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Does Blockchain Technology Promote the Quality of Enterprise Accounting Information?

Chun Wu[a], Shanyue Jin[b]*

[a]*Department of Accounting, Jiangsu Vocational College of Finance and Economics, China*
[b]*College of Business, Gachon University, South Korea*

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ABSTRACT

Purpose – A crucial technology of the information society, blockchain technology has been introduced to more and more companies because blockchain technology can improve operation efficiency. This study aims to find how to apply blockchain technology to improve the quality of accounting information, so as to help investors better understand the company.

Design/Methodology/Approach – This study conducts a fixed-effect regression analysis on the data of Chinese A-share listed companies from 2010 to 2019 to examine whether blockchain technology impacts the quality of accounting information.

Findings – The empirical results show that investment in blockchain technology indeed positively affects the quality of enterprise accounting information. Furthermore, we found that the greater the attention of analysts, the higher the degree to which blockchain technology improves the quality of accounting information. Also, when the company has a stronger innovation ability, there is a higher degree to which blockchain technology improves the quality of accounting information.

Research Implications – This study enriches the relevant research of the impact of blockchain technology on enterprise accounting information quality. It suggests that companies devoted to blockchain technology can promote trust between all parties and improve information transparency. Meanwhile, companies should increase R&D investment so that blockchain can effectively improve the quality of accounting information.

Keywords: accounting information quality, analyst attention, blockchain technology, enterprise innovation
JEL Classifications: O16, O32, O38

* *Corresponding Author, E-mail: jsyrena0923@gachon.ac.kr*

I. Introduction

With the development of information technology, blockchain technology has been given serious consideration and is regarded as "the most important invention since the Internet". The term "blockchain" first appeared in Nakamoto (2008). With decentralized intelligent contract and asymmetric encryption technology, blockchain ensures high transparency, high security, and credibility of information, and has a broad application prospect in the digital economy era (Nguyen, 2016).

Blockchain has been a concern for the governments of Britain, the United States, Russia, Canada, China, and other countries. In 2016, the British government released an important report, *"Distributed Ledger Technology: Beyond Blockchain,"* which included blockchain in the national strategic deployment and formulated a detailed strategic implementation plan. In February 2018, the US House of Representatives held two consecutive blockchain hearings to discuss new applications of blockchain technology. The US State Department emphasized that improving transparency through blockchain technology could solve the problems of corruption, fraud, or misappropriation of public procurement funds. Russia vigorously promotes the infrastructure construction of blockchain. Sberbank, the largest bank in Russia, cooperates with the government to transfer and save documents with blockchain, a real application case of blockchain. In Canada, a huge blockchain startup community brings together several top blockchain talents, including Vitalik Buterin, founder of Ethereum (Sun et al., 2018). China has also placed blockchain technology in an important strategic position in t*he 13th Five-Year National Informatization Plan* in 2016. In 2019, the meeting of the Political Bureau of the Central Committee once again stressed the need to increase investment in the research and development of blockchain technology and use it to promote a new technological revolution and industrial innovation and development.

Several Fortune 500 companies are also developing and investing in blockchain. JPMorgan Chase, New York Stock Exchange, and Standard Chartered Bank are testing blockchain technology to replace paper and manual transaction processing in trade finance, foreign exchange, cross-border settlement, and securities (Guo & Liang, 2016). Deloitte established an exclusive blockchain laboratory on Wall Street dedicated to the research and development of blockchain-based financial solutions, audit compliance solutions, and asset mortgage applications (Ream et al., 2016). In addition, several Chinese banks and other financial institutions have launched blockchain accounts receivable financing platforms. Industrial and Commercial Bank of China, Bank of China, Shanghai Pudong Development Bank, Du Xiaoman, and Ant Financial have already realized the application of blockchain technology in bill business scenarios and have achieved certain results. Furthermore, China's Internet giant Tencent has application solutions in seven fields: supply chain finance, trusted deposit certificate, electronic bill, data elements, identity management, supply chain management, and digital assets.

Studies on blockchain have gradually increased since 2016, mainly focusing on the financial field, supply chain management, medical field, security traceability, authentication, and the integration and application of other technologies.

The research on blockchain technology in accounting and finance mainly focuses on the remodeling of double-entry bookkeeping, the reform of audit mode, and the interconnection of financial data. Lazanis (2015) analyzed peer-to-peer transactions, automatic settlement, and the updating of account books on the blockchain network; he believed that capital payments could be made through the blockchain network, thus reducing the commission fee across the settlement intermediary. Furthermore, if the digital currency of the blockchain network itself is used for peer-to-peer payment, intermediate costs will be significantly reduced, greatly simplifying the transaction process and reducing the financial operation cost. Hanson (2016) found that a blockchain audit system of would reshape the accounting ecology. The blockchain

information writing process automatically audits accounting transactions, reviews, confirmations, bookkeeping, and other behaviors. Participants jointly confirm whether the accounts are true and complete, thus reducing fraud and meeting stakeholder data accuracy and authenticity requirements. Arvind et al. (2016) mainly focused on the workflow of Bitcoin when using blockchain technology. However, they also studied its underlying applications. The rational application of blockchain technology could promote the long-term development of commercial banks.

In supply chain management, Chris (2016) highlighted that blockchain could make information traceable, and buyers can find upstream suppliers through traceability information, thus making transactions more credible and improving the trust of both parties. Adoma (2018) believed that the emergence of blockchain technology changed the transmission object of internet technology. In the past, it was the transmission of traditional information, but now the transmission of value is the main goal of the Internet, which plays a great role in people's daily routine. Adoma (2018) analyzed the supply chain industry and believed that only by improving the transparency of the supply chain industry can the existing development model be broken. Therefore, it was suggested that blockchain technology should be introduced into the development of supply chain finance.

During integration and application with other technologies, blockchain can promote information sharing, improve trust levels, reduce transaction costs, promote collaboration among enterprises, improve operational agility, improve performance, and promote high-quality development of the real economy (Shahab, 2020). Blockchain technology has great potential in enterprise operations. It communicates in real-time, establishing trust relationships between partners, speeding up payment processing with fewer transaction costs, reducing product costs, shortening delivery time, enhancing product safety, and improving product quality (Ada et al., 2021). However, some scholars believe that the initial investment cost of blockchain is high, and the realization of a consensus mechanism may reduce the speed of information confirmation (Jonathan & Koeppl, 2019). The advantage of blockchain technology is that it can reduce transaction fraud risk while reducing transaction costs (Jonathan & Koeppl, 2019), especially counterparty risk (Kiviat, 2015). It can also save audit time and improve efficiency by comparing corresponding accounting entries with the account books of each counterparty (Fanning and Centers, 2016), and enhance the effectiveness of monitoring and the observability of transactions.

The application of blockchain is in the exploratory stage, and there is little research on whether the use of blockchain technology is more advantageous than traditional information systems. Therefore, this study aims to confirm through empirical analysis whether blockchain technology impacts the quality of accounting information, and judge whether blockchain investment motivation is conceptual hype or effective for enterprise innovation.

The empirical analysis proves that blockchain technology can improve the quality of accounting information and enrich related research. However, this study provides a theoretical basis for enterprises to use blockchain.

II. Theoretical Background

1. The Concept of Blockchain Technology

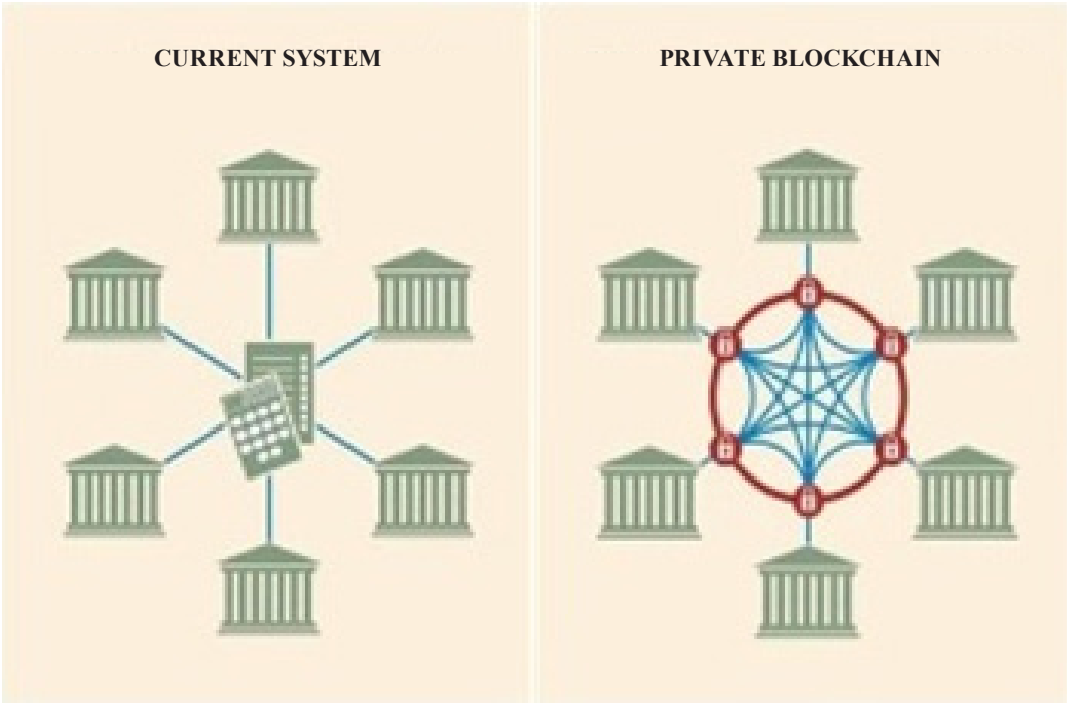
Since 2008, Satoshi Nakamoto wrote an article entitled "Bitcoin: A peer-to-peer electronic cash system", in which the concept of blockchain was first mentioned. As digital currency such as bitcoin gradually became popular, blockchain technology also spread widely. Blockchain is a chain data structure that combines data blocks in a sequential manner according to time sequence, and is a cryptographically guaranteed non-tamperable and non-forgerable distributed ledger. Swan (2015) proposed that the essence of blockchain should be a database, and the database of blockchain should be non-centralized, open, and transparent.

One of the main features of blockchain is

"decentralization", and the transaction information stored on each node is comprehensive. In this way, even if the information on one of the nodes is attacked, other nodes still have related records to ensure the integrity and security of network information. At the same time, because the entire network shares the same ledger, the goal of preventing double-spending is also realized.

As shown in Fig. 1, in a traditional currency system, information is stored in the central server, each node needs to read and write data from the central server, and the authenticity of the information completely depends on the central server. Through the establishment of a private blockchain, information is broadcast among various institutions, and the data is recorded in the entire chain after being confirmed by all, and the entire network is recorded after the transaction is completed. It is a reliable distributed database.

