquidated. The purpose of this law is to achieve practical tax equality by preventing oligopolistic shareholders, who can exercise management rights, from accruing company profits to themselves and burdening the company with losses.

However, the secondary tax liability conflicts with the principle of tax law that imposes taxes only on those liable to pay taxes, and it does not comply with the principle of limited liability of shareholders. There have been many discussions centering on this tax system. Chung (2011) and Kim and Lee (2018) pointed out problems in determining the scope of oligopolistic shareholders. Hwang and Yang (2017) and Kim (2016) examined the legal legitimacy of the second tax payment system. Jun (2019) investigated ways to alleviate the burden on failed small and medium-sized business owners due to the secondary tax liability. Kim and Moon (2020) analyzed the secondary tax liability for investors in venture firms.

Existing discussions have mainly focused on the legal dimension. In particular, numerous studies have held that conscientious oligopolistic stock-holding managers become credit delinquents due to the secondary tax payment system, making economic recovery difficult. However, more research on how the secondary tax liability affects companies’ business activities while firms are active is required.

This paper analyzes the impact of the second tax liability on corporate investment. First, we define the secondary tax liability and present a legal definition as well. I also check the current status of the companies that are subject to this tax system and report how many companies have a secondary tax liability. Finally, I investigate cases in which a firm can become exempted from the secondary tax liability.

This paper constructs a model of a firm to examine the effect of the secondary tax liability. The impact of the secondary tax liability on firm investments is derived by comparing the investment rates made by managers who maximize their profits through a rational decision-making model with and without the secondary tax liability. The findings show that the second tax liability acts as a management burden on oligopolistic stockholders, causing them to reduce their investments in the firm by up to 4% in advance. To the best of the author’s knowledge, this is an economic effect that has never been studied before in the literature related to such a secondary tax liability.

I analyze whether the results found by the model analysis are supported by empirical data. By combining ownership ratio data and the financial data of companies existing in Korea from 2011 to 2016, the paper analyzes the investment rates of companies with a maximum shareholder ownership ratio exceeding 50%, at which point the secondary tax liability would apply. Among companies with the largest shareholder shareholding ratio of 49% to 51%, I looked for differences in investment rates when the shareholding ratio
exceeded 50%. When the largest shareholder shareholding ratio exceeds 50%, the investment rate drops from 2.6%p to 5.3%p. In short, the secondary tax liability is a factor that discourages corporate investment even if the company does not go bankrupt.

The remainder of this paper proceeds as follows. Section 2 describes the secondary tax liability and defines it legally. Section 3 examines how the secondary tax liability can affect a company’s investment decisions through a model analysis. Section 4 examines whether the empirical analysis is consistent with the results of the model analysis. Chapter 5 draws conclusions and policy implications.

II. Secondary Tax Liability

A. Definition

Article 39 of the National Tax Basic Act defines a secondary tax liability that arises when a firm’s assets do not cover the firm’s national taxes. In such cases, designated individuals have an obligation to pay these national taxes. Individuals designated by law include more than members of a general partnership and unlimited partners of a limited liability company. Limited partners of a limited partnership, members of a limited liability company, and members of a limited company are also designated individuals according to the law as long as their share ratio exceeds 50% (oligopolistic stockholders). Because members of a general partnership and unlimited partners of a limited liability company have an obligation under commercial law to repay the company’s debts, they have an obligation to cover the unpaid portion of national taxes. However, in that limited partners of limited partnerships, members of limited liability companies, and members of limited companies are liable for the company only within the limit of the amount invested under the Commercial Act, the principle of limited liability is not observed with regard to this secondary tax liability.

B. Current status of the secondary tax liability

In order to understand the impact of the secondary tax liability on corporate activities, it is necessary to investigate how many companies are burdened with secondary tax obligations and how significant such tax burdens are. I examine how much national tax is collected through the secondary tax liability and determine whether the system is being operated effectively. Table 1 shows that most secondary taxpayers are oligopolistic shareholders rather than partners with unlimited liability. In 2017, there were 16,411 original taxpayers, that is, companies with original tax obligations, and 19,879 secondary taxpayers, who are oligopolistic shareholders obligated to pay the unpaid corporate tax or value-added tax of these companies. This number is gradually increasing, with 19,776 original taxpayers and 21,026 secondary taxpayers in 2019. On the other hand, the number of original taxpayers who are also general partners amounted to 20 in 2019, while there were 27 secondary taxpayers a very low number.
The number of companies that incur secondary tax obligations, which amounts to approximately 20,000 per year, is significant considering the scale of corporate extinction each year in Korea. According to Statistics Korea’s business survival statistics, approximately 46,000 corporations disappeared in 2018. As of 2018, approximately 18,000 companies, nearly 41%, are believed to have incurred secondary tax obligations. The collection rate for such tax obligations is very low, and considering the high likelihood that secondary taxpayers of this size will default on national taxes and become credit delinquents, the impact of the secondary tax liability on Korea’s economy is not negligible.

Table 2 reports that the tax amount to be paid by companies was in the approximate range of KRW 2.3 trillion to KRW 2.5 trillion from 2017 to 2019. Among the incurred liability, the amounts paid by firms equaled approximately 490 billion won in 2017 and 2018, but in 2019, the amount decreased to 320 billion won. The amount of taxes owed by original taxpayers has consistently remained at about two trillion won from 2017 to 2019. Among these, oligopolistic shareholders incur a liability only to an extent corresponding to their shareholding ratio. Thus, the delinquent tax amount is smaller than the amount unpaid by the original taxpayers (tax payable). The amount designated by stockholders was approximately 1.6 trillion won in 2019, up from approximately 1.4 trillion won in 2017. The collection rate is very low and is gradually decreasing. In 2017, about 82 billion won was received, but in 2019, only about 60 billion won was received. The approximate acceptance rate was 3.75% in 2019.

There are a range of tax items that can incur a secondary tax liability. Table 3 shows the secondary tax liability status by tax item in 2019. Corporate taxes and value-added taxes account for the largest portion of the secondary tax liability. In 2019,

### Table 1—Number of Secondary Taxpayers by Type

<table>
<thead>
<tr>
<th>Year</th>
<th>Oligopolistic stockholder</th>
<th>Partners with unlimited liability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original taxpayer (firm)</td>
<td>Secondary taxpayers (individual)</td>
</tr>
<tr>
<td></td>
<td>Original taxpayer (firm)</td>
<td>Secondary taxpayers (individual)</td>
</tr>
<tr>
<td>2017</td>
<td>16,411</td>
<td>19,879</td>
</tr>
<tr>
<td>2018</td>
<td>18,728</td>
<td>19,883</td>
</tr>
<tr>
<td>2019</td>
<td>19,776</td>
<td>21,026</td>
</tr>
</tbody>
</table>

Source: processed by the author based on Kim & Moon (2021).

### Table 2—Secondary Tax Liability Designated and Payment Amounts

<table>
<thead>
<tr>
<th>Year</th>
<th>Tax payable</th>
<th>Delinquent tax amount</th>
<th>Amount paid by original taxpayer (firm)</th>
<th>Secondary tax payer (individual)-designated amount</th>
<th>Amount received by secondary taxpayer (individual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>2,319,589</td>
<td>2,045,563</td>
<td>489,706</td>
<td>1,412,055</td>
<td>82,786</td>
</tr>
<tr>
<td>2018</td>
<td>2,519,717</td>
<td>2,162,349</td>
<td>496,931</td>
<td>1,568,087</td>
<td>87,563</td>
</tr>
<tr>
<td>2019</td>
<td>2,491,722</td>
<td>2,085,214</td>
<td>320,834</td>
<td>1,618,792</td>
<td>60,059</td>
</tr>
</tbody>
</table>

Note: in millions of KRW.

Source: processed by the author based on Kim & Moon (2021).
TABLE 3—SECONDARY TAX LIABILITY BY TAX ITEM IN 2019

<table>
<thead>
<tr>
<th></th>
<th>Corporate tax</th>
<th>Value-added tax</th>
<th>Other indirect taxes</th>
<th>Withholding tax</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delinquent tax amount</td>
<td>771,731</td>
<td>1,110,819</td>
<td>22,718</td>
<td>176,836</td>
<td>3,691</td>
<td>2,085,993</td>
</tr>
<tr>
<td>Designated amount</td>
<td>546,620</td>
<td>921,576</td>
<td>10,314</td>
<td>137,800</td>
<td>2,774</td>
<td>1,619,202</td>
</tr>
<tr>
<td>Amount received</td>
<td>17,376</td>
<td>37,760</td>
<td>202</td>
<td>4,616</td>
<td>98</td>
<td>60,059</td>
</tr>
</tbody>
</table>

Note: in millions of KRW.

Source: processed by the author based on Kim & Moon (2021).

TABLE 4—CHARACTERISTICS OF ORIGINAL TAXPAYER (FIRM)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of delinquent payments</th>
<th>Age (years)</th>
<th>Number of oligopolistic stockholders</th>
<th>Sales (in mil. KRW)</th>
<th>Amount of delinquent taxes (in mil. KRW)</th>
<th>Designated amount (in mil. KRW)</th>
<th>Collected amount (in mil. KRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>6.25</td>
<td>3.98</td>
<td>1.21</td>
<td>2,725.54</td>
<td>124.65</td>
<td>86.04</td>
<td>5.04</td>
</tr>
<tr>
<td>2018</td>
<td>6.80</td>
<td>4.02</td>
<td>1.06</td>
<td>2,432.95</td>
<td>115.46</td>
<td>83.73</td>
<td>4.68</td>
</tr>
<tr>
<td>2019</td>
<td>7.47</td>
<td>4.15</td>
<td>1.06</td>
<td>2,482.27</td>
<td>105.44</td>
<td>81.56</td>
<td>3.04</td>
</tr>
</tbody>
</table>

Source: processed by the author based on Kim & Moon (2021).

approximately 770 billion won in corporate tax was delinquent, resulting in a secondary tax liability of about 540 billion won, of which nearly 17 billion won was collected. Approximately KRW 1.1 trillion in value-added tax was delinquent, and secondary tax obligations of approximately KRW 920 billion were designated, of which approximately KRW 37 billion was collected.

Table 4 reports the average characteristics of the original taxpayer (firm) with a secondary tax liability. Companies must pay various taxes, and each company has an average of six to seven delinquent payments given that if one tax item is delinquent, the company’s financial capacity is insufficient, and the likelihood of other tax items being delinquent increases. Companies with a secondary tax liability have been in business for approximately four years on average, implying that liquidity and the business environment are more likely to be challenging for younger companies than for older companies. The number of oligopolistic shareholders subject to a tax liability ranged from approximately 1.06 to 1.21, most likely due to the existence of more than one person exercising a strong influence on a firm. Most firms that incur a secondary tax liability are small firms. Average sales amount to approximately 2.8 billion won, and the average amount of delinquent taxes is about 120 million won. The average amount designated for the secondary tax liability is close to 80 million won, of which only about three to five million won is collected.

C. Exceptions to the second tax liability

If certain conditions are met, the tax authorities may exempt companies from the secondary tax liability or postpone or extinguish previously imposed liabilities in accordance with established requirements. For an accurate examination of the impact
of a secondary tax liability on corporate activities, it is necessary to investigate the companies to which the system applies and cases in which it does not apply. It appears that policy authorities are generally aware of the side effects of the secondary tax liability to some extent and have made efforts to prepare their own devices to alleviate them. Nonetheless, judging whether the scope or requirements are sufficient is complicated by many factors.

The secondary tax liability is postponed or extinguished or companies are exempted from paying it in the following cases. Companies listed on the stock market, certain venture companies, companies that have received re-startup funds from the Small and Medium Venture Business Corporation after they meet specific requirements, and cases where specific requirements are met during business conversion support projects are eligible for tax exemption or postponement.

It appears that policy authorities are somewhat aware of the side effects of the secondary tax liability, as noted above. They are thus attempting to form a consensus to try to alleviate them. However, in order to be exempted from a secondary tax liability in advance, a company must maintain a minimal sales volume and must use more than 5% of sales to pay research and development expenses. Unlisted companies with sales of approximately one to 12 billion won or more, depending on the industry, are not exempt from the secondary tax liability. In addition, because companies that meet the sales standard must also meet the R&D expense standard, companies that do not engage in R&D activities are incentivized to create extra R&D expenses.

In order to defer or extinguish the secondary tax liability ex-post, firms must receive re-startup financing from the Small and Medium Business Corporation. This condition only applies to limited cases, however. Thus, although policies exist to relieve companies of the secondary tax liability, there are limits to how much the burden can actually be reduced for a wide range of owners of small and medium-sized businesses.

### III. Model analysis

In this section, I construct a model of a firm to examine the effects of the secondary tax liability as defined above. In particular, the examination focuses on the ex-ante impact of the secondary tax liability on corporate investments. In other words, the purpose is to analyze the effect of the secondary tax liability before a company goes bankrupt. Previous research has focused on the fact that a secondary tax liability imposed after a corporate bankruptcy hinders a recovery by conscientious managers. Taxes for a corporation must be paid with the personal property of oligopolistic shareholders, but in many cases, the oligopolistic stockholder becomes a credit delinquent because he or she is unable to pay these taxes. Additionally, an oligopolistic stockholder who becomes a credit delinquent has difficulty starting another business.