Fig. 1. Current System and Private Blockchain



Source: Brennan and Lunn (2016).

2. Information Asymmetry Theory

In the 1970s, scholars proposed the theory of information asymmetry (Akerlof, 1970; Alchian & Demsetz, 1972). According to the information asymmetry theory, the seller and the buyer have different levels of transaction information in a market economy. Therefore, the buyer receives less information; that is, the buyer is in a disadvantaged position and is willing to pay a certain price to get more information. In this process, the seller benefits. Nevertheless, problems caused by information asymmetry will diminish because buyers and sellers can receive some signals in the market economy.

Information asymmetry theory lays a theoretical

foundation for the formation and development of Bitcoin, a typical blockchain application. As blockchain can improve company efficiency and reduce costs, it is a financial tool that may play an important role in the sustainable development of the global economy (Broby & Karkkainen, 2016). With decentralized credit, blockchain ensures high transparency, high security, and credibility of information, and eliminates information asymmetry in the transaction process.

Information asymmetry can lead to adverse selection and moral hazard, and the research of this theory is further extended to the field of accounting. When company management records accounting information, it tends to whitewash its financial performance through earnings management, which affects the quality of accounting information. Blockchain technology records information into the blockchain through the function of distributed accounting, and improves the reliability of information by recording the credits of transaction entities in different nodes, helping to alleviate information asymmetry. In addition, there is no need for intermediaries to intervene when conducting transactions, which reduces transaction costs. Therefore, blockchain is a new technology that promotes the solution of information asymmetry.

3. Synergetics Theory

Haken (1977) proposed synergetics theory. He believed that although different systems have different attributes, there are mutual influences and cooperative relationships among them in the whole environment. The main point of synergetics theory is that the system changes from disorder to order, and the original organizational structure is constantly improved to achieve a harmonious relationship. Finally, there is the most system state (Kröger, 2015).

Synergetics theory states that the synergetic development of various subsystems or components determines whether a system can exert an interaction effect. For example, if subsystems such as people, organizations, and environment are managed effectively and work together around a goal, a synergetic effect of 1+1>2 can be produced. On the contrary, if a management system has internal conflicts, the friction of the whole management system will increase. Therefore, each subsystem will find it difficult to play its due function, resulting in the entire system being in a chaotic state.

An accounting information system based on blockchain technology can, to a great extent, guarantee the synergy of accounting information (Sheel & Nath, 2019). Every computer connected to the blockchain network system is the bookkeeper in the bookkeeping system, and they are responsible for recording transaction data in data blocks. Timestamps will connect each block in order, and every client must store and process information data according to rules (Tan & Low, 2019). Furthermore, accounting information is processed through a consensus mechanism, and it will not crash because of the failure of a single client. At the same time, it will not be paralyzed when the data center is under attack (Xue et al., 2020). Therefore, the blockchain network is a stable and effective synergetic system.

III. Research Hypothesis

1. Impact of Blockchain Technology on the Quality of Accounting Information

A blockchain network is a credibility system that cannot be tampered with. Moreover, the characteristics of a distributed bookkeeping system keep the information of each participant in the chain unchanged in the synchronization process (Liao, 2021), ensuring that enterprises can share a synergetic information system. However, the data stored in the blockchain cannot be modified, guaranteeing the authenticity and integrity of accounting information quality (Cong & He, 2019).

Blockchain technology can significantly impact the quality of accounting information as, firstly, it can promote trust between the trading parties and reduce opportunistic behaviors, especially when there is a lack of trust among participants. Based on the permanent tracking and unchangeable

characteristics of blockchain, the transaction behaviors of all participants will be recorded permanently, accessed, and tracked by blockchain members at any time. Blockchain members will thus constrain their behaviors. In addition, enterprises can also utilize smart contracts to write contract content into the system (Hu et al., 2021). For instance, after the supplier's products are delivered, the customer automatically makes the payment at the specified time. Furthermore, the parties automatically pay the liquidated damages according to the contract, thus reducing the time and cost of dispute settlement. Consequently, blockchain technology is used to upgrade the intelligence level and improve the effectiveness and timeliness of accounting information.

Secondly, Blockchain can increase synergy between businesses. The original process of information transmission among suppliers, enterprises, and customers is difficult, and enterprises are reluctant to set up information systems to share data. Blockchain enables only authorized individuals to see the complete information through the distributed ledger and encryption technology. Under the development of blockchain technology, information can be transmitted accurately and quickly, accelerating the synergy effect between enterprises. The blockchain network is a stable and effective synergetic system, and the direct transmission of data improves the authenticity of accounting information.

In addition, blockchain technology can facilitate data sharing and make the product transaction and circulation process more transparent and traceable. It enables enterprises to check the product price, transaction date, location, quality, authentication materials, customs documents, lading bills, and other logistics in real-time. Therefore, the coordination and planning of goods flow and documents benefit the supply chain, avoid repeated operations in the supply chain because of information asymmetry, and enhance the accuracy of accounting information (Wu et al., 2020). Furthermore, problems with goods or funds in the transaction process need not be confirmed with upstream and downstream enterprises. Instead, it can be checked forthrightly through the blockchain information system, which reduces the cost of communication and dispute handling. Finally, blockchain technology reduces manual data entry and has the characteristics of non-tampering, reducing human error and manipulation.

Based on the above analysis, this study proposes the research hypothesis below.

H1: Investment in blockchain technology improves the quality of enterprise accounting information.

2. Impact of Analyst Attention to the Quality of Accounting Information in the Context of Blockchain

As an important information intermediary in the capital market, analyst participation in the market is essentially an all-around intervention in information collection, processing, and dissemination to alleviate information asymmetry (Wu et al., 2020). External media organizations, such as analyst research reports, weaken information asymmetry (Amiram et al., 2016). Hansen (2015) found that media attention has a strong governance effect, raising the quality of accounting information by restraining earnings management. Mcnichols (2002) surveyed the impacts of listed companies' information disclosure policies on the number and quality of analyst forecasts, and discovered that the more transparent the company's information disclosure, the more analysts follow up, the more accurate the earnings forecast, and the smaller the divergence.

Meanwhile, investors worry about analyst earnings forecasts. If the company's earnings reach analyst forecasts, investor expectations for the company's future development are heightened, and the company's market value increases in excess (Dai & Vasarhelyi, 2017). Compared with companies with specialized operations, blockchain companies usually have a high-tech threshold for new technologies. The information asymmetry of emerging industries, such as blockchain, is greater than in ordinary industries. The improvement of science and technology makes it harder to receive

information, allowing managers to manipulate hot concepts for earnings management (Useche, 2014).

With investments in blockchain technology, the tamper-proof function of blockchain and the improvement of information disclosure reduce the functional space of earnings management (Cheynel & Levine, 2020). In addition, the technical features of blockchain can alleviate the motivation of conceptual speculation to a certain extent.

Based on the above analysis, this study proposes the research hypothesis below.

H2: The more the attention of analysts obtained by enterprises, the higher the degree blockchain technology will improve the quality of accounting information.

3. Impact of Technological Innovation on the Quality of Accounting Information in the Context of Blockchain

Blockchain technology innovation facilitates the transformation of the management mode of enterprises. In addition, modern information technology supports blockchain technology, integrating financial accounting, management accounting, and informatization in business activities. Secinaro et al. (2021) studied the distributed bookkeeping mode of blockchain accounting information systems and future trends based on the analysis framework in finance and accounting. They considered that blockchain technology could be used to curb accounting fraud and realize accounting transformation. Furthermore, the data on the blockchain is verified and agreed upon by most nodes without central authorization, greatly reducing the transaction cost caused by information asymmetry.

The innovation of blockchain technology promotes enterprise technology research and development. Disclosure of blockchain technology innovation information provides important information for investors to understand the achievements of innovation activities and the future development direction of enterprises (Yu et al., 2018). Management signals its development plans and strong position in the industry to investors by disclosing innovation information in the annual report. This improves investor confidence, encourages enthusiasm for innovation activities (Simpson & Tamayo, 2020), and stabilizes or pursues long-term stable competitive advantages, promoting innovation.

The technical characteristics of blockchain promote accurate accounting information. The decentralization of blockchain ensures that accounting information is no longer provided by central management organizations (Simpson & Tamayo, 2020). This makes accounting data more authentic and reliable, greatly reduces the internal control of enterprises, reduces labor costs, and curbs the risk of management fraud to the greatest extent. Furthermore, the supplier and customer can view the material turnover and payment situation of the whole supply chain, reduce the decision-making mistakes caused by opaque earnings information, and improve trust between enterprises (Lumineau et al., 2021). Therefore, blockchain plays a stronger role in promoting accounting information quality for companies with strong innovation abilities.

Based on the above analysis, this study proposes the research hypothesis below.

H3: The stronger the innovation ability of enterprises, the higher the degree blockchain technology will improve the quality of accounting information.

IV. Research Design

1. Data Sources

Chinese listed companies from 2010 to 2019 were selected for research. Data, such as finance and corporate governance, were obtained from the China Stock Market & Accounting Research Database (CSMAR).Whether an enterprise uses blockchain technology is obtained from its annual report. The data are processed as follows: (1) financial enterprises are excluded; (2) the samples of companies with ST are excluded; (3) irrelevant

industries are eliminated; and (4) control variables are winsorized at 1% ~ 99% to reduce the errors caused by outliers.

2. Design of Variables

2.1. Blockchain Indicators

The Python language is used to write programs to extract word frequency from the annual reports of listed companies. As blockchain technology has only been popularized in recent years, the frequency of blockchain keywords mentioned in the annual reports of listed companies was less before 2016. As the forerunner of blockchain technology, big data and blockchain can complement each other and have the same 5V characteristics (Volume, Variety, Velocity, Veracity, and Value) (Hassani et al., 2018; Wamba et al., 2015). This study selects keywords such as blockchain and big data, and takes the logarithm according to word frequency plus one as the blockchain index. The financial industry, special treatment companies, and some unrelated industries are excluded, and companies without keywords are marked as 0.

2.2. Quality of Accounting Information

Management fraud is the main cause of accounting information distortion. The most basic motivation of earnings management by insiders is to gain controlling rights for personal gain (Jiraporn et al., 2008), such as achieving performance goals, increasing on-the-job consumption, and building an enterprise empire to obtain salary incentives (Laux & Laux, 2009). The personal benefits realized through earnings management can make relevant institutions or individuals misjudge and misprice the performance of enterprises (Duong & Pescetto, 2018). Therefore, it is reasonable to measure the quality of accounting information by the degree of earnings management.