In the analysis here, rather than analyzing the aspects of investors’ secondary tax liability making it difficult for them to recover as entrepreneurs, a model is designed to show that an investor’s secondary tax liability can act as a pre-emptive factor that ultimately shrinks the company’s management, even when a business failure has not
occurred. This section aims to show qualitatively that these exceptions to limited liability function as a burden on entrepreneurs so as to clarify the direction of the economic effect.

A. Model

I model a firm that makes rational decisions about their investments dynamically. The objective function of a firm is to maximize its value. State variables are the company’s investments and deferred corporate tax liabilities as determined in the previous period. Taxes are determined based on the previous year’s profits and are paid in the current year. This reflects that Korea’s current corporate tax payment schedule is from March to May of the year subsequent to the company’s settlement of accounts ending in December. In this model, it is assumed that deferred corporate tax liabilities do not accumulate but are determined at the current period and paid in full the following year. The choice variable is the company’s investment \((i)\).

The firm’s production function, that is, its operating profit \((\pi)\), is defined as follows:

\[
\pi = e^{x}k^{\alpha} - f.
\]

The operating profit \((\pi)\) increases as the amount of capital \((k)\) increases or productivity \((x)\) increases. However, the marginal rate of return on capital is assumed to decrease given that parameter \((\alpha)\) is set to be less than 1. In addition, the production function reflects a realistic business environment such that fixed costs \((f)\) are incurred even if there are no sales, which allows the company’s value to fall below 0 even if the company’s debt is not assumed in the model.

In this model, a firm’s productivity follows a first-order autoregressive process. This process is defined as follows:

\[
x' = \rho x + (1 - \rho)\bar{x} + \sigma \epsilon',
\]

where \(x'\) is the next period productivity, \(\rho\) is the persistence parameter, \(\sigma\) is the standard deviation of the error term, and \(\epsilon'\) is a random variable that follows a standard normal distribution \(N(0,1)\). Productivity follows autoregression centered on long-term averages, \(\bar{x}\).

The process of asset accumulation is as follows. The next period’s capital \((k')\) is deducted at the depreciation rate \((\delta)\) of the current period’s capital, and it increases as it is invested \((i)\).

\[
k' = i + (1 - \delta)k
\]

Adjustment costs, \(c\), are incurred when adjusting a company’s assets. The definition of the adjustment cost is as follows:

\[
c = a \left( \frac{i}{k} \right)^2 k.
\]
The parameter $a$ governs the level of the adjustment costs. Adjustment costs add reality to a firm’s capital accumulation. They increase sharply as investments increase and decrease when the existing capital amount is large, reflecting that such costs are higher for a firm that rapidly increases its investment and lower for a firm with enough assets to accumulate additional assets.

The taxes($z'$) that a company must pay in the next period are defined as follows:

$$z' = \max(0, \tau_c(\pi - \delta k)).$$

The corporate tax rate is denoted by $\tau_c$. Tax is levied only on operating profit after depreciation that is greater than 0.

A firm’s cash flow ($d$) is defined using the equation below.

$$d = \pi - i - c - \frac{1}{1 + r_f} z \lambda I_{n,II}$$

The risk-free rate is denoted by $r_f$. The default probability is $\lambda$, and $I_{n,II}$ is a dummy variable and takes a value of 1 if the investor’s has a secondary tax liability, taking a value of 0 otherwise. The characteristics of this model are derived from the last term ($z\lambda I_{n,II}$), indicating the potential burden felt by an entrepreneur due to the secondary tax liability. In the rational decision-making model, when an entrepreneur makes an investment, he or she determines the optimal investment level to maximize profits by considering the expected profits and costs.

Firm value, $v(k,z,x)$, can be expressed as state variables $k$, $z$, and $x$. The entrepreneur determines the investment amount that satisfies the following equation, thus determining the firm value:\(^1\)

$$v(k,z,x) = \max_i \left[ d + \frac{1}{1 + r_f} E_v'(k,z,x) \right].$$

B. Parameter

Table 5 shows the calibration results of the model parameters. The curvature parameter determines the decreasing, constant, or increasing returns to scale of the production function. It is set to 0.7 and assumes a diminishing return to scale. It is appropriate to assume that individual firms have diminishing returns to scale because as returns to scale increase, the optimal amount of corporate investment will increase infinitely. Empirically, the smaller the company, the higher the return on investment, and as the size of the company increases, the marginal return on investment tends to decrease.

\(^1\)This model does not address the fact that the secondary tax liability can potentially prevent shareholders from engaging in moral hazard to some extent. Although empirical data show that collected taxes in relation to the secondary tax liability are minuscule, from the perspective of corporate managers, the incentive to tunnel may be reduced due to such a secondary tax liability.
The average productivity parameter, $\bar{x}$, is set to -0.6. The average firm value is determined by this parameter, and the average firm value determines the investment rate. The parameter is set such that the investment-to-total assets ratio with medium-level assets is 0.06 to 0.08. The ratio is similar to the investment rate shown in the empirical analysis data in the next section.

The productivity persistence parameter $\rho$ and the standard deviation of productivity $\sigma$ are set to 0.62 and 0.2, respectively. These two parameters are parameters of the autoregressive process (AR(1)) and determine the unconditional standard deviation of a firm’s productivity, $\sigma_x$. If the parameters and are 0.62 and 0.2, the unconditional standard deviation of productivity is approximately 0.25, similar to the standard deviation of the ROA of Korean companies.\(^2\)

There are fixed costs, $f$, in this model. This value is assumed to be 0.5 such that the corporate extinction rate is 0.12, which is the average corporate extinction rate from 2013 to 2018 in the corporate survival and extinction administrative statistics published by Statistics Korea.

The discount rate $r_f$ is set to 0.05, the depreciation rate $\delta$ is set to 0.1, and the capital adjustment cost $\alpha$ is set to 15. The capital adjustment cost is set so that the firm’s market value is zero to two times the book value.

The corporate tax rate is 0.2 in the model analysis. Korea’s corporate tax rate is assumed to be 25% if the tax base exceeds KRW 300 billion, 22% if the tax base exceeds KRW 20 billion but is less than KRW 300 billion, 20% if the tax base exceeds KRW 200 million but is less than KRW 200 billion, and 10% if the tax base is less than KRW 200 million. I set a tax rate of 20% because most firms of interest fall into this tax bracket.

I model a firm that makes rational decisions about its investments. The objective function of a firm is to maximize its value.

<table>
<thead>
<tr>
<th>Table 5—Parameters</th>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production function curvature</td>
<td>$\alpha$</td>
<td>0.7</td>
</tr>
<tr>
<td>Average productivity</td>
<td>$\bar{x}$</td>
<td>-0.6</td>
</tr>
<tr>
<td>Productivity persistence</td>
<td>$\rho$</td>
<td>0.62</td>
</tr>
<tr>
<td>Productivity standard deviation</td>
<td>$\sigma$</td>
<td>0.2</td>
</tr>
<tr>
<td>Fixed costs</td>
<td>$f$</td>
<td>0.5</td>
</tr>
<tr>
<td>Default probability</td>
<td>$\lambda$</td>
<td>0.12</td>
</tr>
<tr>
<td>Discount rate</td>
<td>$r_f$</td>
<td>0.05</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>$\delta$</td>
<td>0.1</td>
</tr>
<tr>
<td>Capital adjustment costs</td>
<td>$\alpha$</td>
<td>15</td>
</tr>
<tr>
<td>Corporate tax rate</td>
<td>$\tau_c$</td>
<td>0.2</td>
</tr>
</tbody>
</table>

\(^2\)Lee (2018).
C. Analysis results

The figure on the left in Figure 1 shows the investment rate without the secondary tax liability and the rate with the secondary tax liability. The horizontal axis of the figure represents the asset size. As the asset size decreases, the investment ratio relative to total assets gradually decreases from more than 20% to less than 5%. This reflects that the marginal return on investment decreases as the asset size increases by assuming a diminishing return to scale. In the figure, when a secondary tax liability exists, the investment rate is lower than when there is no secondary tax liability.

The figure on the right in Figure 1 shows the rate at which the investment decreases when there is a secondary tax liability compared to when there is no secondary tax liability. Interestingly, for a very small company, any secondary tax liability has little effect on reducing the investment rate. This is related to the characteristics of the model, defined to reflect reality. Suppose a company is currently unable to generate enough profits to pay taxes. In such a case, it is reasonable for the secondary tax liability not to be considered during the investment process. This is why the secondary tax liability does not impact a firm’s investment decision when the firm’s assets are close to 0.

As a company’s assets grow, the company’s profits and the resulting taxes also increase, which further increases the burden of the secondary tax liability. In the benchmark model, the investment reduction rate due to the investor’s secondary tax liability could be as high as nearly 4%.

At this point, I examine the impact of a secondary tax liability for companies with a high probability of extinction. If the investment rate of companies decreases indeed due to the secondary tax liability in the previous benchmark result, the investment rate should decrease more when the expected burden on the firms increases. In order to confirm the appropriateness of the economic effect of the model, I analyze case with a high probability of extinction.

Analyzing such cases is meaningful from a policy perspective. In the benchmark model, the corporate extinction rate is set to 12% using data from Statistics Korea’s
corporate survival and extinction administrative statistics. The attrition rate can differ if a company operates under difficult conditions. In particular, in new companies, the probability of extinction is much higher compared to established companies. Considering the investor’s secondary tax liability as one of the factors hindering the start-up of a company, it is important to analyze secondary tax liabilities in companies with a high probability of extinction.

Figure 2 shows the investment rate when the bankruptcy rate is 24%. The figure on the left shows the investment rate according to the presence or absence of the secondary tax liability. That on the right depicts the investment reduction rate with the secondary tax liability. Compared to the benchmark case, the decline in investment rate nearly doubled when the extinction rate was 24%. If the asset size is small and the probability of paying taxes is low, the secondary tax liability has little effect on investment. However, as the size of the company increases, the secondary tax liability becomes a greater burden and can reduce the investment amount by approximately 7%. This marks a nearly double increase in the investment reduction rate compared to the mid-3% level in the benchmark case.

In short, as the expected burden of a company’s secondary tax liability increases with an increase in the probability of a bankruptcy as well, the company reduces its investment. This implies that the secondary tax liability becomes a greater burden for corporate management of new companies or for companies who operate in risky industries.

If the limited liability principle is well observed, a firm makes investment decisions to maximize its value, but with a secondary tax liability, entrepreneurs ultimately make decisions to maximize their own expected profit, including that of the firm. When a company goes bankrupt, there is a burden on the business owner, which ultimately burdens the firm. This effect has not received attention in existing discussions regarding secondary tax liabilities. Existing discussions mainly focus on

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**FIGURE 2. INVESTMENT RATE AND DECREASING RATE UNDER A SECOND TAX LIABILITY (HIGH EXTINCTION RATE)**

The jagged line of I/A in the figure on the left is due to numerical errors.
the problem of failed entrepreneurs becoming credit delinquents due to the secondary tax liability, but such an analysis proposes a reducing effect on firm investments.

IV. Estimation

In this section, I empirically analyze the impact of exceptions to the limited liability principle, the secondary tax liability, on firm investment outcomes. The secondary tax liability is applied to unlisted firms in which the largest shareholder and related parties have an ownership ratio that exceeds 50%. The critical point is that secondary tax liability is not imposed if the shareholding ratio is precisely 50%. Suppose the secondary tax liability affects the investment activities of companies. In such a case, one can find differences in investment scenarios between companies where the largest shareholder’s shareholding ratio exceeds 50% and companies where the shareholding ratio is less than 50%. Using corporate ownership data and financial data, I analyze this and find evidence of the impact of investors’ secondary tax liabilities on investments.

A. Data

The ownership data and financial data are obtained from Korea Enterprise Data (KED). KED provides information related to the governance structure of Korean companies. One can uncover who the company’s largest shareholder is, what the shareholding ratio is, and who the CEO is. Unfortunately, this information is not provided as a time series of the ownership ratio. Only ownership information at a specific point in time is available. Therefore, it is not possible to construct panel ownership data. However, because it is possible to establish ownership information at a specific point in time, a cross-sectional analysis can be conducted by combining this information with financial data from companies. The data used in the analysis range from 2011 to 2016. Financial data are used up to the next year at the time that the ownership ratio is observed. Regarding the investment rate, data from the year following the year in which the shareholding ratio is noted are observed to consider the time leading to an actual investment under a specific shareholder composition.

The companies included in the data are general corporations and externally audited corporations, excluding listed companies and sole proprietorships. Observations where the company’s CEO is the largest shareholder of the firm at the same time are included in the analysis because the secondary tax liability only applies to those with a shareholding exceeding 50% and who have a dominant influence on the corporation. Companies with total assets of less than 300 million won, deemed too small for the purpose here, are also excluded.

The secondary tax liability only applies to shareholders whose shareholding exceeds 50%, as noted above. In order to examine differences in investments between two groups where the largest shareholder and CEO have an ownership ratio of less than 50% and more than 50%, I utilize data with an ownership ratio of between 49% and 51% and investigate the differences between these two groups. The total number of observations is 4,373. Because the sample contains cross-
sectional data, there are 4,373 largest shareholder ownership ratio-company observations. One aspect to note is that the yearly distribution of each company varies from 2011 to 2016.