The revised Jones model proposed by Dechow et al. (1995) is used to measure accrued earnings management and the quality of accounting information. The model is as follows:

$$\frac{TA_{i,t-1}}{A_{i,t-1}} = \beta_0 \frac{1}{A_{i,t-1}} + \beta_1 \frac{\Delta REV_{i,t}}{A_{i,t-1}} + \beta_2 \left(\frac{PPE_{i,t}}{A_{i,t-1}}\right) + \epsilon_{i,t} \tag{1}$$

$$NDA_{i,t} = \hat{\beta}_0 \frac{1}{A_{i,t-1}} + \hat{\beta}_1 \frac{\Delta REV_{i,t} - \Delta REC_{i,t}}{A_{i,t-1}} + \hat{\beta}_2 \left(\frac{PPE_{i,t}}{A_{i,t-1}}\right) \tag{2}$$

$$DA_{i,t} = \frac{TA_{i,t}}{A_{i,t-1}} - NDA_{I,T} \tag{3}$$

TA: Total accrued profit = operating profit minus net cash flow from operating activities;
NDA: Non-discretionary accrued profits;
DA: Controlling accrued profits, the greater the absolute value, the greater the space for earnings management, and the lower the quality of accounting information;
$\triangle REV_t$: Change in operating income;
$\triangle REC_t$: Change in accounts receivable;
PPE_T: Net fixed assets of *T* period;
A_{t-1}: Eliminate scale effect and use the total assets at the end of the *t-1* year.

In Formula (1), regression is carried out by industry and year, and the regression coefficient is brought into Formula (2) to get the uncontrollable accrued profit *NDA,* and then brought into Formula (3) to get the modified controllable accrued profit *DA*. The prefix code of "C" in the manufacturing industry takes two digits, and that in other sectors take one digit to classify the industries. We exclude samples with less than ten samples and missing related data.

Referring to Kothari et al. (2002), this study revises the Jones earnings management model and considers the absolute value of discretionary accrued (*DA*) profit as the absolute value. For the convenience of analysis, the index is multiplied by -1 to take a negative value. The greater the value of *DA*, the higher the quality of accounting information.

2.3. Analyst Attention

Securities analyst concerns for enterprises mainly manifests in collecting market information and writing analysis reports through field research. The types of analysis include strategy, M&A, research, rating, and profit forecast. Based on existing literature, the measurement indicators that analysts are concerned about are (1) the number of analysts who issue profit forecast reports to target enterprises (He & Tian, 2013); (2) the number of profit forecast reports issued by analysts; and (3) set dummy variables according to whether the number of people tracked by analysts reaches a certain level. This study mainly uses the number of analysts that make profit forecasts for the enterprise each year, and takes the natural logarithm as the proxy variable of analyst attention.

2.4. Enterprise Innovation

According to existing literature, the measurement indicators of enterprise innovation are (1) R&D expenditure, (2) number of R&D personnel, (3) number of new product development and sales revenue, and (4) patent applications, the number of grants, and frequency of citations (Cornaggia et al., 2015). The first two indicators focus on measuring the innovation input, while the last two focus on measuring the innovation output of enterprises. As patent activity can measure the effectiveness of enterprise innovation investment, it is considered a better proxy variable for innovation activities. Using patents to measure enterprise innovation capability has become a standard in the innovation research literature (He & Tian, 2013). Therefore, this study uses the number of patent applications, the sum of invention patent, utility model patent, and design patent, plus 1, to take the natural logarithm to measure enterprise innovation.

2.5. Control Variables

Following the existing literature, this study adopts the company size (Cohen & Klepper, 1996), nature of property rights (Cohen & Klepper, 1996), asset-liability ratio (Chaney et al., 2010), income growth rate (Hribar & Nichols, 2007), and free cash flow (Hribar & Nichols, 2007).

Table 1 shows the research variables.

3. Research Model

This study adopts a fixed-effect model and Model 4 to test Hypothesis 1 using the Hausman Test. If β_0 is greater than 0, it means that the investment in blockchain technology improves the quality of enterprise accounting information, which implies that Hypothesis 1 is established.

$$DA_{i,t} = \beta_0 BlockChain_{it} + \beta_1 Control_{it} + \Sigma\, YEAR + \Sigma\, INDUS + e_{it} \quad (4)$$

Model 5 is used to test Hypothesis 2. If β_2 is greater than 0, it means that the more the attention of analysts obtained by enterprises, the higher the degree of blockchain technology to improve the quality of accounting information; that is, Hypothesis 2 is true.

$$DA_{i,t} = \beta_0 BlockChain_{it} + \beta_1 Attention_{it} + \beta_2 BlockChain \times Attention_{it} + \beta_2 Control_{it} + \Sigma\, YEAR + \Sigma\, INDUS + e_{it} \quad (5)$$

Table 1. Research Variables

Variable		Definition
Independent Variable	DA	The modified JONES model calculates the DA value of discretionary accrued profit, and the absolute value is multiplied by -1 to take the negative value. Taking the negative value indicates that the greater the DA value, the higher the quality of accounting information.
Dependent Variable	BlockChain	Annual reports of listed companies extract word frequency and select the keywords most related to blockchain: blockchain and big data. Then, 1 is added to take the logarithm according to word frequency.
	Innovation	For enterprises to innovate, the number of patents applied by listed companies in the year increases by 1 to take the logarithm.
	Attention	Within one year, how many analysts (teams) have conducted follow-up analysis on the company, and the number of one team is 1, so the calculated number of its members is not listed separately. Instead, add 1 to it and take the logarithm.
Control Variable	Size	Company size is the natural logarithm of total assets at the end of the year.
	Lev	Asset-liability ratio, total liabilities divided by total assets at the end of the year.
	SOE	For the state-owned holding company, it is 1. Otherwise, it is 0.
	CashFlow	Cash flow, operating cash flow divided by total assets
	Growth	Growth, sales profit growth rate

This study sets Model 6 to test Hypothesis 3. If β_2 is greater than 0, it implies that the stronger the innovation ability of enterprises, the higher the degree of blockchain technology to improve the quality of accounting information; Hypothesis 3 holds.

$$DA_{i,t} = \beta_0 BlockChain_{it} + \beta_1 Inno_{it} + \beta_2 BlockChain \times Innovation_{it} + \beta_2 Control_{it} + \Sigma\, YEAR + \Sigma\, INDUS + e_{it} \quad (6)$$

V. Empirical Results and Analysis

1. Descriptive Statistics

Table 2 reports the descriptive statistical results of the main variables. The sample earnings management coefficient is between -6.3338 and 0, and the higher the value, the lower the degree of earnings management. There are 75 analysts (teams) in the company with the most attention from analysts who have followed the company, and the logarithmic average number of R&D innovation patents is 0.9504. In terms of control variables, the average asset-liability ratio is 41.99%, the average proportion of operating cash flow to total assets is 4.3%, the average growth rate of main business income is 18.61%, and 6,989 state-owned enterprises are in panel data, accounting for 34.86%.

Table 2. Descriptive Statistics of Main Variables

Variable	Obs	Mean	Std.Dev.	Min	Max
DA	20,049	-0.0785	0.1558	-6.3338	0.0000
BlockChain	20,049	0.1344	0.4434	0.0000	5.0626
Attention	20,049	1.4802	1.1735	0.0000	4.3307
Innovation	20,049	0.9504	0.7901	0.0000	4.3034
State	20,049	0.3486	0.4765	0.0000	1.0000
Lev	20,049	0.4199	0.2041	0.0534	0.9010
Size	20,049	22.0768	1.2196	19.7810	26.1201
Cash flow	20,049	0.0433	0.0685	-0.1792	0.2373
Growth	20,049	0.1861	0.4225	-0.5682	2.8849

2. Results of Empirical Analysis

Hypothesis 1 was tested by regression, and the results are shown in Table 3 (4). The quality of accounting information using blockchain technology is higher, and blockchain can positively influence the business activities of enterprises; that is, Hypothesis 1 is established. However, the use of blockchain enhances the operational efficiency of enterprises, increases the transparency of information of all parties in the supply chain, and the data cannot be tampered with, making it challenging when implementing earnings management.

Table 3 (5) shows the result of regression analysis on Hypothesis 2. Therefore, the interaction coefficient between blockchain investment and analyst attention is 0.0042, which is significant. This indicates that blockchain technology investment alleviates concept hype, investments improve the informatization level, and promotes the quality of accounting information, supporting Hypothesis 2.

Table 3 (6) presents the result of regression analysis on Hypothesis 3. The interaction coefficient between blockchain investment and innovation is 0.0041, which is significant. It indicates that with strong innovation, blockchain technology can be better integrated into management, trust between enterprises can be improved through technical means, and the information transparency of enterprises can be improved. That is, Hypothesis 3 holds.

VI. Research Conclusions and Policy Recommendations

In this study, we use the data of listed companies in China from 2010 to 2019 to examine whether blockchain technology improves the quality of accounting information in practical applications. The following conclusions are found through inspection. (1) The use of blockchain technology promotes trust among all parties, restrains opportunistic behaviors, and improves information transparency and the quality of accounting information. (2) For firms with high analyst attention, blockchain technology can alleviate

Table 3. Results of Regression Analysis

Variable	(4) DA	(5) DA	(6) DA
BlockChain	0.0036* (1.7955)	-0.0033 (-1.0608)	-0.0004 (-0.1432)
Attention		-0.0031*** (-2.8378)	
BlockChain×Attention		0.0042*** (2.8506)	
Innovation			0.0063*** (3.4501)
BlockChain×Innovation			0.0041* (1.9121)
State	0.0127*** (5.2406)	0.0118*** (4.9170)	0.0127*** (5.2324)
Lev	-0.0354*** (-5.5814)	-0.0386*** (-6.0189)	-0.0339*** (-5.3064)
Size	0.0058*** (4.8462)	0.0072 (5.6335)	0.0041*** (3.0836)
Cash flow	0.2705*** (10.1457)	0.2773*** (10.1095)	0.2671*** (10.1342)
Growth	-0.0341*** (-4.9761)	-0.0335*** (-4.8721)	-0.0341*** (-4.9755)
Constant	-0.2012*** (-8.2658)	-0.2266*** (-8.7676)	-0.1701*** (-6.4522)
Observations	20,049	20,049	20,049
Adjusted R-squared	0.0959	0.0962	0.0965

concept manipulation behaviors, and its integration can further build the quality of accounting information. (3) For enterprises with strong innovation ability, blockchain technology has a better effect on improving the quality of accounting information.