Table 6 reports summary statistics. I/A is the amount invested divided by the total assets of the previous year. The investment amount is the difference between the tangible assets of the current year and the previous year plus the depreciation in sales and administrative expenses and the depreciation in the manufacturing cost statement. LnTA is the natural logarithm of the total asset amount in thousand KRW. D/A is total debt divided by total assets. AG refers to the increase in total assets divided by the total assets of the previous period. The sample includes very small companies, meaning that extreme values have a strong impact on the statistics. Therefore, LnTA, D/A, and AG are winsorized to the 1% level.

The sample firms invest approximately 6.5% of their total assets on average. The standard deviation is about 18.6%, which shows that the investment deviation across firms is quite large. Figure 3 shows the distribution of I/A outcomes. In most cases, I/A is between 0 and 10%, but in some cases, it exceeds 100%. This occurs because the sample includes very small firms, such as those not externally audited. The average LnTA is 14.695, meaning that the average total asset amount is approximately 2.4 billion KRW. The minimum and maximum values of LnTA are correspondingly 12.726 and 18.236, meaning that the total asset amount ranges from 340 million KRW to a maximum of 83 billion KRW and implying that most firms in the sample are small and medium-sized enterprises.

The average of D/A is 0.543, and the standard deviation is 0.254. About half of the total assets of these companies are raised with debt capital, and the debt ratios vary widely. While some firms use debt for only about 4% of total assets, there are also cases where 96% of total assets are debt. AG equals approximately 35% on average. This is due to the fact that the firms in the sample are very small and have a high marginal return on capital, showing a high asset growth rate.

Figure 4 presents a scatter plot of the shareholding ratio and investment rate. It shows an interesting relationship between the largest shareholder’s shareholding ratio and the investment rate. Observations of the shareholding ratio are highly concentrated around 50%; there is a wide variety of investment rates at a 50% shareholding ratio, and in companies that invest considerable amounts, there are many cases where the largest shareholder’s shareholding is 50%.

Observations of the shareholding ratio are highly concentrated around 50%. It is important to note that there are numerous investment rate observations of cases in which the shareholding ratio is precisely 50%, suggesting that when companies set up corporate governance, they intentionally set the shareholding ratio of the largest

<table>
<thead>
<tr>
<th>Table 6—Summary Statistics</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>I/A</td>
</tr>
<tr>
<td>Share Ratio (%)</td>
</tr>
<tr>
<td>LnTA</td>
</tr>
<tr>
<td>D/A</td>
</tr>
<tr>
<td>AG</td>
</tr>
</tbody>
</table>

Note: LnTA, D/A, and AG are winsorized to the 1% level.
shareholder to 50% rather than exceeding 50%. If the shareholding ratio of the largest shareholder exceeds 50%, the largest shareholder must bear the additional burden of a secondary tax liability in case of a bankruptcy. From the perspective of the largest shareholder, it is better for them intentionally to avoid an ownership ratio exceeding 50%. Of course, one cannot say that those intense observations of a shareholding ratio of 50% are solely due to the investor’s secondary tax liability. However, the data here are consistent with the prediction by the model analysis in the previous section that such secondary tax liabilities reduce firm investments.

![Figure 3. Distribution of the Investment Rate](image)

![Figure 4. Scatter Plot of the Shareholding Ratio and Investment Rate](image)
B. Empirical analysis

In the empirical analysis, we examine whether there is a difference in the investment rate depending on the shareholding ratio of companies when the largest shareholder’s shareholding ratio is between 49% and 51%. If the investor’s secondary tax liability has no impact on investment, there should be no correlation between investments whether or not the largest shareholder’s share exceeds 50%, the condition in which the investor’s secondary tax liability applies. The model analysis in the previous section shows that the secondary tax liability discourages the investment willingness of entrepreneurs. I examine whether the effect can be confirmed through empirical data.

The unit of analysis is the shareholding ratio of the manager, who is both the largest shareholder and CEO at the same time, and the investment rate of the firm. The largest shareholder will have a dominant influence on the corporation. The largest shareholders are able to affect decisions on whether to invest in the company. If the largest shareholder’s shareholding rate exceeds 50%, he or she must bear tax arrears in the event of a corporate bankruptcy, sacrificing their personal property, whereas if the shareholding ratio is less than 50%, the secondary tax liability is not imposed.

The first predictable action of the largest shareholder under the secondary tax liability is to set their shareholding ratio below 50%. There may be a variety of factors that affect a company’s governance structure, but if the largest shareholder’s stake is determined to be around 50%, there is an incentive to keep the stake below 50% to avoid the secondary tax liability. This pattern, as found earlier, is confirmed in Figure 3. The shareholding ratio of the largest shareholder is very high at precisely 50%, with much variance in the largest shareholders with shareholdings below 50% and above 50%.

If the majority shareholder’s shareholding ratio is less than 50%, the secondary tax liability can be avoided. It would be rational for oligopolistic stockholders to have shares less or equal to 50%. However, due to various management conditions, there may be cases in which an oligopolistic shareholder holds a stake exceeding 50%. In cases where legal problems may arise in the future if management rights cannot be secured, securing management rights is advantageous, bearing the potential cost of the secondary tax liability. In such cases, the largest shareholder can choose to secure a stake exceeding 50%.

In the presence of the secondary tax liability, the largest shareholder with a stake exceeding 50% is likely to invest less due to the burden of potential tax payment costs. In this empirical analysis, I focus on these investment incentives and seek to determine whether there is a significant decrease in the investment rate in corporations in which the largest shareholder’s shareholding exceeds 50%. The empirical specification is as follows:

\[
Y_i = \beta_0 + \beta_1 Dum_{50i} + \beta_2 ShareRatio_i + control_i + timeFE_i + indFE_i + \epsilon_i
\]

The dependent variable \( Y_i \) refers to I/A for firm \( i \). The dummy variable, \( Dum_{50i} \), has a value of 1 if the largest shareholder’s shareholding ratio exceeds 50% and has
a value of 0 if it is less than 50%. The independent variable, \( ShareRatio_i \), refers to the shareholding ratio of the largest shareholder. The control variable, \( control_i \), includes LnTA, D/A, and AG, which are variables that can affect a company’s investments. As the asset size increases, the investment rate usually tends to decrease. It is known that if existing debt impedes additional capital raising efforts, the result can be a decrease in the investment rate (debt overhang). On the other hand, debt can increase investment levels due to the risk-taking incentive of managers (risk-shifting). Companies with a higher asset growth rate tend to have a higher return on investment, and their investment rate also tends to be higher. The analysis includes year-fixed effects, \( timeFE_i \), and industry-fixed effects, \( indFE_i \). Industries are categorized by the first English notation of the Standard Industrial Classification Code (KSIC 10th). A total of eighteen industries are considered in the analysis. The last term, \( \varepsilon_i \), in the equation denotes the error.

In this analysis, I examine whether the coefficient of the dummy variable has a negative value. If there is a significant decrease in the investment rate in groups with a stake exceeding 50%, one can see that the secondary tax liability investors acts as a burden on the largest shareholders and reduces corporate investment levels. This can be interpreted in two ways. First, when a company seeks to make a large investment, it can be set such that the largest shareholder has an equity ratio of exactly 50% in order to avoid the secondary tax liability. Second, if the largest shareholder’s shareholding ratio exceeds 50% for any reason, investments may be reduced to a limited extent in order to reduce the burden of the secondary tax liability. In either case, the results are consistent with the implications drawn from the model analysis.

C. Results

Table 7 reports the estimation results of equation (1). In the first column, firms for which the largest shareholder’s shareholding exceeds 50% invest 5.3% points less than companies with a corresponding shareholding rate of less than 50%. Even after considering industry fixed effects in the second column, firms with the largest shareholder’s shareholding rate exceeding 50% invest 4.7% points less. When controlling for management indicators that may affect investments, it is estimated that firms with the largest shareholder’s shareholding rate exceeding 50% invest approximately 2.6% points less. As the total asset size increases, the investment rate decreases, and companies with a steep asset growth rate invest more. Leverage does not have a significant effect on the investment rate. The estimation results are consistent with the prediction that firms with the largest shareholder’s shareholding rate exceeding 50% invest less due to the secondary tax liability.

The secondary tax liability is a national tax borne by the largest shareholder when a company goes bankrupt. The burden of the secondary tax liability on the largest shareholders is heavier in companies that are more likely to go bankrupt. If a firm has a high debt ratio, the risk of bankruptcy may increase as the interest burden increases. The largest shareholder of a firm with a high debt ratio is subject to a greater risk of the secondary tax liability. Therefore, if it is true that the secondary tax liability of investors has a significant impact on the investment rate, the difference
in the investment rate depending on whether the secondary tax liability is imposed on investors may be more evident in companies with a high debt ratio. In this analysis, I sample only firms with a debt ratio of 30% or more relative to total assets and examine the impact on investment in cases in which the largest shareholder’s shareholding exceeds 50%.

Table 8 shows summary statistics of the sample with firms with a debt ratio of 30% or more. Except for the minimum debt ratio of 0.3, there is no significant difference in its characteristics from the firms used in the previous analysis. Because this is a sample with a limited debt ratio, the debt ratio is somewhat higher and the asset growth rate is decreased slightly, but considering the standard deviation, the difference is not significant.

Table 9 shows the estimation results of equation (1) for firms with a debt ratio of 30% or more. In companies with a high debt ratio, whether the largest shareholder’s shareholding ratio exceeds 50% has a greater impact on the investment rate as compared to this factor in the entire sample. In the first column in Table 9, the investment rate decreases by 5.8% points, which is approximately 10% greater than in the entire sample. In the second column, the investment rate is shown to decrease by 5.5% points, marking a 17% greater effect than in the entire sample. In the third column, the investment rate decreases by 3.1% points, also showing a greater effect than the entire sample. This suggests that the secondary tax liability is a greater burden on entrepreneurs in companies with a higher debt ratio, posing a greater risk of default.
### Table 9—Effects of Oligopolistic Stockholder on Investments (High Debt Ratio)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dum50</td>
<td>-0.058***</td>
<td>-0.055***</td>
<td>-0.031*</td>
</tr>
<tr>
<td></td>
<td>0.018</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td>Share Ratio</td>
<td>0.069***</td>
<td>0.065***</td>
<td>0.045***</td>
</tr>
<tr>
<td></td>
<td>0.021</td>
<td>0.021</td>
<td>0.021</td>
</tr>
<tr>
<td>LnTA</td>
<td>-0.016***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/A</td>
<td>-0.058***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.021</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AG</td>
<td>0.025***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>timeFE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>indFE</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.0045</td>
<td>0.0146</td>
<td>0.0351</td>
</tr>
</tbody>
</table>

### D. Placebo Test

Considering that second tax liability applies to companies where the largest shareholder’s shareholding exceeds 50%, we looked at changes in the investment rate depending on whether the shareholding rate exceeds 50%. If the secondary tax liability does not affect the investment rate, but rather the shareholding ratio itself influences the investment rate, one should be able to find a break in the investment rate at a threshold other than 50%. I examine whether changes in the investment rate can be found by setting the largest shareholder’s shareholding to 48% as a placebo test. The dummy variable dum48 has a value of 1 if the largest shareholder’s shareholding ratio exceeds 48% and a value of 0 if it is less than 48%. The sample consists of firms with CEOs with ownership ratios greater than 47% and less than 49%. The remaining variables are identical to those in the previous analysis. Table 10 shows summary statistics pertaining to companies for which the largest shareholder’s shareholding ratio exceeds 47% and for those where it is less than 49%. The total number of observations is 1,000, and the investment rate, debt ratio, and asset growth rate are all slightly lower than in the sample used for the main analysis.

Table 11 shows whether the investment rate changes significantly as the shareholding ratio increases from around 48% to over 48%. These results show that the investment rate does not change significantly when the investment rate exceeds 48%.

### Table 10—Summary Statistics for the Placebo Test

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/A</td>
<td>0.044</td>
<td>0.124</td>
<td>-0.213</td>
<td>1.123</td>
</tr>
<tr>
<td>Share Ratio (%)</td>
<td>48.000</td>
<td>0.449</td>
<td>47.04</td>
<td>48.98</td>
</tr>
<tr>
<td>LnTA</td>
<td>15.041</td>
<td>1.119</td>
<td>12.726</td>
<td>18.236</td>
</tr>
<tr>
<td>D/A</td>
<td>0.497</td>
<td>0.234</td>
<td>0.041</td>
<td>0.965</td>
</tr>
<tr>
<td>AG</td>
<td>0.234</td>
<td>0.622</td>
<td>-0.355</td>
<td>5.557</td>
</tr>
</tbody>
</table>
TABLE 11—EFFECTS OF Oligopolistic STOCKHOLDERS ON INVESTMENTS (PLACEBO TEST)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dum48</strong></td>
<td>-0.012</td>
<td>-0.010</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>0.013</td>
<td>0.013</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>Share Ratio</strong></td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.004</td>
</tr>
<tr>
<td></td>
<td>0.014</td>
<td>0.014</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>LnTA</strong></td>
<td></td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td><strong>D/A</strong></td>
<td></td>
<td>0.013</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td><strong>AG</strong></td>
<td></td>
<td>0.016***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td><strong>timeFE</strong></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>indFE</strong></td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.0197</td>
<td>0.0442</td>
<td>0.0528</td>
</tr>
</tbody>
</table>

Not only is the coefficient not statistically significant, but the magnitude of the coefficient is also smaller than the coefficient in Table 7.

In this section, I investigate investments of firms with CEOs whose share ratio exceeds 50% of their firm. Consistent with the model predictions, the empirical analysis implies that the potential burden from the secondary tax liability on an entrepreneur can decrease the investments of such firms.

V. Conclusion

The principle of limited liability for shareholders is a core principle in many countries. The principle is crucial because it becomes easier to raise capital when the limited liability of stocks is recognized, and this allows large-scale projects that cannot be carried out at an individual level to be realized by dispersing risks.

This paper examines the impact of the current shareholder limited liability exception system on firm investment outcomes. First, it is widely known that the secondary tax liability makes it challenging for failed entrepreneurs to recover. This represents a limiting factor in actual entrepreneurship. This paper suggests that the secondary tax liability can act as a factor inhibiting investments even before a company goes bankrupt. The model analysis shows that if an entrepreneur must pay national taxes out of his personal property in the event of a corporate bankruptcy, he invests less. The empirical analysis also found a significant decrease in investment levels at the point where the company’s largest shareholder’s shareholding ratio exceeded 50%, which is the threshold at which the secondary tax liability applies.

In no country except Korea, shareholders of a stock company are not subject to national taxes beyond the scope of limited liability unless a criminal offense such as breach of trust or embezzlement has occurred. It appears better to hinder tax evasion attempts with clear criminal charges and to adhere to the principle of limited liability for shareholders. Observing the limited liability principle can improve the business start-up and investment environment and can failed entrepreneurs recover.
REFERENCES

Hwang, Nam Seok & Yang, In-Jun. 2017 「Secondary tax liability system improvement plan」, Korea Tax Research Forum.
Kim, Jae-jin & Moon, Ye Young. 2021. In-depth evaluation of special tax treatments: exemption from secondary tax liability for investors in venture companies, Korea Institute of Public Finance.

LITERATURE IN KOREAN

김재진⋅문예영. 2020 「조세특례 임의심층평가: 벤처기업 출자자의 제2차 납세의무 면제」, 한국조세재정연구원.
김태완. 2016 「출자자의 제2차 납세의무제도의 고찰」, 「경영연구」, 31(1).
김태희⋅이건훈. 2018 「국세기본법상 출자자의 제2차 납세의무의 범위 단계적 제2차 납세의무의 인정 여부를 중심으로」, 「조세법연구」, 24(2).
이장욱. 2018 「연구개발비 세액공제효과에 관한 연구: 기업재무적 관점을 중심으로」, 한국개발연구원.
이정욱. 2021 「주주 유한책임원칙의 예외가 기업활동에 미치는 영향」, 한국개발연구원.
전병욱. 2019 「중소기업 실패기업인의 제2차 납세의무 완화방안 연구 -출자자의 제2차 납세의무를 중심으로」, 세무와 회계연구 8(2).
정연식. 2011 「과점주주의 제2차 납세의무에 관한 연구」, 조세연구 11(1).
황남석⋅양인준. 2017 「제2차 납세의무제 개선방안」, 기획재정부 연구용역, 한국조세연구포럼.
A Theoretical Analysis of Public Procurement for Innovation

By SUNJOO HWANG*

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
JEL Code: D86, H57, O38

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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* Received: 2023. 12. 13.
* Referee Reports Completed: 2024. 2. 23.
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:

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

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 \( \varepsilon \) follows a normal distribution with a zero mean and variance of \( \sigma^2 \). The higher the variance is, the larger the uncertainty of the quality of the new good becomes.

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

Let \( \Delta = (m' - m) \) denote the difference in the ex-ante quality between an innovative product and a standard product. \( \Delta \) 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>
<thead>
<tr>
<th>TABLE 1—CRITERIA FOR THE DESIGNATION OF INNOVATIVE PRODUCTS</th>
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<tbody>
<tr>
<td>Criteria</td>
</tr>
<tr>
<td>Innovativeness of technology</td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>Marketability</td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>Satisfaction of social needs</td>
</tr>
<tr>
<td>5. (Social value) This criterion assesses if the new good creates social value in the sense that it solves certain problems faced by society.</td>
</tr>
<tr>
<td>6. (Importance and urgency) This criterion assesses if this new product is effective in solving an important and urgent problem.</td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*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 \( \theta \) 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 \( \rho \). The more risk-averse a supplier is, the higher the disutility \( \rho \) 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.

\[
\theta(p - k) + (1 - \theta)(-k - \rho) = 0
\]

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 \( \alpha \in [\alpha, 1), \alpha > 0 \), denotes the quality-contingent payoff and \( \beta \) 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 $\alpha$ for the size of quality-contingent payoff $\alpha$. Later in this paper, we examine the government problem of considering $\alpha$ as a choice variable. However, the SOE considers $\alpha$ as a given rule. The base payoff $\beta$ 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 $\alpha y$ 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 $\alpha y$ 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 $(\alpha, \beta, b, p)$, 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) $X$.

$$X \equiv (\alpha y + \beta - (c + \delta + p))x + (\alpha m + \beta - c)(1-x) + bx$$
$X$ 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’s quality is good, manager A is blamed and usually cannot share the good outcome manager 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, $\gamma$.

\begin{equation}
\begin{aligned}
\gamma > 0
\end{aligned}
\end{equation}

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

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

Then, the expected utility is given by

$$E[u(X)] = E[-\exp[-\gamma(X)]]$$

$$= E[-\exp[-\gamma((\alpha \Delta - \delta - p + b)x + (\alpha m + \beta - c))]] \times E[-\exp[-\gamma \alpha \varepsilon x]]$$

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

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

where the third inequality above is derived by using the mathematical property that $E[-\exp[A \varepsilon]] = -\exp\left[\frac{A^2 \sigma^2}{2}\right]$ 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 $W$.

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

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 $\Delta$.

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

The SOE enjoys only $\alpha$ 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’ $\delta$ 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 $\gamma$ is high), it suffers more. If the underlying uncertainty is the larger (i.e., $\sigma^2$ is large), the SOE is hurt more. Note that the SOE is responsible for quality only to the extent of $\alpha$. Thus, higher levels of risk arise if the compensation depends more on performance (i.e., if $\alpha$ 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 $\alpha$ 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 $\alpha$ for a given $b$. That is, an increase in $\alpha$ provides both an incentive and a disincentive to procure innovative goods. However, this is not the case when the procurement policy $(\alpha, \beta, b, p)$ is endogenously set by the government. I show that the value is independent of $\alpha$, while the risk remains dependent on $\alpha$ 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:

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

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:

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

The following proposition summarizes these optimal procurement choices.

**Proposition 1**: Suppose Assumptions 1 and 2 hold. Given a procurement policy $(\alpha, \beta, b, p)$, 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 $(\alpha, \beta, b, p)$ 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

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

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 $(\alpha, \beta, b, p)$ 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

\[
W = (\alpha \Delta - \delta - p + b)x + (\alpha m + \beta - c) - \frac{\gamma \alpha^2 \sigma^2}{2} x^2 \geq 0.
\]

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:

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

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:** \( \alpha > \frac{\Delta - \delta}{\gamma \sigma^2} \)
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,

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

\[
\alpha^* = \alpha,
\]

\[
\beta^* = -\frac{\Delta-\delta-p^*}{2} - \frac{\alpha m + c}{\gamma \alpha^* \sigma^*},
\]

\[
b^* = (1-\alpha)\Delta,
\]

\[
x^* = \frac{\Delta-\delta-p^*}{\gamma \alpha^* \sigma^*},
\]

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

(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 \(\beta\) 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 \(0 < \alpha^* \Delta + b^* - \delta - p^* < \gamma (\alpha^*)^2 \sigma^*\). 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

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

(12)

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.

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

\[
= \frac{\left[ \alpha \Delta - \delta - p^* + b \right]^2}{2 \alpha \sigma^2} + (\alpha m + \beta - c)
\]

By rewriting the equality above, the following expression for \(\beta\) can be obtained:

\[
\beta = - \frac{\left[ \alpha \Delta - \delta - p^* + b \right]^2}{2 \alpha \sigma^2} - \alpha m + c
\]

(13)

By replacing \(\beta\) in (12) using equation (13), the government’s objective function is rewritten as

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

(14)

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

\[
b = b(\alpha) \equiv (1 - \alpha) \Delta.
\]

(15)

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

\[
x^* = x(\alpha) \equiv \frac{\Delta - \delta - p^*}{\gamma \alpha \sigma^*}.
\]

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

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

Because \(\Delta > \delta + p^*\), the government’s objective function is maximized if \(x(\alpha)\) is maximal. As \(x(\alpha)\) is decreasing in \(\alpha\), the optimal quality-dependent compensation factor equals \(\alpha^* = \alpha\). Equations (13), (15), (16), and (17) imply that \(\beta^* = \frac{-(\Delta - \delta - p^*) - \alpha m + c}{2\alpha}, b^* = (1 - \alpha)\Delta, x^* = \frac{\Delta - \delta - p^*}{\gamma\alpha^2},\) and \(V^* = \frac{(\Delta - \delta - p^*)^2}{2\gamma\alpha^2} + m - c\). Note that \(\alpha^*\Delta + b^* - \delta - p^*\) equals \(\Delta - \delta - p^*\), which is greater than zero and less than \(\gamma\alpha^2\sigma^2\) 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 \(\frac{(\Delta - \delta - p^*)^2}{2\gamma\alpha^2} + m - c\). 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 \(\alpha\), it must be that \(\alpha = \alpha\). Then, \(V\) equals \((\Delta - \delta - p^*) - \frac{\gamma(\alpha^*)^2\sigma^2}{2} + m - c\). This is smaller than \(\frac{(\Delta - \delta - p^*)^2}{2\gamma\alpha^2} + m - c\) as the function \((\Delta - \delta - p^*)x - \frac{\gamma(\alpha^*)^2\sigma^2}{2} - x^2\) is maximized at \(x = \frac{\Delta - \delta - p^*}{\gamma\alpha^2}\). Note that \(x = \frac{\Delta - \delta - p^*}{\gamma\alpha^2}\) is less than 1 according to Assumption 3. Note also that the function \((\Delta - \delta - p^*)x - \frac{\gamma(\alpha^*)^2\sigma^2}{2} - x^2\) equals \(\frac{[\Delta - \delta - p^*]^2}{2\gamma\alpha^2\sigma^2}\) at the maximum \(x = \frac{\Delta - \delta - p^*}{\gamma\alpha^2}\), while it equals \((\Delta - \delta - p^*) - \frac{\gamma(\alpha^*)^2\sigma^2}{2}\) 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

\[
\beta = -\alpha m + c - (\alpha\Delta + b - \delta - p^*)x + \frac{\gamma(\alpha^*)^2\sigma^2}{2}x^2.
\]
By plugging $\beta$ in equation (18) into the government’s objective function in (10), it follows that

\begin{equation}
V = (\Delta - \delta - p^*)x - \frac{\gamma x^2}{2} - x^2 + m - c.
\end{equation}

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 $\alpha$ 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 $\Delta$ is less than the added cost $\delta$ 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., $\gamma x^2 \sigma^2$). 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., $\alpha'$ 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., $\alpha'^2 = \alpha^2$) while raising the power of the quantity-dependent payment (i.e., $b' = (1 - \alpha')\Delta$) 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 $x^* = \frac{\Delta - \delta - p^*}{\gamma x^2 \sigma^2} > 0$ and the social welfare becomes $V^* = m - c$. Finally, the procurement of innovative goods contributes to
social welfare as much as $\frac{\Delta - \delta - p^\ast}{2} x^\ast$.

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 $\Delta$ must exceed the sum of the increase in cost $\delta$ and the increase in payment $p^\ast$. 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 $\rho$, whereas it decreases with the probability $\theta$ 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 $\Delta$. 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 $\alpha^*$ will be scant. 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 (2018-222) 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%88%AA%EC%A0%84%EB%A0%A5%EA%B3%B5%EC%82%AC&capbaNm=&sortType=LAT-EST&tab=jeonggi, 2023.09.19).
TABLE 2—SOE MANAGEMENT EVALUATION CRITERIA THAT RELATED TO THE PROCUREMENT OF NONSTANDARD PRODUCTS

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


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

Firstly, the procurement of innovative products is evaluated mostly qualitatively. 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

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3 Coate 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.

4 In 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 $\Delta$. The theoretical analysis shows that an optimal subsidy increases in $\Delta$. 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


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


박정호. 2020. 『기업의 혁신성과에 대한 혁신공공구매(PPI)의 효과』, 과학기술정책, 3(1), pp. 5-32.

허라윤, 박인환. 2022. 『혁신조달의 현황과 개선과제』, NARS 현안분석, 제253호, 국회임법조사처

New Indicators of Global Integration
Using Input-Output Analysis†

By DONGSEOK KIM*

The import content of export (ICE) has served as an indicator of global integration for several decades. It is defined as the share of imported products embodied in exports and can be interpreted as the relative degree of the utilization of global production network (GPN) over the domestic supply chain (DSC) in terms of ‘value-added.’ This paper proposes two new indicators of global integration. They are defined as the ratios of imports (foreign products) to gross output (domestic products) generated by exports and can be interpreted as the relative degrees of the utilization of GPN over DSC in terms of ‘production.’ Both indicators are easy to compute and can be compared between years, between countries, between industries, and between groups of industries. The paper applies the new indicators to the recent edition of the OECD’s Input-Output Database. Finally, the paper shows that the recent slowdown in international trade is mostly due to the decrease in the international trade of intermediate goods, with significant implications regarding the future of global integration.