This study has two policy suggestions. First, the enterprise can consider using blockchain technology in supply chain management, strengthen investments in information software, and use blockchain to manage the whole supply chain. Blockchain technology adopts a distributed ledger, enabling the enterprise to view the information of the entire supply chain in real-time. Asymmetric encryption technology must be adopted for

important data, and only authorized parties can see the complete information, thus realizing the combination of openness and confidentiality. However, members of the supply chain change at any time, and the blockchain platform can easily include and remove group members to realize dynamic adjustment. Second, enterprises with weak innovation ability can strengthen investment in R&D and actively invest in the blockchain platform. Existing platform service providers must be selected to reduce the R&D cost of enterprises for establishing a blockchain platform. This technology is applied by introducing blockchain technology to traditional enterprises, changing the business model, and placing the transaction data on the blockchain for preservation and circulation.

The following are the limitations of this research. First, as the research and products of blockchain technology are still in the primary stage, application scenarios, technical features, and practical values are still developing. Second, as investment in blockchain technology is non-quantifiable information, the current text analysis and natural language recognition cannot grasp the annual reports of listed companies. Therefore, a certain deviation exists between calculating blockchain investment, the frequency of yearly reports, and the actual situation. Furthermore, the theory and technology of blockchain are still in the process of rapid development, and many new problems exist in its popularization in various social fields. Therefore, the research results of this study need to be further improved based on the further development of blockchain technology.

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Dynamic Association among Economic Growth, Oil Prices, and Key Macroeconomic Factors: Evidence from the US and Korea*

Il-Hyun Yoon[a], Yong-Min Kim[b]**

[a]*Division of Global Business Administration, Dongseo University, South Korea*
[b]*Department of Social Education, Busan National University of Education, South Korea*

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ABSTRACT

Purpose – This study aims to investigate how economic growth responds to oil price volatility and key macroeconomic factors, such as interest rate, inflation and unemployment rate in two big oil consumers and importers in the world, the US and Korea.

Design/Methodology/Approach – This study used quarterly time-series data of each variable for the period 1990 to 2022, consisting of two sub-periods, to employ ARDL (autoregressive distributed lag) method and the Granger causality test in order to identify the role of the movement of oil prices and key macroeconomic factors in national economic growth in the US and Korea.

Findings – The results show that economic growth is correlated with interest rate, CPI, and unemployment rate in the US and Korea, with no significant relationship between economic growth and crude oil price shocks for both the pre- and post-GFC periods in the two countries. For the long-run and short-run effects among variables based upon the ARDL model estimation, there exists a long-run impact of past CPI value on the Korea's economic growth in the pre-GFC period and, in the post-GFC, various variables affect economic growth in the US and Korea. In the short run, there is no evidence of an oil price shock effect on national economic growth in the US and Korea.

Research Implications – The findings confirmed that the impact of oil price shocks on the national economic performance has weakened. This study has significant implications for policymakers attempting to address the effects of oil price shocks in their economies. Policymakers need to focus on the relatively manageable economic variables for sustainable economic growth rather than oil price changes. It is also suggested that oil price as a production cost and policy-manageable macroeconomic variables that have been used as growth strategies have limitations in using them any longer because the expansion of potential growth through reform or innovation is believed to be the source of economic growth.

Keywords: ARDL model, economic growth, granger causality test, oil price shocks
JEL Classifications: C22, C32, E37

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*** Corresponding Author, E-mail: kymin@bnue.ac.kr.*

I. Introduction

Recent fluctuations in crude oil prices have been dramatic in the wake of COVID-19 and the conflict between Russia and Ukraine. Since the COVID-19 pandemic started in late December 2019, the global oil price plummeted to as low as below $10 per barrel on April 21, 2020 from around U$60 in December, the price before the Covid-19, thanks to the negative world economic outlook. However, due to the outbreak of the war between Russia and Ukraine, the oil price went up to much higher than what it was before the outbreak of coronavirus. The price of crude oil hit $139 per barrel at one point on March 7, its highest point since 2012.

Oil has been the driving force of worldwide economic growth, though its importance as an energy source has weakened due to the development of the alternative energy such as biomass energy, hydroelectric energy, solar energy, wind energy, and others. (Yoon & Kim, 2015). Consequently, oil price is critical information in economic terms (Kang, 2014).

Recent oil price volatility in the wake of the COVID-19 pandemic and the Russian invasion into Ukraine directed attention to the impact of oil price fluctuations on the economy. The impact of oil price shocks on the economy has become a key issue in the literature since the energy crises in 1970s.

Theoretically, rising oil price leads to inflation, reducing the quantity of real balances in the system and eventually causing lower output growth (Ferderer, 1996). A higher oil price also reallocates income between importers and exporters of net crude oil, giving rise to lower aggregate demand (Cunado & Perez de Gracia, 2003). In empirical studies, the relation between oil price and economic growth has been widely examined, and some impacts of the oil price fluctuations on economic growth have been identified. However, there exist differences between the expected effects predicted by theoretical models and the observed effects during the crisis of 1970's. Empirical studies are discussed in the following section.

The impact of oil price shocks on the economy is believed to be asymmetric in oil importers and oil exporters because an oil price rise is considered to be favorable for oil exporters and detrimental for oil importers, and vice versa. In 2021, the biggest oil importing country in the world is China, followed by the US, India, Korea, and Japan, while the biggest oil exporter is Saudi Arabia, followed by Russia, Canada, Iraq, the UAE, and the US. The US is ranked the biggest oil consumer with a consumption of 20.3% of world oil, and Korea is the 8th biggest consumer accounting for 2.7% of the world's consumption of oil (Workman, n.d.).

It is necessary to examine the role of the changes in key macroeconomic variables, as well as oil price shocks, on the national economic growth since the economic growth in a nation is not affected by a single factor, evidenced by the aforementioned previous studies on US data. There have been relatively fewer studies carried out on the Korean issue. There have been few studies on how economic growth in Korea responds to oil price shocks and other macroeconomic variable changes. In similar studies, Kang (2014) investigated that WTI (West Texas Intermediate) crude oil price shocks affect Korea's macroeconomic variables, including interest rate, inflation, Industrial Production Index, and exchange rate employing a Vector Autoregression (VAR) method for the period 2000-2015 to find that before the 1998 Asian financial crisis, oil price shocks had an insignificant impact on the Korean macroeconomic factors while, after the crisis, oil price positively affected interest rate and inflation, indicating that a higher oil price leads to a higher interest rate and inflation. Using the monthly data series of oil price, interest rate, inflation, Industrial Production Index, and exchange rate for the period 1991-2013, Kim and You (2016)

examined the impacts of oil price shocks on macroeconomic factors and demonstrated that oil price shocks have an impact on interest rate, inflation, and exchange rate in Korea with different responses to oil price rises and declines. These studies, including other studies on Korean data, showed the effects of oil price shocks on various economic variables with mixed findings. Most existing studies employed a relatively short

research period with insufficient sample sizes, and have not reflected the recent dramatic movement of oil prices.

This study aims to examine how oil prices, along with the key macroeconomic variables, affect national economic growth and compares results between the US and Korea. National economic growth is affected by diverse factors, not just oil prices. Therefore, macroeconomic factors, such as interest rate, inflation rate, and unemployment rate are included in the analysis. Considering data availability, quarterly data for futures prices of WTI crude oil, interest rate, consumer price index (CPI), and unemployment rate are used for the period from the 1st quarter of 1990 to the 1st quarter of 2022. For the comparative analysis, the research period is split into two sub-periods: the period leading up to the 2008 global financial crisis (pre-GFC period) and the period thereafter (post-GFC period). The pre-GFC period saw a steady upward movement of oil prices, while the post-GFC period saw extraordinary price fluctuations of crude oil (see Fig. 1).

The remainder of this paper is organized as follows. Section 2 provides a literature review, and Section 3 describes the data and research method. Section 4 reports the empirical results, and Section 5 concludes the paper and provides implications.

II. Literature Review

Literature has investigated the impact of oil price shocks on economic growth following the seminal work of Hamilton (1983), which found a significant correlation between oil price changes and US economic growth over the period 1948-72, and suggested that oil price shocks were a contributing factor in US recessions before 1972. This work was followed by many researchers, including Mork (1989), Ferderer (1996), Cunado and Perez de Garcia (2003, 2005), and Bachmeier (2008). Mork (1989) reexamined the work of Hamilton (1983), and conducted research over a period of upward oil price movements. He attempted to identify whether the correlation also existed in periods of downward price movements and found no significant impacts of lower oil prices on US economic growth. The findings of Mork (1989) were supported by Hamilton (1996, 2008) and Lee et al. (1995), which showed that only rises in oil price had an impact on the US GDP growth rate, and a falling oil price did not have any effect on economic activity in the US. In addition, Mork (1989), Lee et al. (1995), Hamilton (1983, 1994, 1996, 2008), and Barlet and Crusson (2009) noted that the relationship between GDP growth rate and oil price variations has weakened.

A large amount of literature also examined the impact of oil price shocks on various economic factors across the world afterward. For example, Nusair (2019) studied the impact of oil price fluctuations on inflation in Gulf Cooperation Council (GCC) countries using ARDL and panel cointegration to find the positive impact of rising oil price on inflation with no significant impact of falling price of oil. Ioannidis and Ka (2018) investigated the impact of oil price shocks on the interest rates in the US, Canada, Norway, and Korea using a VAR framework to find that yield factors of the highly oil-dependent countries fluctuate more with oil price shocks, and the impact of oil shocks on yield curve is more evident in normal times. Lorusso and Pieroni (2018) employed a Vector Autoregressive (VAR) model to examine the impact of oil price changes on the UK economy, and found that oil supply and demand have an impact on GDP growth, inflation, nominal interest rate, and unemployment rate, and showed evidence of the government responding to the underlying bases of oil price fluctuations rather than oil price shocks themselves. There were some studies examining the impact of oil price shocks on unemployment, such as Cuestas and Ordonez (2018) for the UK, Cuestas and Gil-Alana (2018) for Central and Eastern Europe, and Ordonez et al. (2019) for Spain, reporting asymmetric findings that rising oil prices have a negative impact on unemployment, and declining oil prices have a positive impact on unemployment.

Other studies investigated the impact of oil price changes on stock market returns. The effect of oil price shocks on the economy is assumed to be different depending on oil importers and oil

exporters. Nusair and Al-Khasawneh (2017) used quantile regression analysis to analyze the effect of oil price volatility on stock markets in GCC countries to find that higher oil prices enhanced stock market returns during the bullish period and declining oil prices reduced stock market returns during the bearish period. However, Hammoudeh and Aleisa (2004) and Al-Janabi and Irandoust (2014) expounded that oil prices did not influence stock markets in oil importing economies. Wei and Guo (2017) investigated the relationship between oil price and stock market in China using a structural VAR framework to find that stock returns are deeply related to oil price changes. Bastianin et al. (2016) examined the impact of oil price shocks on G7 stock market volatility to demonstrate that stock market volatility responds to oil demand shocks, while it does not respond to oil supply shocks. Yoon and Kim (2022) examined, based upon GARCH (1,1) estimation, the impact of oil price shocks on stock market returns in Japan, Korea, and the US to find that oil price fluctuations are positively correlated to all three stock market returns, with particularly strong relationship with the US stock markets.