Key Word: New Indicators of Global Integration, Import Content of Export, Input-Output Analysis, OECD’s Input-Output Database (OECD IO-DB)
JEL Code: F15, F14, D57

I. Introduction and Motivation

The rapid growth of international trade would be the most noteworthy change in the global economy over the past century. Trade, whether domestic or international, enhances the welfare of the economic agents involved in it, and

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* Received: 2023. 11. 1
* Referee Process Started: 2023. 11. 13
* Referee Reports Completed: 2023. 11. 29
† I thank two anonymous referees for their valuable suggestions. All remaining errors are mine.
international trade has contributed to the world’s economic development immensely, especially since World War II.

International trade, simply defined as the exchange of goods and services among countries, eventually leads to the economic and social integration of the countries that engage in it. Global integration is a complicated phenomenon, and many indicators have been developed to measure the degree of global integration.

One of the most elementary yet frequently used indicators would be the magnitude of international trade – specifically, exports or the sum of exports and imports – or its ratio relative to the size, e.g., as a percentage of GDP, of economic activity. Maddison (2001) estimated that world exports as a percentage of the world GDP amounted to only 5.5% in 1950. However, this rate subsequently skyrocketed, reaching 12.8% in 1970, 20.4% in 1980 and 31.0% in 2008, as shown in Figure 1.

More rigorous and scientific investigations of global integration require the use of intermediate input data. Industries’ input structures, expressed in terms of input coefficients, reflect the production functions. Specifically, domestic and imported input coefficients vividly describe the degrees and patterns with which industries make use of domestic supply chains (DSC) and the global production network (GPN). This is why input-output (IO) analyses are extensively used in studies of international trade and especially global integration in recent decades, as intermediate inputs are studied extensively and rigorously in studies of international trade and global integration.

Figure 2 depicts the share of imported intermediate inputs out of total imports into Korea since the beginning of the country’s rapid economic growth in the 1970s.

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1World Bank, “World Development Indicator.”
Korea began its export-driven economic growth in the 1970s, but the economy was not equipped with sufficient capacity to produce intermediate inputs. Hence, the country had to depend heavily on imported intermediate inputs, which can be confirmed from the first increase in this share during the period of 1970-1985. This was followed by a decline during the period of 1985-1995, reflecting the country’s efforts to alleviate the dependence on imported intermediate inputs through intensive R&D to enhance the competitiveness of domestic parts and components.

The second rise of this share (1995-2010) in Figure 2 is explained by Korea’s active engagement in global integration in various forms, such as off-shoring, international out-sourcing, and other such means. The Korean government’s trade policy toward general trade liberalization also contributed to the increase in imported intermediate inputs. While the second decline of the share since 2010 can be partially attributed to reshoring and onshoring, the enhanced comparative advantage of domestic parts and components, and the slowdown of international trade, among other factors, additional investigations and research are needed in this area.

The import content of export (ICE) metric has frequently been used as an indicator of global integration over the past several decades. ICE, defined as the increase in imports when exports increase by one unit, can be interpreted as the share of imported goods and services embodied in exported products. It can be said that the larger the ICE, the more the industry or the economy depends on the foreign sector, explaining why it has served as an indicator of global integration.

Unlike ICE, this paper proposes alternative indicators based on the relative degree of the utilization of GPN compared to the degree of the utilization of DSC. Understanding the motivation behind the use of these alternative indicators and how they differ from ICE requires knowledge about the special characteristics of imports in the circulation of a national economy. The basic equation for the determination of a country’s national income in an open economy is \( V = C + I + (E - M) \), where the

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Imported Intermediate Inputs}
\end{figure}
terms $V$, $C$, $I$, $E$ and $M$ denote GDP or value-added (VA), consumption, investment, exports and imports, respectively. The equation is alternatively referred to as the ‘definition of expenditure GDP.’

The above equation can be rewritten as $V + M = C + I + E$. When exports change by $\Delta E$ while consumption and investment are fixed, therefore, we have $\Delta V + \Delta M = \Delta E$, where $\Delta V$ and $\Delta M$ denote the changes in VA and imports generated by $\Delta E$, respectively. In other words, an increase in exports increases VA and imports, and the sum of the increases equals the increase in exports. It should be noted that the increase in imports is the increase in exports for the exporting countries, i.e., of the trade partners, and hence, will lead to an increase in foreign VA of the same amount. Thus, an increase in exports will increase domestic and foreign VA, and the sum of these two equals the increase in exports.

If we divide both sides of $\Delta V + \Delta M = \Delta E$ by $\Delta E$, the result is $\Delta V / \Delta E + \Delta M / \Delta E = 1$. The second term on the left-hand side is defined as ICE, while the first term could be called the ‘(domestic) value-added content of export (VCE).’ Note that ICE implies a competing relationship between domestic VA and foreign VA – even if it is not mentioned explicitly, while also defining the impact of a one-unit increase in exports on foreign VA as an indicator of global integration. In other words, ICE measures the degree of global integration according to the relative degree of the utilization of GPN compared to the degree of the utilization of DSC in terms of VA.

As mentioned previously, imports have a special characteristic in the circulation of a national economy. While imports are equivalent to VA in the foreign sector, imports are a significant component of the total supply in the domestic market. In other words, imports have dual competing relationships in the national economy: foreign VA (imports) vs. domestic VA (GDP), and foreign production (imports) vs. domestic production (gross output).

It is possible that in certain contexts, researchers or policymakers may become more interested in the extent to which an economy or an industry utilizes GPN and DSC in terms of production compared to those in VA. For example, production-based measures may be more informative than VA-based measures for those interested in the impacts on the market shares of imported and domestic products. This paper proposes two new indicators of global integration based on the relative degree of the utilization of GPN compared to the degree of the utilization of DSC in terms of ‘production.’ Specifically, the paper defines the increases in imports and gross output generated by exports as the degrees of the utilization of GPN and DSC, respectively, and proposes the ratios of these two as indicators of global integration. The first indicator uses the ‘amounts’ of imports and gross output generated by exports, while the second uses the ‘shares’ of these amounts in total exports and gross output, respectively.

The indicators proposed in this paper have an advantage in that their interpretation is straightforward because they are constructed as the ratios of the degrees of the utilization of GPN and DSC. When the values of the indicators of two countries are

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2 Government consumption and investment are classified as consumption ($C$) and investment ($I$), respectively.
0.2 and 0.1, for example, we can say that the relative utilization degree of GPN of the first country is twice that of the second country. The indicators suggested in this paper enjoy the advantages of ICE. These indicators are derived from an elementary IO analysis, and the computing burden is negligible. Also, the indicators can be compared between countries, between years, between industries, and between groups of industries. The paper will apply the new indicators to the recently released 2021 edition of the OECD’s Input-Output Database (OECD IO-DB). The 2021 edition, the latest of the OECD’s IO-DB, contains the IO tables of 66 countries for 24 years (1995-2018).

The paper is organized as follows. Section II reviews the literature briefly, and the new indicators of global integration are explained in Section III. Section IV explains the data and the empirical results, and Section V concludes the paper.

II. Literature

Integration of the world economy through international trade has been one of the most remarkable changes in the world economy, and enormous efforts have been made to devise indicators to measure various aspects of the global integration of countries and industries. The body of literature in this field is enormous, and this section is limited to studies of ICE and related topics.

It is interesting to observe that imports and the VA contents of exports have attracted attention in a seemingly remote context. Loschky and Ritter (2006) realized that the exports of Germany recorded unparalleled rapid growth in the 2000s but that it was accompanied by more rapid growth of imported intermediate inputs, discounting the contribution of exports to GDP. They computed, by means of an IO analysis, the amount of imported intermediate inputs caused by exports; they also computed its share in exports, referring to it as ICE, and reported that Germany’s ICE soared from 31% in 1995 to 42% in 2005.

Kim (2004) examined the widening gap between the growth rates of foreign demand (exports) and domestic demand (consumption and investment) in Korea. Korea’s exports achieved remarkable growth in the early 2000s, but domestic demand showed an extremely sluggish trend. In 2003, for example, the growth rate of exports was 15.7% whereas consumption and investment recorded extremely low growth rates of -0.5% and 3.6%, respectively. The widening gap continued in early 2004, which resulted in a large current account surplus (GDP less domestic demand).

Previously, a gap between foreign and domestic demand was not usual in Korea. Generally, an increase in exports generates more income, resulting in an increase in domestic demand with a lag of several quarters. The widening gap, therefore, implies that the exports → VA → domestic demand channel has weakened. Kim (2004) called the share of VA generated by exports out of total exports the VA multiplier (VAM), referred to as ‘VCE’ here. According to Kim (2004), Korea’s VAM increased from 0.629 in 1980 to 0.711 in 1993, at which point it began to decline, reaching 0.630 in 2000. He also showed that (i) the VAM of exports was lower than that of domestic demand, and (ii) while the VAMs of both exports and domestic demand have declined since 1993, the former declined far more rapidly.
While global integration can be defined in many ways, basically it refers to an increase in international trade accompanied by an increase in the share of imported intermediate inputs in exports. Global integration can take various forms and has been given various names depending on the specific context, such as the international fragmentation of production, global outsourcing, the integration of GPN, and offshoring, among others.

Hummels et al. (2001) paid attention to the strengthening ‘vertical linkages’ caused by the increase in ‘the use of imported (intermediate) inputs in producing goods that are exported,’ referring to this phenomenon as ‘vertical specialization.’ They used the IO tables of ten OECD member and nonmember countries from the OECD’s IO-DB, showing that vertical specialization explains 21% of the exports of these countries and that this rate increased by 30% over the period of 1970-90.

Breda et al. (2009) interpreted ICE ‘as a measure of internationalization,’ and they computed the ICEs at aggregate and industry levels in the 1990s using the IO tables of seven European countries. They found an increasing trend in most industries in most countries despite the fact that there were heterogeneous patterns of internationalization in some industries and in some countries to some extent.

Backer and Yamano (2008) defined ‘globalization’ as ‘the emergence of the global value chain’ and used ICE as an indicator of globalization. Considering that the classification of products into final and intermediate products is not possible using traditional trade statistics, they emphasized the use of IO tables to investigate new trend in international trade. They computed the ICEs of 38 countries during the period of 1970-2000 using the 1995, 2002 and 2006 editions of the OECD IO-DB, confirming the trend of global integration empirically.

Due to the increase in the use and the importance of ICE in examining international trade and global integration, the OECD has published ICE data in more recent editions of their IO-DBs.

Kim (2020) and Kim (2021) emphasized the need to consider the amounts of gross output, as well as imports, generated by exports simultaneously when measuring the degree of global integration. They computed (i) the share of imports generated by exports out of total imports and (ii) the share of gross output generated by exports out of total gross output, interpreting the two shares as the degree to which an economy or industry utilizes the GPN and DSC, respectively. Kim (2020) computed the two shares at the aggregate and industry levels for 64 countries during the period of 1995-2015 using the 2015 and 2018 editions of the OECD’s IO-DB. Kim (2021) computed the two shares for Korea for the period of 1970-2018. Kim (2020) and Kim (2021) examined the patterns of global integration empirically.

Although Kim (2020) and Kim (2021) considered the amounts of both gross output and imports generated by exports, they did not construct an indicator of global integration per se. They only used the two shares and built a scatter diagram to investigate the trend of global integration. However, the indicators of global integration suggested in this paper represent a direct development of the ideas in Kim (2020) and Kim (2021).
III. New Indicators of Global Integration

The layout of the IO tables in the OECD IO-DB is depicted in Figure 3. The rows and the columns of IO tables describe the market structures of products and the input structures of industries, respectively. Let $n$ be the number of products/industries, and let $i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, n$ be the indices for products (rows) and industries (columns), respectively.

In Figure 3, $Z = [z_{ij}]$ is an $n \times n$ matrix of the inter-industry trade of intermediate inputs. Specifically, $z_{ij}$ is the amount of product $i$ used as intermediate input in industry $j$. $Z^d = [z^d_{ij}]$ and $Z^m = [z^m_{ij}]$ are $n \times n$ matrices of domestic and imported intermediate inputs, respectively, and $Z = Z^d + Z^m$.

Intermediate inputs $z_{ij}$ have dual meanings. In the market structure context, $z_{ij}$ is the intermediate demand for product $i$ by industry $j$, while in the input

![FIGURE 3. LAYOUT OF INPUT-OUTPUT TABLES IN THE OECD IO-DB](image-url)
structure context, \( z_{ij} \) is the intermediate input of product \( i \) in industry \( j \). Let \( o \) be an \( n \times 1 \) vector of 1s. Then, \( u = Z o \) is the horizontal sum of \( Z \) and is an \( n \times 1 \) intermediate demand vector, and \( w = o' Z \) is a \( 1 \times n \) intermediate input vector. We can similarly define the domestic and imported intermediate demand and input vectors \( u^d = Z^d o \), \( u^m = Z^m o \), \( w^d = o' Z^d \) and \( w^m = o' Z^m \). Subsequently, we have \( u = u^d + u^m \) and \( w = w^d + w^m \). \(^5\)

In Figure 3, \( c \) and \( i \) are the \( n \times 1 \) vectors of consumption and investment, respectively, and are decomposed into corresponding domestic and imported components, i.e., \( c = c^d + c^m \) and \( i = i^d + i^m \). The \( n \times 1 \) export vector contains domestic components only. Consumption, investment and exports constitute the final demand of the economy. We define the total, domestic and imported final demands as \( f = c + i + e \), \( f^d = c^d + i^d + e \) and \( f^m = c^m + i^m \), respectively.

The total supply of the economy consists of the total supply of domestic products (\( x \)) and the total supply of imported products (\( m \)), and the total demand consists of the total intermediate demand (\( u \)) and the total final demand (\( f \)). These are all \( n \times 1 \) vectors. The market equilibrium of the total market is described by \( x + m = u + f \), and those of the markets for imported and domestic products are described respectively by

\[
\begin{align*}
x &= u^d + f^d, \\
m &= u^m + f^m.
\end{align*}
\]

We now investigate the input structure. In Figure 3, \( v \) and \( x' \) are \( 1 \times n \) vectors of VA and the total input, respectively. \(^6\) Total input consists of the total intermediate input and VA; that is,

\[
x' = w + v = w^d + w^m + v.
\]

Input coefficients facilitate advanced and useful analyses. The \( n \times n \) domestic and imported input coefficient matrices are defined as \( A^d = [a^d_{ij}] = [z^d_{ij} / x_j] \) and \( A^m = [a^m_{ij}] = [z^m_{ij} / x_j] \), respectively. Note that \( a^d_{ij} \) and \( a^m_{ij} \) are the shares of domestic and imported \( i \)th intermediate inputs in the total input of the \( j \)th industry, respectively.

According to the construction of \( A^d \) and \( A^m \), we can show that \( u^d = A^d x \) and \( u^m = A^m x \). The market equilibrium of domestic products can then be rewritten as \( x = u^d + f^d = A^d x + f^d \), where the second equality follows from \( u^d = A^d x \). Solving this for \( x \) results in \( x = (I - A^d)^{-1} f^d = R^x f^d \), where \( R^x = (I - A^d)^{-1} \). The equation \( x = R^x f^d \) describes the determination of gross output as a function of the domestic final demand. The \( (i, j) \)th element of \( R^x = [r^x_{ij}] \) is the increase in the gross output of the \( i \)th product when the final demand for the \( j \)th domestic

\(^5\)While the intermediate demand and input vectors are explicitly included in the IO tables of some countries, they are not included in the IO tables of the OECD IO-DB. These vectors are indicated in Figure 3 to clarify the layout.

\(^6\)Total input and the transpose of gross output are identical in the IO tables.
product increases by one unit; i.e., \( r_{ij}^e = \Delta x_i / \Delta f_{ij} \).

The market equilibrium of the imported products can be expressed as

\[
m = u^m + f^m = A^m x + f^m = A^m (I - A^d)^{-1} f^d + f^m = R^m f^d + f^m
\]

with \( R^m = A^m (I - A^d)^{-1} \),

where the third equality follows from \( x = (I - A^d)^{-1} f^d \). This equation describes the determination of imports as a function of the domestic and imported final demand levels. The \((i, j)\)th element of \( R^m = [r_{ij}^m] \) is the increase in the import of the \(i\)th product when the final demand for the \(j\)th domestic product increases by one unit; i.e., \( r_{ij}^m = \Delta m_{ij} / \Delta f_{ij} \).

Let \( A^v = \text{diag}(a_{ij}) = \text{diag}(v_i / x_i) \) be the \(n \times n\) VA coefficient diagonal matrix. This leads to \( v = A^v x = A^v (I - A^d)^{-1} f^d = R^v f^d \) with \( R^v = A^v (I - A^d)^{-1} \), where the second equality follows from \( x = (I - A^d)^{-1} f^d \). The \((i, j)\)th element of \( R^v = [r_{ij}^v] \) is the increase in the VA in the \(i\)th industry when the final demand for the \(j\)th domestic product increases by one unit; i.e., \( r_{ij}^v = \Delta v_i / \Delta f_{ij} \).

We rewrite the decomposition of \( x \) and \( m \) as follows, where the second equalities follow from \( f^d = c^d + i^d + e \) and \( f^m = c^m + i^m \), respectively.

\[
x = R^v f^d = R^v c^d + R^v i^d + R^v e,
\]
\[
m = R^m f^d + f^m = R^m c^d + R^m i^d + R^m e + c^m + i^m.
\]

These two equations decompose gross output and imports into the contributions of the individual final demand terms. We premultiply \( o^i \) to both sides to obtain

\[\begin{align*}
o'^i x &= o'^i R^v c^d + o'^i R^v i^d + o'^i R^v e, \\
o'^i m &= o'^i R^m c^d + o'^i R^m i^d + o'^i R^m e + o'^i c^m + o'^i i^m.
\end{align*}\]

The third terms on the right-hand sides are the amounts of gross output and imports generated by exports, respectively, and can be interpreted as the magnitudes of the country’s utilization of GPN and DSC to facilitate exports, respectively. Hence, the ratio of the two amounts can be interpreted as the relative degree of the utilization of or dependence on GPN compared to DSC;

\[
\text{MXR}^a = \frac{o'^i R^m e}{o'^i R^v e}.
\]

MXR\(^a\) can also be computed for individual industries as follows. Assume that the country in question exported only the \(i\)th product. Then, the numerator of MXR\(^a\) becomes \([o^i R^m] \cdot e_i \) where \([a]_i\) denotes the \(i\)th element of vector \( a \) and \( e_i \) is the export of the \(i\)th product. Similarly, the denominator of MXR\(^a\)
becomes $[o'R^x] \cdot e_i$. The ratio of these two amounts can be rewritten as

$$MXR_i^a = \frac{[o'R^m] \cdot e_i}{[o'R^x] \cdot e_i}$$

and is interpreted as the relative degree of the utilization of the GPN compared to the DSC of the $i$th industry. $MXR_i^a$ is the first indicator of global integration proposed in this paper.

We divide both sides of (1) by $o'x$ and $o'm$, respectively, which results in

$$1 = \frac{o'R^x e^d}{o'x} + \frac{o'R^i e^d}{o'x} + \frac{o'R^e}{o'x},$$

$$1 = \frac{o'R^m e^d}{o'm} + \frac{o'R^m i^d}{o'm} + \frac{o'R^m e}{o'm} + \frac{o'c^m}{o'm} + \frac{o'i^m}{o'm}.$$ 

The third terms on the right-hand sides are the shares of gross output and imports generated by exports in the total gross output and imports, respectively, and can be interpreted as the degree to which the country depends on GPN and DSC expressed in shares, respectively. Hence, the ratio of the two shares

$$MXR^s = \frac{o'R^m e}{o'm} / \frac{o'R^e}{o'x}$$

can also be interpreted as the relative degree of the utilization of or dependence on GPN compared to DSC. This ratio can also be computed for individual industries, as follows:

$$MXR_i^s = \frac{[R^m e]}{[R^e]} / \frac{m}{x_i}.$$ 

$MXR^s$ is the second indicator of global integration proposed in this paper. Both indicators, $MXR^a$ and $MXR^s$, are defined as the relative utilization of or dependence on GPN compared to DSC; the former uses ‘amounts’ and the latter uses ‘shares.’

$MXR^s$ is the ratio of the shares of imports (foreign production) and gross output (domestic production) generated by exports out of total imports and gross output,

---

7In the actual computation, one can use element-by-element (EBE) division, which is supported by most computing software for matrix algebra. Let $a = [a]$ and $b = [b]$ be either $n \times 1$ or $1 \times n$ vectors. Then, the EBE division of $a$ by $b$ is defined as $a \odot b = [a / b]$, where $\odot$ is the EBE division operator. For example, $\odot$ is the EBE division operator in the GAUSS software package. The vector of $MXR$’s for individual products can easily be obtained by $o'R^x / o'R^e$.

8$MXR$ is an abbreviation of the ‘imports (m) / gross output (x) ratio,’ while the superscripts ‘a’ and ‘s’ signify ‘amounts’ and ‘shares,’ respectively.
respectively. In other words, MXR⁰ explicitly uses ‘aggregate’ exports and gross output data, and we can say, therefore, that the ‘macroeconomic’ aspects of exports are taken into consideration in the MXR⁰ metric. On the other hand, MXRᵃ is the ratio of imports and gross output generated by exports, and macroeconomic or comprehensive perspectives are not taken into consideration. In consequence, it is conjectured that MXR⁰ can be more useful when the emphasis is placed on macroeconomic aspects, while MXRᵃ can be more useful when the comparison at the product level is afforded more attention. Active empirical studies using these indicators are anticipated in the future.

Both indicators can be compared between years, between countries, and between industries. They can also be computed for a group of industries; for instance, we can compute these indicators for the manufacturing sector, i.e., a group of industries in the manufacturing sector, and compare them between years or between countries.⁹

ICE is defined as the increase in imports when exports increase by one unit and is computed as the share of imports generated by exports out of total imports. ICE can also be computed for individual industries.

\[ ICE = \frac{o'Re}{o'e}, \]
\[ ICE_i = \left[ o'R^m \right]. \]

We now investigate the relationships among the indicators discussed thus far. We define the production multiplier of exports (PME) as the increase in gross output when exports increase by one unit; that is, \( PME = \frac{o'Re}{o'e} \). MXRᵃ and MXR⁰ can then be expressed as

\[ MXR^a = \frac{o'R^m e}{o'R^e} = \frac{o'R^m e / o'e}{o'R^e / o'e} = \frac{ICE}{PME}, \]
\[ MXR^s = \frac{o'R^m e / o'm}{o'R^e / o'x} = \frac{o'R^m e}{o'R^e} \frac{o'x}{o'm} = \frac{ICE}{PME} \frac{o'x}{o'm}. \]

In summary, MXRᵃ is the ratio of the increase in imports to the increase in gross output when exports increase by one unit, and MXR⁰ is the same ratio adjusted by the ratio of gross output to imports.

Secondly, VCE is defined as the increase in VA when exports increase by one unit and is computed as the share of domestic VA out of total exports. VCE can also be computed for individual industries.

⁹Let \( g \) be the group of industries, and let \( e^g, x^g \) and \( m^g \) be the exports, gross output and imports vectors, respectively, constructed in such a way that the amounts of the industries that do not belong to \( g \) are all zero. Then, MXR⁰ and MXRᵃ computed using \( e^g \), \( x^g \) and \( m^g \) are indicators of the global integration of the group of industries \( g \). In fact, MXR⁰ and MXRᵃ of the entire economy represent a special case.
\[ VCE = \frac{o' R^* e}{o' e}, \]
\[ VCE_i = [o' R^*]. \]

It can be easily proved that \( ICE + VCE = 1 \) and \( ICE_i + VCE_i = 1 \) for all \( i = 1, 2, \ldots, n \). (The proof is in the Appendix.) It can be said, therefore, that ICE and VCE have same amount of information, and VCE can also be used to measure the degree of global integration. The only difference is that the larger the VCE is, the smaller the degree of global integration also is.

Both MXR\(^a\) and MXR\(^s\) are proportionate to the relative degree of the utilization of GPN over DSC because they are defined as the ratios of foreign production (imports) and domestic production (gross output) generated by exports. It can be said, therefore, that the interpretation of these indicators is straightforward. If the values of MXR\(^a\) of two countries are 0.2 and 0.1, for example, we can say that the degree of global integration of the first country is twice that of the second country.

This does not hold for ICE because it is not defined as the ratio of ICE to VCE. The relative degree of the utilization of GPN over DSC in terms of VA is \( \frac{ICE}{VCE} = \frac{ICE}{1 - ICE} \) because \( ICE + VCE = 1 \). Therefore, if the values of ICE of two countries are 0.2 and 0.1, for example, then the relative degrees of utilization of GPN over DSC in terms of VA are \( \frac{0.2}{0.8} \) and \( \frac{0.1}{0.9} \), and we can say that the first country’s degree of global integration is \( \frac{0.2}{0.8} / \frac{0.1}{0.9} = \frac{9}{4} = 2.25 \) times that of the second country.

### IV. Data and Empirical Results\(^{10}\)

#### A. Data

The 2021 edition of the OECD’s IO-DB was used in the empirical analysis in this paper. This edition was released in 2021 and 2022 and is the latest edition of the OECD IO-DB. It contains the IO tables of 66 OECD member and non-member countries for 24 years (1995-2018). These countries account for over 90% of the world’s GDP and international trade and over 70% of the world’s population as of 2018.

All IO tables in the OECD IO-DB are harmonized; they are arranged in accordance with common industry classification and common currency unit. There are two IO tables for a country: the ‘TTL’ (total) table and the ‘DOMIMP’ (domestic and imported) table, as depicted in Figure 3. The industry classification of the OECD IO-DB is based on the International Standard Industrial Classification (ISIC), Revision 4, and categorizes the entire economy into 45 industries. The currency unit of the OECD IO-DB is million US dollars.

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\(^{10}\)Tables and figures in this section were constructed based on the author’s computations using IO tables from the 2021 edition of the OECD IO-DB.
It was determined that the classification system with 45 industries is excessively finely classified considering the goals of this paper, and the tables were rearranged according to a 25-industry classification. A concordance table between the industry classification systems of the OECD IO-DB and this paper is given here as Table 1.