Some literature examined how national economic growth responds to changes in macroeconomic variables. For example, Philip (2010), Ayyoub et al. (2011), and Mamo (2012) identified the relationship between inflation and economic growth with mixed results. Agalega and Antwi (2013) examined the impact of inflation and interest rate on economic growth to find a strong influence of changes in both interest rate and inflation on GDP changes of Ghana. Semuel and Nurina (2015) explored the effect of inflation, interest rate, and exchange rate on the Indonesian economic to find that inflation was significantly and the exchange rate was insignificantly related to GDP growth.

There has been more attention on the relationship among various macroeconomic variables, including oil price shocks and economic growth, as the national economy is not believed to be affected by a single factor or two. Therefore, this study used various macroeconomic factors such as inflation, interest rate, unemployment rate, oil price shocks, and economic growth rate, which were selected for comparative analysis between the US and Korea. Thus, exchange rate or trade balance, another vital variable, is not included as they are not believed to be relevant in comparing the two countries.

III. Data and Methodology

The data used in this study consist of gross domestic product (GDP), WTI crude oil futures, and key macroeconomic factors such as interest rate, consumer price index (CPI), and unemployment rate. All data are quarterly closing data for the period 1990 Q1 to 2022 Q1, corresponding to 129 observations each. WTI crude oil futures price data was obtained from Investing.com, and macroeconomic variables were collected from the economic statistics of the Bank of Korea and the Federal Reserve Bank of St. Louis. Detailed discussions of the data are reported in Table 1.

For the analysis, the data were transformed into their log returns to represent the quarterly changes of data, denoted by $R_{i,t}$ in Equation (1) below:

$$R_{i,t} = \log\left(\frac{P_{i,t}}{P_{i,t-1}}\right) \quad (1)$$

where $R_{i,t}$ is the percentage change of i variable in time t, and $P_{i,t}$ and $P_{i,t-1}$ are closing data of i variable at time t and t-1, respectively.

Based upon the above variables, this study investigates how economic growth responds to changes in other variables using the function below:

$$GDP_t = f(WTI_t, INTR_t, CPI_t, UNEMP_t, \varepsilon_t) \quad (2)$$

where GDP_t is the economic growth rate, while WTI_t, $INTR_t$, CPI_t, and $UNEMP_t$ represent WTI oil price changes, interest rate changes, CPI changes, and unemployment rate changes in the US and Korea in time t, respectively, and ε_t is the error term.

Table 1. Description of the Data

Variables	
GDP	Gross Domestic Product, Billions of Dollars (Billions of Won for Korea), Quarterly, Seasonally Adjusted Annual Rate
WTI	Crude Oil WTI Futures Price
INTEREST	10-year Long-Term Government Bond Yields for the United States, 5-year National Housing Bonds Type1 for Korea, Percent, Quarterly, Not Seasonally Adjusted:
CPI	Consumer Price Index: Total All Items, Index 2015=100 (Index 2020=100 for Korea), Quarterly, Seasonally Adjusted
UNEMPLOYMENT	Unemployment Rate, Percent, Quarterly, Seasonally Adjusted

Sources: Federal Reserve Bank of St. Louis (2022), Economic statistics of the Bank of Korea (2022), and Investing.com (2022).

Fig. 1 exhibits the trend of WTI crude oil futures price and Fig. 2 and 3 illustrate the trend of each variable in the US and Korea for the period from the 1st quarter 1990 to the 1st quarter 2022. The oil price rose to the peak of $140 per barrel in mid-2008 during the time of the global financial crisis before plummeting and recovering. The oil price repeated rises and falls afterwards before the occurrence of the COVID-19 in December 2019. Following COVID-19 in late 2020, the oil price fluctuated significantly and rose sharply with Russia's invasion of Ukraine in early 2022. Economic output (GDP) and inflation (CPI) rose over time, and interest rates declined for the sample period in both countries, while the unemployment rate in the two countries showed a different pattern.

The analysis has been conducted based upon the log returns of the data (equation (1)) for the period leading to the global financial crisis spanning from the start of the sample period until June, 2008, and the period thereafter to compare the effect of the variables on the US and Korea's GDP between the pre-GFC period and the post-GFC period, which happen to be the period of upward price movement and volatile price movement of crude oil, respectively.

Fig. 1. Trend of WTI Prices

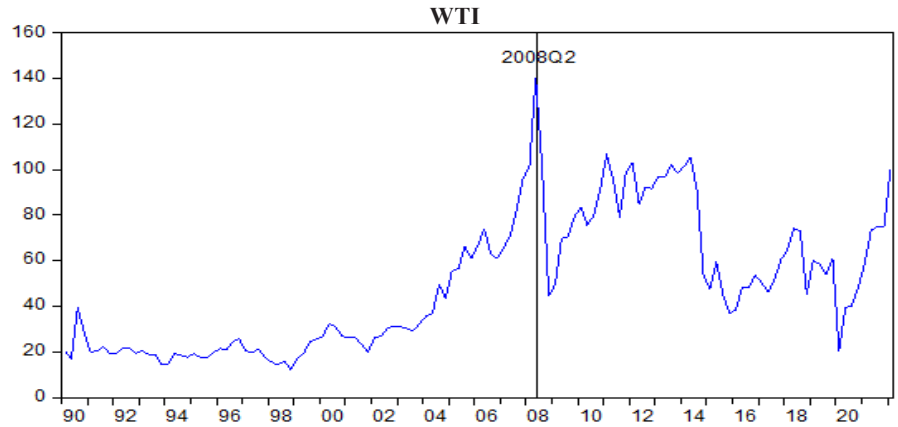


Fig. 2. Trend of US Macroeconomic Data

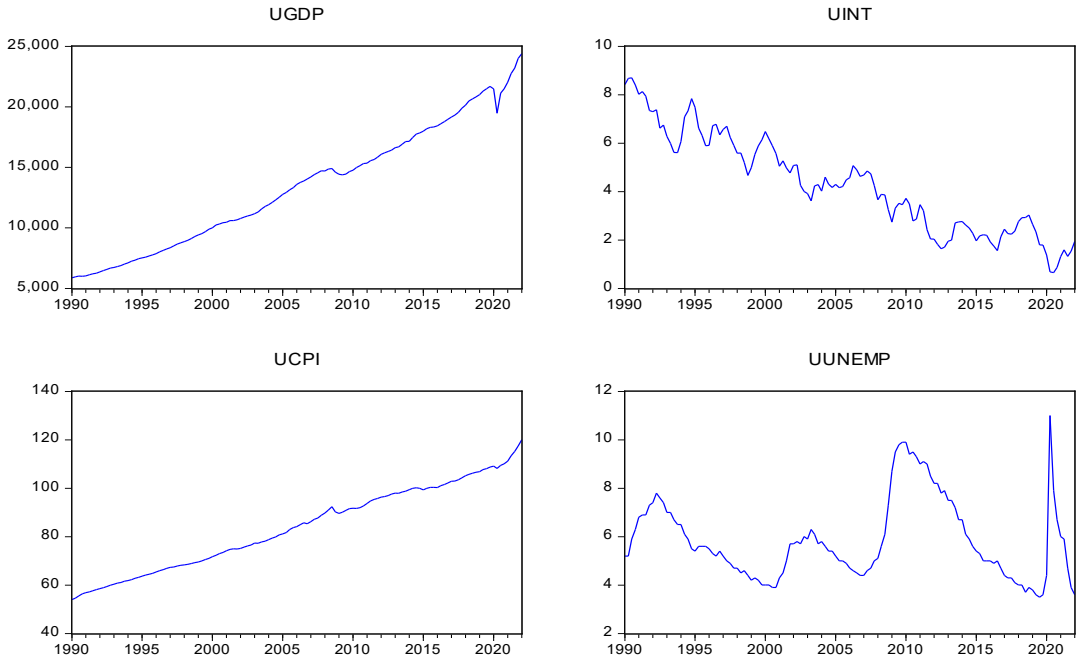
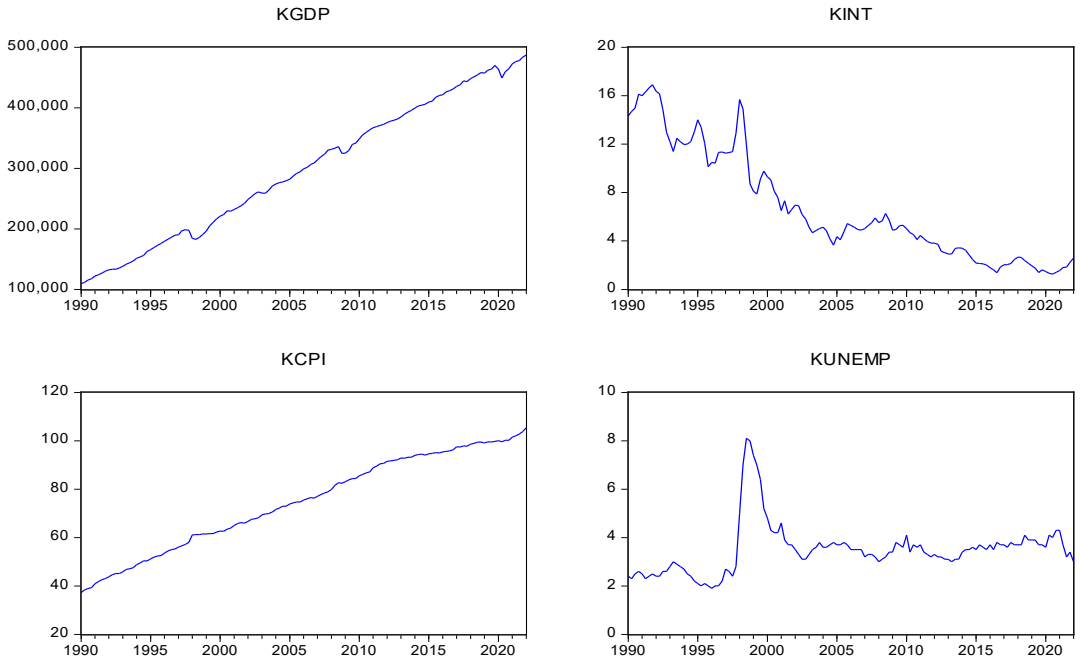


Fig. 3. Trend of Korean Macroeconomic Data



The descriptive statistics for the log returns of each variable are reported in Table 2. Mean values of GDP and CPI in the two countries are positive for both the pre-GFC and post-GFC periods, while the mean value of interest is negative for both pre-GFC and post-GFC periods, indicating the steady rise of GDP and CPI, and a steady decline of interest over time. For unemployment rate, the negative mean value of the US data is compared with Korea's positive mean value. Regarding oil price changes, mean value for the pre-GFC period is positive, while the mean value for the post-GFC period is negative. It is noted that the standard deviation for the post-GFC period is much higher than that for the pre-GFC period, meaning that oil prices are on the rise for the pre-GFC period, and are volatile for the post-GFC period. The Jarque-Bera test rejects the null hypothesis of normal distribution for most variables, but some follow a normal distribution, similar to the results of the skewness and kurtosis analyses.