Although most terms and indicators were computed for all 66 countries in the empirical study, the results for the top eight countries in terms of total exports in 2018 are reported in this paper. These countries are China, the United States, Germany, Japan, France, Korea, United Kingdom, and Italy.11 The United States was the top exporting country until 2011 but was surpassed by China in 2012. Total exports of the eight countries are depicted in Figure 4. These eight countries accounted for 50.0% of the total exports of the 66 countries in 2018. It is readily observed from Figures 1 and 4 that the financial crisis of 2018 caused enormous damage to international trade.

### Table 1—Concordance Table Among the Three Industry Classifications

<table>
<thead>
<tr>
<th>Sector</th>
<th>OECD IO-DB Sector</th>
<th>ISIC Revision 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agricultural, forest and fishery goods 1–2</td>
<td>01–03</td>
</tr>
<tr>
<td>2</td>
<td>Mined and quarried goods 3–5</td>
<td>05–09</td>
</tr>
<tr>
<td>3</td>
<td>Food, beverage and tobacco products 6</td>
<td>10–12</td>
</tr>
<tr>
<td>4</td>
<td>Textile and leather products 7</td>
<td>13–15</td>
</tr>
<tr>
<td>5</td>
<td>Wood and paper products 8–9</td>
<td>16–18</td>
</tr>
<tr>
<td>6</td>
<td>Coal and petroleum products 10</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>Chemical products 11–13</td>
<td>20–22</td>
</tr>
<tr>
<td>8</td>
<td>Non-metallic mineral products 14</td>
<td>23</td>
</tr>
<tr>
<td>9</td>
<td>Basic metal products 15</td>
<td>24</td>
</tr>
<tr>
<td>10</td>
<td>Fabricated metal products 16</td>
<td>25</td>
</tr>
<tr>
<td>11</td>
<td>Electric and electronic equipment 17–18</td>
<td>26–27</td>
</tr>
<tr>
<td>12</td>
<td>Machinery and equipment 19</td>
<td>28</td>
</tr>
<tr>
<td>13</td>
<td>Motor vehicles and trailers 20</td>
<td>29</td>
</tr>
<tr>
<td>14</td>
<td>Other transport equipment 21</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>Other manufactured products 22</td>
<td>31–33</td>
</tr>
<tr>
<td>16</td>
<td>Electricity, gas and water supply 23–24</td>
<td>35–39</td>
</tr>
<tr>
<td>17</td>
<td>Construction 25</td>
<td>41–43</td>
</tr>
<tr>
<td>18</td>
<td>Wholesale and retail 26</td>
<td>45–47</td>
</tr>
<tr>
<td>19</td>
<td>Transportation and warehousing 27–30</td>
<td>49–52</td>
</tr>
<tr>
<td>20</td>
<td>Communication services 31, 33–34</td>
<td>53, 58–61</td>
</tr>
<tr>
<td>21</td>
<td>Accommodation and food services 32</td>
<td>55–56</td>
</tr>
<tr>
<td>22</td>
<td>Business services 35–39</td>
<td>62–82</td>
</tr>
<tr>
<td>23</td>
<td>Public administration and defense 40</td>
<td>84</td>
</tr>
<tr>
<td>24</td>
<td>Education, healthcare and social work 41–42</td>
<td>85–88</td>
</tr>
<tr>
<td>25</td>
<td>Other services 43–45</td>
<td>90–98</td>
</tr>
</tbody>
</table>

Note: 1) Less 67 and 76.

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11We use the following country codes in the tables and figures in this paper: CHN (China), USA (United States), DEU (Germany), JPN (Japan), FRA (France), KOR (Korea), GBR (United Kingdom), and ITA (Italy). These are identical to the codes in the OECD IO-DB.
B. Indicators of Global Integration at the Country Level

The ICEs of the eight countries during the period of 1995-2018 are given in Figure 5. The ICE of Korea was highest during the entire period, and those of Japan and United States were lowest. France, Germany and Italy showed a highly similar pattern during the period, possibly reflecting their similar patterns of exports and imports of both final and intermediate products, while those of China and United Kingdom were similar to each other.

We observe from Figure 5 that the ICEs of the eight countries in general increased until the late 2000s, after which they began to decrease. Although some countries did not show a clear declining trend, the slopes are diminishing in such cases. To clarify the patterns, Hodrick-Prescott filtering was applied; these results are given in Figure 6, where these conjectures are confirmed. Figure 7 presents the average ICE
of the eight countries. This value was approximately 0.129 in 1995, but it increased rapidly to 0.213 in 2011, then dropped to 0.170 in 2016, and recovered to 0.186 in 2018. It appears that the time-series fluctuation became stronger in recent years, suggesting an important research topic.

The MRX values of the eight countries and the average of these values during the period of 1995-2018 are given in Figure 8 and Figure 9, respectively. While the patterns of individual countries’ MRX values are similar to those of the ICE values, we also observe significant differences at the same time. For instance, France,

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12This is the weighted average of the ICEs of the eight countries which was computed from the aggregated IO tables of the eight countries. It is evident that the ICE began declining around early 2010s. A sharp decline of ICE in 2009 was the result of the freezing of international trade following the financial crisis in 2008 and must not be interpreted as a sharp retreat of ‘global integration’ itself.
Italy and Germany showed very similar patterns for ICE, whereas their MRX\(^{a}\)'s were significantly dissimilar.

In addition, China’s ICE and MRX\(^{a}\) trends imply highly distinct patterns of global integration according to both time-series and cross-country assessments. Specifically, China’s ICE time series implies that the relative degree of global integration was higher than that of Italy, though the two have become similar in recent years. The MRX\(^{a}\) trend, however, implies that China’s degree of global integration was lower than Italy’s during the entire period. Clearly, this arose because these two indicators are constructed differently.

Comparing Figure 9 with Figure 7, we learn that the average ICE and MRX\(^{a}\) outcomes for the eight countries are highly similar in terms of the corresponding time-series patterns, though the ranges of the values are different. In fact, it is expected that the ICE value is close to the share of foreign VA (imports) in total VA
However, ICE can be slightly larger than the latter because the share of foreign VA (imports) embodied in exports is usually greater than that in domestic final demand. In 2018, for example, the average ICE for the eight countries was 0.186, while the share of foreign VA was 0.168. Similarly, it is expected that the value of MRX is close to the ratio of the supply of imported products (imports) relative to that of domestic products (gross output). In 2018, the average MRX for the eight countries was 0.095, while the ratio of imports to gross output was 0.099. This conjecture can also be confirmed at both country and industry levels.

The MRX’s of the eight countries and the average of these values during the period of 1995-2018 are given in Figure 10 and Figure 11, respectively, where we can observe that the patterns of MRX are considerably different from those of MRX and ICE. First, while Korea’s MRX level is higher than those of other countries’ for all years and the pattern of MRX is similar to that of MRX, the
turning point appears earlier. Second, France, Germany and Italy reveal similar patterns in that their MRX\(^a\)s show an increasing pattern while their MRX\(^s\)s have a rising and then declining pattern. Third, Germany’s positions in terms of MRX\(^a\) and MRX\(^s\) are substantially different, and fourth, the United States maintained a declining degree of global integration as expressed in MRX\(^s\) during the entire period. Above all, MRX\(^s\) is based on shares, not on amounts, which very likely caused these differences.

In the figures above, we observed that ICE and MRX\(^a\) display similar patterns for individual countries, with the corresponding averages also similar, while MRX\(^s\) showed somewhat different patterns. This can be directly confirmed by the correlation coefficients. The pairwise correlation coefficients among the three indicators were computed for each of the eight countries and for their averages, as shown in Table 2. The correlation coefficients between ICE and MRX\(^a\) exceed 0.95 for all countries and for the average. However, the correlation coefficients between MRX\(^s\) and the other two indicators are significantly smaller, on average, and reveal a major variation among the countries.

Such differences in the formulae and the resulting differences in the behaviors frequently cause discrepancies in the relative degrees, i.e., the rankings, of global integration among countries. The estimates of the three indicators of China, Germany and Italy in 2018 are given in the first panel of Table 3, while the second panel gives their rankings. Interestingly, Italy ranked first in terms of ICE, China ranked first in terms of MRX\(^a\), and Germany ranked first in terms of MRX\(^s\).

These types of reversals or discrepancies among the indicators can also arise in a time-series context; in fact, there are many years in which the three indicators imply different directions of change in the degree of global integration. The values of the three indicators for China, for instance, and the yearly change rates are computed in Table 4. We observe that (i) in 2001, ICE decreased by 1.8% while MRX\(^a\) and MRX\(^s\) increased by 1.9% and 2.5%, respectively; (ii) in 2003, MRX\(^s\) decreased by 1.5% while ICE and MRX\(^a\) increased by 18.2% and 16.0%, respectively; and (iii) in 2005, MRX\(^a\) decreased by 2.8% while ICE and MRX\(^s\) increased correspondingly by 0.5% and 1.5%. These types of reversals occurred in many years in many countries.

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**Table 2—Correlation Coefficients Among the Three Indicators**

<table>
<thead>
<tr>
<th>Country</th>
<th>Correlation Coefficients Between</th>
<th>ICE – MRX(^a)</th>
<th>ICE – MRX(^s)</th>
<th>MRX(^a) – MRX(^s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td></td>
<td>0.961</td>
<td>0.366</td>
<td>0.180</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td>0.993</td>
<td>0.945</td>
<td>0.913</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td>0.992</td>
<td>0.871</td>
<td>0.811</td>
</tr>
<tr>
<td>United Kingdom</td>
<td></td>
<td>0.995</td>
<td>0.952</td>
<td>0.923</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td>0.996</td>
<td>0.938</td>
<td>0.923</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td>0.997</td>
<td>0.931</td>
<td>0.925</td>
</tr>
<tr>
<td>Korea</td>
<td></td>
<td>0.998</td>
<td>0.509</td>
<td>0.513</td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td>0.986</td>
<td>0.532</td>
<td>0.410</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.990</td>
<td>0.915</td>
<td>0.888</td>
</tr>
</tbody>
</table>
Table 3—Three Indicators for China, Germany and Italy in 2018

<table>
<thead>
<tr>
<th>Country</th>
<th>Estimates</th>
<th>Rankings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICE</td>
<td>MRX&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>China</td>
<td>0.165</td>
<td>0.948</td>
</tr>
<tr>
<td>Germany</td>
<td>0.235</td>
<td>0.761</td>
</tr>
<tr>
<td>Italy</td>
<td>0.237</td>
<td>0.854</td>
</tr>
</tbody>
</table>

Table 4—Three Indicators of Global Integration of China

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimates</th>
<th>Change Rates (%)&lt;sup&gt;1)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICE</td>
<td>MRX&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1995</td>
<td>0.152</td>
<td>0.061</td>
</tr>
<tr>
<td>1996</td>
<td>0.149</td>
<td>0.060</td>
</tr>
<tr>
<td>1997</td>
<td>0.152</td>
<td>0.062</td>
</tr>
<tr>
<td>1998</td>
<td>0.134</td>
<td>0.052</td>
</tr>
<tr>
<td>1999</td>
<td>0.144</td>
<td>0.057</td>
</tr>
<tr>
<td>2000</td>
<td>0.162</td>
<td>0.066</td>
</tr>
<tr>
<td>2001</td>
<td>0.159</td>
<td>0.067</td>
</tr>
<tr>
<td>2002</td>
<td>0.167</td>
<td>0.074</td>
</tr>
<tr>
<td>2003</td>
<td>0.198</td>
<td>0.086</td>
</tr>
<tr>
<td>2004</td>
<td>0.220</td>
<td>0.095</td>
</tr>
<tr>
<td>2005</td>
<td>0.222</td>
<td>0.093</td>
</tr>
<tr>
<td>2006</td>
<td>0.212</td>
<td>0.085</td>
</tr>
<tr>
<td>2007</td>
<td>0.210</td>
<td>0.082</td>
</tr>
<tr>
<td>2008</td>
<td>0.209</td>
<td>0.084</td>
</tr>
<tr>
<td>2009</td>
<td>0.163</td>
<td>0.062</td>
</tr>
<tr>
<td>2010</td>
<td>0.183</td>
<td>0.074</td>
</tr>
<tr>
<td>2011</td>
<td>0.196</td>
<td>0.080</td>
</tr>
<tr>
<td>2012</td>
<td>0.188</td>
<td>0.073</td>
</tr>
<tr>
<td>2013</td>
<td>0.180</td>
<td>0.069</td>
</tr>
<tr>
<td>2014</td>
<td>0.173</td>
<td>0.065</td>
</tr>
<tr>
<td>2015</td>
<td>0.152</td>
<td>0.055</td>
</tr>
<tr>
<td>2016</td>
<td>0.151</td>
<td>0.056</td>
</tr>
<tr>
<td>2017</td>
<td>0.163</td>
<td>0.063</td>
</tr>
<tr>
<td>2018</td>
<td>0.165</td>
<td>0.063</td>
</tr>
</tbody>
</table>

Note: 1) The years in which the signs of the three indicators’ change rates are not identical are shaded in gray.