Table 3 shows the correlation coefficients between the pairs of variables. The economic growth in the US is positively correlated with interest rate and negatively correlated with unemployment rate for the pre-GFC period. For the post-GFC period, the US economic growth is positively correlated with interest rate and CPI, and negatively correlated with unemployment rate. In Korea, economic growth is negatively correlated with CPI and unemployment rate for the pre-GFC period, and positively correlated with interest rate and CPI for the post-GFC period. There exists no significant relationship between economic growth and crude oil price shocks for both the pre- and post-GFC periods in the two countries.

To investigate the relationship among economic growth, oil price shocks, interest rate, inflation, and unemployment rate changes, this study applied the autoregressive distributed lag (ARDL) model, proposed by Pesaran et al. (2001). The advantage of the ARDL method is that it does not necessitate pretests for unit roots, unlike other model estimation. Hence, the model estimated by ARDL is preferable when using variables that are integrated of different orders, *I(0)* and *I(1)*. It also performs better and is more robust for the analysis of a long run relationship between the underlying variables in a relatively small sample size (Nkoro & Uko, 2016).

The ARDL model contains the lagged values of the dependent variable, and the current and lagged variables of regressors as independent variables, as specified in Equation (2). This model takes sufficient numbers of lags to capture the data generating process in a general-to-specific modeling framework. The generalized ARDL (p, q) model is specified below:

$$Y_t = \alpha_{0i} + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{i=0}^{q} \gamma_i X_{t-i} + \varepsilon_t \quad (3)$$

Where α is the constant, β and γ are coefficients, $i=1, \ldots, k$, p and q are optimal lag orders for the dependent variable and the independent variables, respectively, and ε_t is error terms. The dependent variable is a function of its lagged values, the current and lagged values of independent variables in the model. p lags are used for the dependent variable, and q lags are used for the independent variables.

For the application of the ARDL model, the bounds test should be conducted for cointegation, checking whether a long-run relationship exists among the variables. If there exists cointegration, the error correction model (ECM) is estimated for the short-run effects.

Table 2. Descriptive Statistics

	UGDP	WTI	UINT	UCPI	UUNEMP	KGDP	KINT	KCPI	KUNEMP
Pre-GFC									
Mean	0.01275	0.022378	-0.01156	0.007054	-0.00027	0.015404	-0.01324	0.010597	0.003099
Median	0.012296	0.022511	-0.02276	0.007334	0	0.017379	-0.00811	0.009836	-0.00621
Maximum	0.024252	0.839231	0.156516	0.017125	0.131028	0.042898	0.195934	0.051248	0.579818
Minimum	-0.00173	-0.37074	-0.17997	-0.00411	-0.0702	-0.07062	-0.31573	-0.00324	-0.20764
Std. Dev.	0.005058	0.174466	0.069227	0.003452	0.044423	0.014382	0.092295	0.009057	0.105465
Skewness	-0.4634	1.151104	0.315086	-0.05409	1.00511	-2.9473	-0.35956	1.631548	2.704688
Kurtosis	3.732921	8.431407	3.024467	5.292004	3.713849	19.1141	3.782542	8.007269	14.94122
Jarque-Bera	4.188362	104.401	1.193149	15.79496	13.6517	883.2318	3.388484	107.1616	515.562
Probability	0.123171	0	0.550695	0.000372	0.001085	0	0.183738	0	0
Observations	72	72	72	72	72	72	72	72	72
Post-GFC									
Mean	0.009031	-0.00023	-0.01135	0.005195	-0.00622	0.006878	-0.01348	0.004933	8.92E-18
Median	0.010072	0.035563	-0.00546	0.005349	-0.02213	0.007703	-0.02735	0.004591	0
Maximum	0.081842	0.651012	0.422058	0.022005	0.916291	0.029488	0.298867	0.020583	0.130053
Minimum	-0.09793	-1.09241	-0.69557	-0.02317	-0.33103	-0.03339	-0.23014	-0.00511	-0.18721
Std. Dev.	0.019512	0.26986	0.178	0.007025	0.152147	0.00989	0.104531	0.005449	0.064694
Skewness	-2.08773	-1.60194	-0.59162	-0.84475	3.907312	-2.11357	0.591407	0.628847	-0.41095
Kurtosis	20.53492	7.860902	5.779669	7.03809	25.70796	10.58062	3.210163	3.40329	3.812532
Jarque-Bera	758.1183	79.08415	21.29541	44.70802	1345.68	175.7804	3.367503	4.070355	3.116724
Probability	0	0	0.000024	0	0	0	0.185676	0.130657	0.210481
Observations	56	56	56	56	56	56	56	56	56

Note: The figures for IMPORT, PRICONS, GOVCONS, INVEST, and EXPORT denote the natural log value of the volumes for the aggregate imports, the final consumption expenditure in private sector, the government final consumption expenditure, the investment expenditure, and exports. PRICE denotes the natural logarithmic form of the ratio of the relative price of imports to the GDP deflator.

Table 3. Correlation Analysis

	UGDP	WTI	UINT	UCPI	UUNEMP
Pre-GFC					
UGDP	1				
WTI	0.187126	1			
UINT	0.447174***	0.187494	1		
UCPI	-0.140890	0.142897	0.071102	1	
UUNEMP	-0.542780***	0.027319	-0.315610***	0.185224	1
Post-GFC					
UGDP	1				
WTI	-0.028170	1			
UINT	0.518089***	0.175530	1		
UCPI	0.544453***	0.327747**	0.474101***	1	
UUNEMP	-0.919110***	0.077610	-0.552920***	-0.459690***	1
	KGDP	WTI	KINT	KCPI	KUNEMP
Pre-GFC					
KGDP	1				
WTI	0.167932	1			
KINT	-0.11314	0.126146	1		
KCPI	-0.31922***	-0.154900	0.238999**	1	
KUNEMP	-0.68849***	-0.177680	0.025851	0.341943***	1
Post-GFC					
KGDP	1				
WTI	0.21436	1			
KINT	0.263874**	0.255301*	1		
KCPI	0.404533***	0.191156	0.354547***	1	
KUNEMP	-0.17734	0.130638	-0.091320	0.018449	1

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

IV. Empirical Results

As a first step for model estimation, unit tests are conducted. Table 4 shows the outcomes of the unit root tests at level and first difference for series of each variable. The test results prove that all series of log returns are stationary.

Table 4. Unit Root Test

Variables	At Level		At First Difference	
	ADF t-statistic	p-value*	ADF t-statistic	p-value*
UGDP	1.90362	0.9998	-12.3028	0
WTI	-2.03025	0.2737	-10.1223	0
UINT	-1.94581	0.3106	-8.34579	0
UCPI	1.463773	0.9992	-6.60547	0
UUNEMP	-2.39585	0.1449	-11.6884	0
KGDP	-0.14257	0.9414	-9.29205	0
KINT	-1.93256	0.3165	-9.12378	0
KCPI	-2.41895	0.1386	-10.5681	0
KUNEMP	-3.56378	0.0078	-6.65496	0

Source: MacKinnon (1996).

To examine the impact of oil prices and macroeconomic variables on economic growth, this study applies the autoregressive distributed lag model (ARDL), taking the form of equation below:

$$GDP_t = \alpha_{0i} + \sum_{i=1}^{p} \beta_i GDP_{t-i} + \sum_{i=0}^{q} \gamma_{1i} WTI_{t-i} + \sum_{i=0}^{q} \gamma_{2i} INTR_{t-i} + \sum_{i=0}^{q} \gamma_{3i} CPI_{t-i} + \sum_{i=0}^{q} \gamma_{4i} UNEMP_{t-i} + \varepsilon_t \quad (4)$$

where *GDP*, *WTI*, *INTR*, *CPI,* and *UNEMP* are quarterly changes of GDP, oil price, interest rate, CPI, and unemployment rate, while β, γ_1, γ_2, γ_3, and γ_4 are their coefficients, respectively.

Table 5 shows the results of the long-run coefficient estimation of the ARDL model of the pre- and post-GFC US data series, in which UGDP, the US economic growth, is the dependent variable and changes in oil price, the US interest rate, US CPI, and US unemployment rate are independent variables. Selected models based upon the AIC optimal lag method are ARDL (3,0,0,0,0) for the pre-GFC period and ARDL (4,1,0,2,3) for the pre-GFC period. Statistically significant variables

affecting US current economic growth in the long run, at the 5% level, are interest rate changes and unemployment rate changes in the pre-GFC period, while it is affected by it lagged values, one-lagged oil price shocks, 2-lagged CPI changes, and current unemployment rate changes in the post-GFC period. Understandably, unemployment rate variations have a negative impact on US economic growth. Regarding the impact of oil price fluctuation on US economic growth, there is no significant impact on the economic growth pre-GFC, while there exists a slight impact for the post-GFC period, with the coefficient of 0.01145 of the previous oil price changes, meaning that when the previous oil price shocks increased by 1%, the US economy increased by 0.0115%.

The long-run coefficient estimation of the ARDL model of the pre- and post-GFC Korean data series are reported in Table 6. KGDP, Korea's economic growth, is the dependent variable, and changes in oil price, Korea's interest rate, CPI, and unemployment rate are independent variables. Selected models based upon the AIC optimal lag method are ARDL (1,0,3,3,0) for the pre-GFC period and ARDL (1,1,1,0,4) for the pre-GFC period. For the pre-GFC period, Korea's economic growth was positively affected in the long run by the 3-lagged CPI variation, and negatively affected by current unemployment rate changes at the 5% statistical significance level with the respective coefficients of 0.38103 and –0.09339, meaning that Korea's economy increased by 0.3810% when the 3-lagged CPI changes increased by 1%, while Korea's economy decreased by 0.0934% when unemployment rate changes increased by 1%. For the post-GFC period, Korea's economic growth was positively affected by a one-lagged oil price shock, current CPI changes, and 3-lagged unemployment rate changes, and negatively affected by one-lagged interest rate changes at the 5% statistical significance level with the respective coefficients of 0.01926, 0.49162, 0.03608, and –0.01902, meaning that Korea's economy increased by 0.4916% when current CPI changes increased by 1%, while Korea's economy increased by 0.0361% when 3-lagged unemployment rate changes increased by 1%. Korea's economy decreased by 0.0190% in response to 1% increase in one-lagged interest rate changes. Regarding the impact of oil price fluctuation on Korea's economic growth, as in the US, there is no significant impact on economic growth in the pre-GFC, while there exists a slight impact for the post-GFC period, with the coefficient of 0.01926 of one-lagged oil price changes, meaning that Korea's economy increased by 0.0192% according to the 1% increase in previous oil price changes.

The long-run relationship among the variables specified in the model is represented in the equations below:

- Estimated Model of US GDP for the pre-GFC period:

$$GDP_t = 0.01407 + 0.02166INTR - 0.04858UNEMP \quad (5)$$

- Estimated Model of US GDP for the post-GFC period:

$$GDP_t = 0.00625 + 0.31307GDP(-3) - 0.10459(-4) + 0.0114WTI(-1) + 0.41100CPI(-2) - 0.10873UNEMP + 0.04097UNEMP(-3) \quad (6)$$

- Estimated Model of Korea's GDP for the pre-GFC period:

$$GDP_t = 0.01053 + 0.38103CPI(-3) - 0.09339UNEMP \quad (7)$$

- Estimated Model of Korea's GDP for the post-GFC period:

$$GDP_t = 0.00374 + 0.01926WTI(-1) - 0.01902INTR(-1) + 0.49162CPI + 0.03608UNEMP(-3) \quad (8)$$

Table 5. ARDL Estimates and Bounds Tests (US)

Variable	Coefficient (γ)	Std. Error	t-Statistic	Prob.
		Pre-GFC Period		
	Dependent Variable: UGDP, Selected Model: ARDL(3,0,0,0,0)			
UGDP (-1)	-0.079877	0.117853	-0.677771	0.5005
UGDP (-2)	0.196677*	0.104378	1.884270	0.0643
UGDP (-3)	-0.156409	0.100708	-1.553098	0.1256
WTI	0.003688	0.003540	1.041629	0.3017
UINT	0.021661***	0.007236	2.993604	0.0040
UCPI	-0.077451	0.161218	-0.480411	0.6327
UUNEMP	-0.048578***	0.014246	-3.409887	0.0012
C	0.014069	0.002171	6.479954	0.0000
		F-Bounds Test		
	Value	Significance	I(0)	I(1)
F-statistic	11.62130	10%	2.45	3.52
No of Order	4	5%	2.86	4.01
		1%	3.74	5.06
		Post-GFC period		
	Dependent Variable: UGDP, Selected Model: ARDL(4,1,0,2,3)			
UGDP (-1)	-0.178190	0.111641	-1.596100	0.1190
UGDP (-2)	0.007945	0.114375	0.069467	0.9450
UGDP (-3)	0.313065**	0.129746	2.412912	0.0209
UGDP (-4)	-0.104589**	0.043027	-2.430759	0.0200
WTI	-0.001429	0.003227	-0.442847	0.6605
WTI (-1)	0.011451**	0.005280	2.168892	0.0366
UINT	-0.009190	0.005521	-1.664902	0.1044
UCPI	0.393855	0.236057	1.668470	0.1037
UCPI (-1)	-0.434103*	0.226360	-1.917755	0.0629
UCPI (-2)	0.411001**	0.160652	2.558340	0.0147
UUNEMP	-0.105731***	0.006271	-16.86138	0.0000
UUNEMP (-1)	-0.001830	0.013414	-0.136406	0.8922
UUNEMP (-2)	0.011077	0.012768	0.867574	0.3912
UUNEMP (-3)	0.040970**	0.015332	2.672260	0.0111
C	0.006253	0.001686	3.707831	0.0007
		F-Bounds Test		
	Value	Significance	I(0)	I(1)
F-statistic	7.694816	10%	2.45	3.52
No of Order	4	5%	2.86	4.01
		1%	3.74	5.06

Note: *p*-values and any subsequent tests do not account for model selection.

Table 6. ARDL Estimates and Bounds Tests (Korea)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Pre-GFC Period				
Dependent Variable: KGDP, Selected Model: ARDL(1,0,3,3,0)				
KGDP (-1)	-0.004907	0.120429	-0.040746	0.9676
WTI	0.004541	0.010584	0.429050	0.6695
KINT	-0.016647	0.015324	-1.086326	0.2819
KINT (-1)	0.014279	0.014524	0.983141	0.3297
KINT (-2)	-0.015551	0.014331	-1.085184	0.2824
KINT (-3)	-0.025578*	0.015051	-1.699444	0.0947
KCPI	-0.198403	0.164890	-1.203249	0.2339
KCPI (-1)	-0.058360	0.149497	-0.390373	0.6977
KCPI (-2)	0.248211*	0.144317	1.719897	0.0909
KCPI (-3)	0.381027**	0.158400	2.405480	0.0194
KUNEMP	-0.093391***	0.016394	-5.696789	0.0000
C	0.010529	0.003529	2.891879	0.0054
F-Bounds Test				
	Value	Significance	I(0)	I(1)
F-statistic	14.61631	10%	2.45	3.52
No of Order	4	5%	2.86	4.01
		1%	3.74	5.06
Post-GFC period				
Dependent Variable: KGDP, Selected Model: ARDL (1,1,1,0,4)				
KGDP (-1)	0.128820	0.112592	1.144127	0.2594
WTI	0.003413	0.003931	0.868032	0.3906
WTI (-1)	0.019258***	0.004428	4.349228	0.0001
KINT	0.005809	0.009542	0.608853	0.5461
KINT (-1)	-0.019016**	0.009391	-2.025024	0.0496
KCPI	0.491618**	0.220568	2.228875	0.0315
KUNEMP	-0.000220	0.015022	-0.014632	0.9884
KUNEMP (-1)	0.020231	0.015268	1.325048	0.1927
KUNEMP (-2)	0.010630	0.015678	0.677994	0.5017
KUNEMP (-3)	0.036075**	0.016351	2.206338	0.0332
KUNEMP (-4)	0.023696	0.017611	1.345518	0.1860
C	0.003740	0.001648	2.268883	0.0287
F-Bounds Test				
	Value	Significance	I(0)	I(1)
F-statistic	21.88561	10%	2.45	3.52
No of Order	4	5%	2.86	4.01
		1%	3.74	5.06

Note: *p*-values and any subsequent tests do not account for model selection.

In order to identify the existence of cointegration among variables, bounds tests were conducted and the results are shown in the bottom panel of each period in Tables 5 and 6. The test results show that the F-statistic is greater than the upper bound value at the 1% significance level. Thus, the null hypothesis that there is no long-run relationship among variables is rejected. Because of the evidence of cointegration among variables, the error correction model (ECM) is estimated to investigate the short-run effect and the results are reported in Table 7 and 8. According to the results, US economic growth for the pre-GFC period is affected in the short run by its previous value, but only at the 10% significance level, while GDP growth in the US for the post-GFC period is affected by its previous value, current and past values of CPI, and unemployment rate. In the case of Korea, the economic growth for the pre-GFC period is affected in the short run by past values of interest rate changes and CPI changes and, for the post-GFC period, Korea's economic growth is negatively affected only by past values of unemployment rate changes. In the short run, there is no evidence of an oil price shock effect on national economic growth in the US and Korea.

The short-run relationship among variables specified in the model is represented in the equations below:

- Estimated Model of US GDP for the pre-GFC period:

$$\Delta GDP_t = 0.01407 - 0.93961ECM(-1) \quad (9)$$

- Estimated Model of US GDP for the post-GFC period:

$$\Delta GDP_t = 0.00625 + 0.10459\Delta GDP(-3) + 0.39386\Delta CPI - 0.41100\Delta CPI(-1) - 0.10573\Delta UNEMP - 0.05205\Delta UNEMP(-1) - 0.04097\Delta UNEMP(-2) - 0.96177ECM(-1) \quad (10)$$

- Estimated Model of Korea's GDP for the pre-GFC period:

$$\Delta GDP_t = 0.01053 + 0.04113\Delta INTR(-1) + 0.02558\Delta INTR(-2) - 0.62924\Delta CPI(-1) - 0.38103\Delta CPI(-2) - 0.98491ECM(-1) \quad (11)$$

- Estimated Model of Korea's GDP for the post-GFC period:

$$\Delta GDP_t = 0.00374 - 0.07040\Delta UNEMP(-1) - 0.05977\Delta UNEMP(-2) - 0.87118ECM(-1) \quad (12)$$

In addition, the ECM term, expressed as CointEq(-1) in the Tables, derives from cointegration models and is referred to estimated equilibrium errors. The coefficient of ECM is the short run adjustment coefficient and presents the adjustment speed from equilibrium or the correction of inequilibrium for each period. In Equation (9), the coefficient of ECM, 0.93961, suggests the degree of adjusting of the deviation between the short-run values to reach the long-run equilibrium is at 93.961%.

Table 7. ARDL Error Correction Model Estimates (US)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Pre-GFC Period				
Dependent Variable: D(UGDP), Selected Model: ARDL(3,0,0,0,0)				
C	0.014069	0.001841	7.640835	0.0000
D(UGDP (-1))	-0.040268	0.111340	-0.361667	0.7189
D(UGDP (-2))	0.156409*	0.132119	1.682256	0.0976
CointEq (-1)	-0.939609***	0.624209	-7.868722	0.0000
Post-GFC period				
Dependent Variable: D(UGDP), Selected Model: ARDL(4,1,0,2,3)				
C	0.006253	0.001094	5.713905	0.0000
D(UGDP (-1))	-0.216421	0.142180	-1.522163	0.1365
D(UGDP (-2))	-0.208476*	0.114636	-1.818581	0.0771
D(UGDP (-3))	0.104589***	0.036780	2.843674	0.0072
D(WTI)	-0.001429	0.001793	-0.796751	0.4307
D(UCPI)	0.393855***	0.142814	2.757807	0.0090
D(UCPI (-1))	-0.411001***	0.137273	-2.994054	0.0049
D(UUNEMP)	-0.105731***	0.004721	-22.39504	0.0000
D(UUNEMP (-1))	-0.052047***	0.012334	-4.219714	0.0002
D(UUNEMP (-2))	-0.040970***	0.011042	-3.710537	0.0007
CointEq (-1)	-0.961769***	0.147298	-6.529429	0.0000

Note: *p*-value incompatible with *t*-Bounds distribution.