We investigate the reversals of ICE and MXR<sup>a</sup> in China during the period of 2000-2001 more deeply. Table 5 summarizes the ICE and MXR<sup>a</sup> values and their components in 2000 and 2001, along with the respective change rates in 2001. Recall

\[
\text{ICE} = \frac{o'R^e}{o'e} \quad \text{and} \quad \text{MXR}^a = \frac{o'R^e}{o'R^e}.
\]

Total exports \((o'e)\) of China increased by 4.2% during the period of 2000-01.
TABLE 5—CHANGE RATES OF ICE AND MXR\textsuperscript{a} FOR CHINA IN THE 2001 \textit{o' R\textsuperscript{e}}

(\text{Unit: Million US Dollars})

<table>
<thead>
<tr>
<th>Year</th>
<th>\textit{o' R\textsuperscript{e}}</th>
<th>\textit{o' R\textsuperscript{m} e}</th>
<th>\textit{o' R\textsuperscript{e}}</th>
<th>ICE</th>
<th>MXR\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>237,426</td>
<td>38,542</td>
<td>585,406</td>
<td>0.162</td>
<td>0.066</td>
</tr>
<tr>
<td>2001</td>
<td>247,380</td>
<td>39,422</td>
<td>587,729</td>
<td>0.159</td>
<td>0.067</td>
</tr>
<tr>
<td>Change Rates</td>
<td>4.2%</td>
<td>2.3%</td>
<td>0.4%</td>
<td>-1.8%</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

This increased total imports (\textit{o' R\textsuperscript{m} e}) only by 2.3\%; consequently, ICE decreased by 1.8\%. However, the change rate of the gross output caused by the increase in exports (\textit{o' R\textsuperscript{e}}) was even smaller at only 0.4\%. In other words, the relative utilization of GPN compared to DSC in terms of ‘production’ increased, and MXR\textsuperscript{a} rose by 1.9\%. In conclusion, ICE implies that China’s degree of global integration weakened while MXR\textsuperscript{a} implies that it strengthened.

C. Indicators of Global Integration at the Product/Industry Level

The three indicators of global integration above can be computed at the industry level. While the three indicators for all 25 industries were computed, those of six selected industries are reported here: agricultural, forest and fishery goods; textile and leather products; chemical products; electric and electronic equipment; motor vehicles and trailers; and business services.\textsuperscript{13}

The exports of the six selected products by the eight countries in 2018 are given in Table 6, as are two new indicators, MXR\textsuperscript{a} and MXR\textsuperscript{b}, in Figures 12 and 13, respectively. The charts in Figure 12 show that the industry-level indicators comply with the country-level trends to some extent, while we observe considerable

TABLE 6—EXPORTS OF SIX SELECTED PRODUCTS IN 2018

(\text{Unit: Billion US Dollars})

<table>
<thead>
<tr>
<th>Country</th>
<th>AGRI</th>
<th>TEXT</th>
<th>CHEM</th>
<th>ELEC</th>
<th>AUTO</th>
<th>BUSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>16.5</td>
<td>275.1</td>
<td>219.9</td>
<td>729.2</td>
<td>45.7</td>
<td>104.4</td>
</tr>
<tr>
<td>Germany</td>
<td>7.9</td>
<td>12.9</td>
<td>189.3</td>
<td>139.8</td>
<td>249.9</td>
<td>145.5</td>
</tr>
<tr>
<td>France</td>
<td>16.3</td>
<td>9.5</td>
<td>88.0</td>
<td>45.4</td>
<td>51.2</td>
<td>114.1</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3.4</td>
<td>3.8</td>
<td>41.6</td>
<td>12.3</td>
<td>48.1</td>
<td>260.6</td>
</tr>
<tr>
<td>Italy</td>
<td>6.2</td>
<td>42.4</td>
<td>56.6</td>
<td>35.0</td>
<td>43.4</td>
<td>35.4</td>
</tr>
<tr>
<td>Japan</td>
<td>1.1</td>
<td>4.8</td>
<td>78.1</td>
<td>137.3</td>
<td>156.8</td>
<td>72.0</td>
</tr>
<tr>
<td>Korea</td>
<td>0.9</td>
<td>10.3</td>
<td>86.7</td>
<td>231.6</td>
<td>65.3</td>
<td>30.3</td>
</tr>
<tr>
<td>United States</td>
<td>51.8</td>
<td>10.0</td>
<td>177.1</td>
<td>138.5</td>
<td>104.6</td>
<td>410.7</td>
</tr>
<tr>
<td>Total\textsuperscript{11}</td>
<td>369.0</td>
<td>616.0</td>
<td>1,805.0</td>
<td>2,316.9</td>
<td>1,365.7</td>
<td>2,379.2</td>
</tr>
</tbody>
</table>

Note: 1) Sum of all 66 countries.

\textsuperscript{13}We use the following industry codes in the tables and figures in this paper: agricultural, forest and fishery goods (AGRI, Industry 1); textile and leather products (TEXT, 4); chemical products (CHEM, 7); electric and electronic equipment (ELEC, 11); motor vehicles and trailers (AUTO, 13); and business services (BUSI, 22). The numbers in parentheses are the corresponding industry numbers in the 25-industry classification.
FIGURE 12. MXR* VALUES OF SIX SELECTED INDUSTRIES (HP FILTERED)
FIGURE 13. MXR$^4$ VALUES OF SIX SELECTED INDUSTRIES (HP FILTERED)
variations among industries at the same time. For example, the picture of the world business service market appears substantially different from that of the electronics market. We can also realize, from Figures 12 and 13, that the patterns of the two indicators, $\text{MXR}^a$ and $\text{MXR}^s$, are considerably distinct. Again, this occurs because the two indicators are based on two different measures – amounts and shares, respectively – and that $\text{MXR}^s$ is considered to take into consideration the other final demand terms implicitly.

The inter-country, inter-industry comparisons of the industry-level indicators provide a clearer perspective as to the characteristics of individual countries’ industries in the world market because they contrast the dynamics of global integration among industries vividly. The estimates of $\text{MXR}^a$ and $\text{MXR}^s$ of the six selected industries of the eight countries are given in Figures 14 and 15, respectively. It is interesting to observe that the two indicators appear to provide considerably different implications regarding individual industries’ degrees of global integration. For example, the degree of global integration for business services has remained lower compared to all other selected industries in all eight countries in terms of $\text{MXR}^a$. However, the values of $\text{MXR}^s$ offer contrasting implications due to the difference in the emphasis of the indicators.
Figure 14. MXR\textsuperscript{*} Values of Eight Selected Countries (HP Filtered)
FIGURE 15. MXR^{+} VALUES OF EIGHT SELECTED COUNTRIES (HP FILTERED)
D. Recent Trends in International Trade through the Lens of Global Integration

The global exports/imports market experienced severe turbulence over the past 15 years. World trade experienced a decrease of around 19% in 2009 due to the financial crisis of 2008, and the slow world economy and COVID-19 caused 11% and 9% decreases in 2015 and 2020, respectively. Despite the fact that heightened fluctuations in world trade makes it a challenging task to forecast the future of international trade, it seems reasonable to expect that the intensity of international trade compared to the economic activity of the globe will not strengthen very soon.

As mentioned earlier, world exports as a percentage of the world GDP amounted to only 5.5% in 1950 but exploded to 31.0% in the late 2000s. However, the recent trend gives the impression that the ratio has entered a steady level, or a ‘saturation level’, at about 30% and that it is not reasonable to expect a sizeable increase. This can also be confirmed by the statistics from the OECD IO-DB; total exports as a percentage of GDP rose to 26.5% in 2008 and has stayed in the 24~26% band since then.

The OECD IO-DB presents an important hint as to the relationship between international trade and global integration which cannot be easily obtained without the help of IO tables. Figure 16 shows the share of imported intermediate goods out of total imports by all 66 countries in the OECD IO-DB. The share was 55.6% in 1995 but increased to 62.3% in 2011. It then continually decreased, reaching 58.6% in 2016. Hodrick-Prescott filtering implies a declining trend since the early 2010s. The time-series pattern of the share is strikingly similar to that of the world export/GDP share, and other shares such as the share of total imported intermediate inputs out of total input or out of total intermediate input also reveal very similar patterns. The shares of imported intermediate goods out of total imports by the aforementioned eight countries are given in Figure 17, where we observe declining trends over the past few decades in most countries.
This implies that the decrease in the trade of intermediate inputs has been the main cause of the recent slowdown in international trade. For example, total imports by the 66 countries in the IO-DB decreased from 18,165 to 16,642 billion US$. The decrement was 1,523 billion US$. On the other hand, total imports of intermediate goods decreased from 11,312 to 9,747 billion US$, and the decrement was 1,566 billion US dollars. During the same period, total imports of final goods – consumption and capital goods – increased by 42 billion US$. In consequence, the decrease in total imports was entirely due to the decrease in the imports of intermediate goods, and the imports of final goods even increased, though not by much.\footnote{This was also mentioned in Kim (2023)}

Here, we learned about the role of imported intermediate goods in this study of global integration. In fact, imports of intermediate goods remain at the center of global integration and constitute the gist of the definition of global integration. In this regard, more attention should be directed toward the decline in the share of imported intermediate goods out of total imports rather than toward the slowdown in world trade itself. Also, there is a possibility that the recent decline in the share of imported intermediate goods out of total imports may insinuate a slowdown or even the saturation of global integration. Obviously, it can be too early to reach a conclusion, and further research is thus warranted.

V. Conclusion

ICE is a useful indicator and has considerable advantages. It measures the amount of imported intermediate goods embodied in exported products and thus reflects the degree to which a country or an industry utilizes the GPN measure. However, there are contexts in which measures of global integration based on ‘production’ are more
strongly needed. In this paper, we proposed two new indicators of global integration as alternatives to ICE. Both indicators, termed $\text{MXR}^a$ and $\text{MXR}^s$, are designed to measure the relative degree of the utilization of GPN over DSC and are defined as the ratios of imports (foreign production) to gross output (domestic production) generated by exports. The former uses amounts while the latter uses shares. Both indicators can easily be computed and can be compared between years, between countries, between industries, and between groups of industries. Also, the interpretation of these indicators is straightforward. We applied the two new indicators to the actual IO tables of 66 countries in the 2021 edition of the OECD IO-DB and investigated the trends during the period of 1995-2018 using the indicators computed at country and industry levels.

Three recommendations follow. First, global integration is a complex phenomenon that cannot be easily uncovered and defined by only a few indicators. We can find many years in which different indicators indicate different directions of change, and we can find many countries for which different indicators imply different rankings. For this reason, it is necessary to base research in this area on as many indicators, with much in-depth analysis, as possible.

Second, the global export market has showed considerable fluctuations, especially since the financial crisis of 2008. Hence, the indicators of global integration also reveal strong fluctuations because international trade data is the primary ingredient. For this reason, capturing the mid- and long-term trends of global integration has become increasingly difficult, and it is necessary to adopt a desirable quantitative method to ‘smooth out’ the time series and find the trend.

Third, global integration is a complex phenomenon, and in order to enhance our understanding of it, active empirical studies of the determinants of the degree of global integration would be useful, using as broad a range of indicators as possible. The determinants of the degree of global integration could be categorized into two groups. The first is the group of ‘global’ factors that have a similar impact on most industries in most countries, such as global economic trends, transportation technology, ICT, and the level of piracy, among others. We witnessed that the financial crisis of 2008 presented an enormous shock to almost every indicator in every industry and in every country, and it would be a typical determinant in the first group. The second is the group of country-specific and/or industry-specific factors. The competitiveness of domestic intermediate inputs would be the most important factor in the second group.

Finally, we observed that the slowdown in international trade in recent years was mostly due to the decrease in the international trade of intermediate goods. This has significant implications for the future pattern of global integration, as the international trade of intermediate goods plays a crucial role in this process. Thus, comprehensive research and investigations can be expected in this field.
APPENDIX

Proof of  $\text{ICE} + \text{VCE} = 1$ and $\text{ICE}_i + \text{VCE}_i = 1$ for all $i = 1, 2, \ldots, n$.

We have $\text{ICE}_i = [a^i]'R^m_i$ and $\text{VCE}_i = [a^i]'R^v_i$, where $[a^i]_j$ is the $i$th element of a vector $a$. Thus it suffices to show $[a^i]'R^m_i + [a^i]'R^v_i = [a^i]'$ to prove $\text{ICE}_i + \text{VCE}_i = 1$ for all $i = 1, 2, \ldots, n$. Note that $\text{ICE} + \text{VCE} = 1$ follows from $\text{ICE}_i + \text{VCE}_i = 1$.

Considering that total input consists of domestic intermediate input, imported intermediate input, and value-added, we have $[a^i]'\omega^d + [a^i]'\omega^m + [a^i]'\omega^v = [a^i]'\omega^i$.\(^{15}\) Then, $[a^i]'R^m + [a^i]'R^v$ becomes

$$[a^i]'R^m + [a^i]'R^v = [a^i]'\omega^m (I - \omega^d)^{-1} + [a^i]'\omega^v (I - \omega^d)^{-1}$$

$$= ([a^i]'\omega^m + [a^i]'\omega^v)(I - \omega^d)^{-1}$$

$$= ([a^i]'\omega^m + [a^i]'\omega^v)(I - \omega^d)^{-1} \quad \because \quad [a^i]'\omega^m + [a^i]'\omega^v = [a^i]'\omega^i$$

$$= [a^i]'(I - \omega^d)(I - \omega^d)^{-1}$$

$$= [a^i]' \quad \Box$$

\(^{15}\)This does not imply that $\omega^d + \omega^m + \omega^v = I$.  

REFERENCES


LITERATURE IN KOREAN