Table 8. ARDL Error Correction Model Estimates (Korea)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Pre-GFC Period				
Dependent Variable: D(KGDP), Selected Model: ARDL(1,0,3,3,0)				
C	0.010529	0.001687	6.241910	0.0000
D (KINT)	-0.016647	0.011022	-1.510393	0.1365
D (KINT (-1))	0.041129***	0.012643	3.253088	0.0019
D (KINT (-2))	0.025578**	0.011860	2.156582	0.0353
D (KCPI)	-0.198403	0.142644	-1.390898	0.1697
D (KCPI (-1))	-0.629238***	0.139438	-4.512684	0.0000
D (KCPI (-2))	-0.381027***	0.122515	-3.110053	0.0029
CointEq (-1)	-0.984907***	0.113630	-8.843645	0.0000
Post-GFC period				
Dependent Variable: D(UGDP), Selected Model: ARDL(1,1,1,0,4)				
C	0.003740	0.000860	4.347713	0.0001
D (WTI)	0.003413	0.002510	1.359724	0.1815
D (KINT)	0.005809	0.006788	0.855782	0.3972
D (KUNEMP)	-0.000220	0.012543	-0.017525	0.9861
D (KUNEMP (-1))	-0.070401***	0.020717	-3.398163	0.0015
D (KUNEMP (-2))	-0.059771***	0.019458	-3.071878	0.0038
D (KUNEMP (-3))	-0.023696*	0.013210	-1.793763	0.0804
CointEq (-1)	-0.871180***	0.079405	-10.97137	0.0000

Note: *p*-value incompatible with *t*-Bounds distribution.

Table 9. Autocorrelation Test

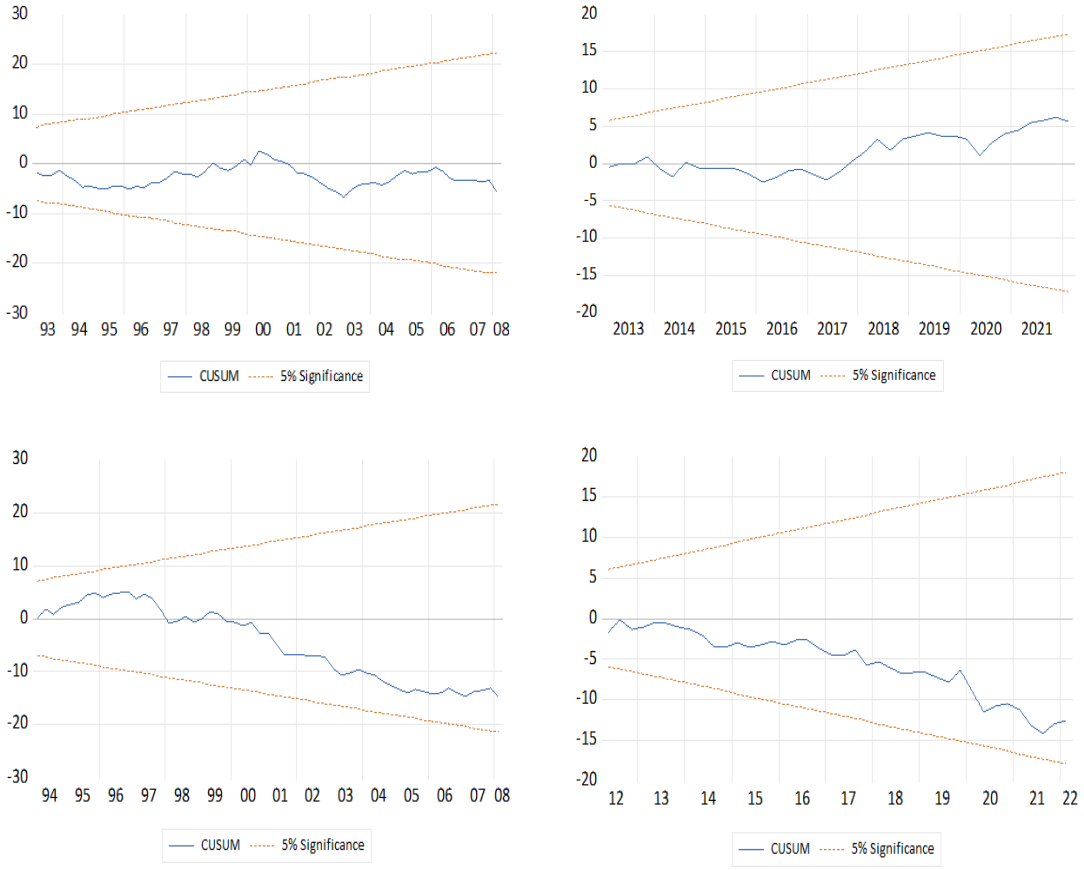
Breusch-Godfrey Serial Correlation LM Test (H_0: No serial correlation)			
Pre-GFC Period (US)			
F-statistic	0.069412	Prob. F(2,59)	0.9330
Obs*R-squared	0.161973	Prob. Chi-Square(2)	0.9222
Post-GFC Period (US)			
F-statistic	0.599207	Prob. F(2,35)	0.5548
Obs*R-squared	1.721553	Prob. Chi-Square(2)	0.4228
Pre-GFC Period (Korea)			
F-statistic	0.103882	Prob. F(2,55)	0.9015
Obs*R-squared	0.259668	Prob. Chi-Square(2)	0.8782
Post-GFC Period (Korea)			
F-statistic	1.133911	Prob. F(2,38)	0.3324
Obs*R-squared	2.928561	Prob. Chi-Square(2)	0.2312

Table 10. Heteroskedasticity Test

Breusch-Pagan-Godfrey (H_0: Homoskedasticity)			
Pre-GFC Period (US)			
F-statistic	0.688035	Prob. F(7,61)	0.6817
Obs*R-squared	5.049222	Prob. Chi-Square(7)	0.6540
Post-GFC Period (US)			
F-statistic	0.620562	Prob. F(14,37)	0.8306
Obs*R-squared	9.888163	Prob. Chi-Square(14)	0.7703
Pre-GFC Period (Korea)			
F-statistic	2.644599	Prob. F(11,57)	0.0083
Obs*R-squared	23.31557	Prob. Chi-Square(11)	0.0159
Post-GFC Period (Korea)			
F-statistic	1.383302	Prob. F(11,40)	0.2183
Obs*R-squared	14.32998	Prob. Chi-Square(2)	0.2153

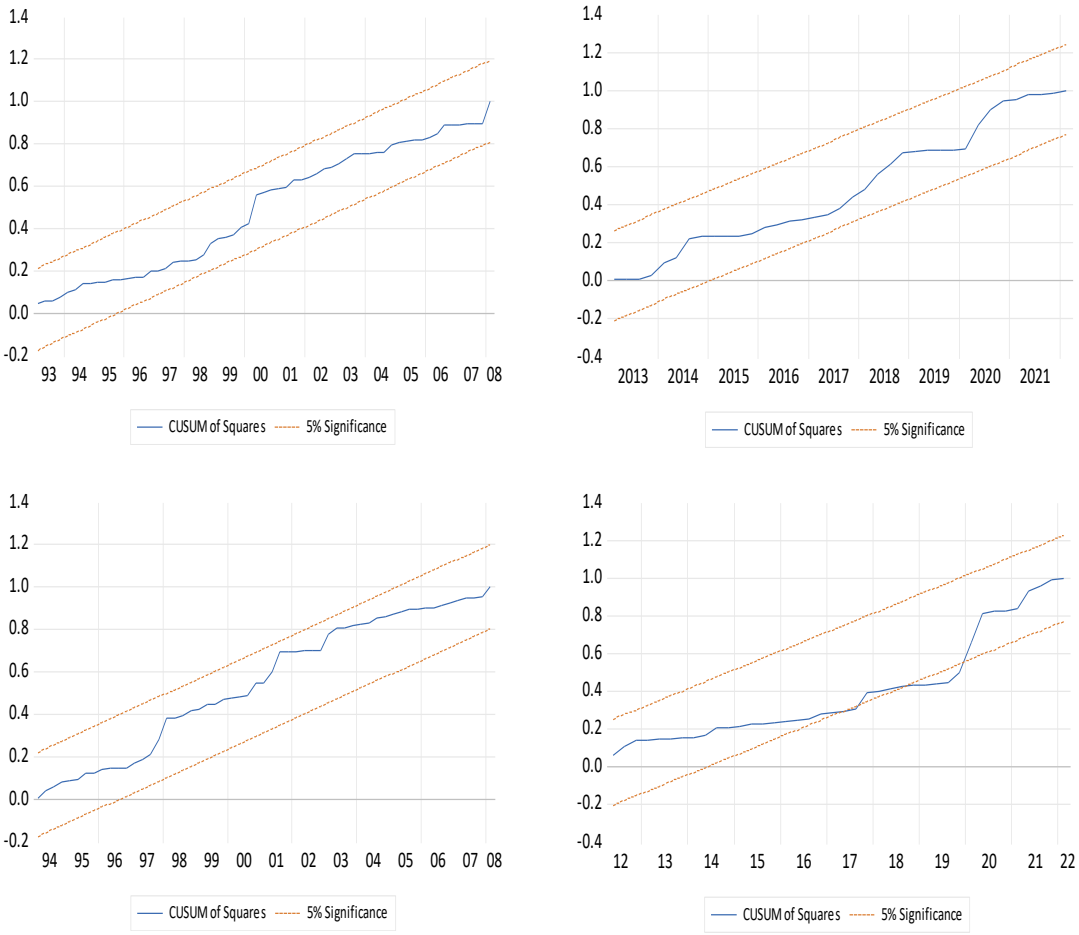
In order to ensure that the estimated model is correctly specified and can be used for prediction, diagnostics tests and stability tests are conducted. For diagnostic tests, autocorrelation and heteroscedasticity tests are performed. Tables 9 and 10 demonstrate the outcomes of autocorrelation and the heteroscedasticity test, which imply that the ARDL models estimated in this study have neither autocorrelation nor heteroscedasticity, as both F-statistics and the Obs*R-squared of Breusch-Godfrey test and Breusch-Pagan-Godfrey test for residuals show that the null hypothesis of no serial correlation and homoscedasticity cannot be rejected as the *p* value is greater than 5%, except for the model of pre-GFC Korea. To confirm the stability of the estimated models in this study, the tests of the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of square recursive residuals (CUSUMSQ), proposed by Brown et al. (1975), are performed. If the plots of CUSUM and CUSUMSQ are within the critical bounds at the 5% level of significance, the null hypothesis that all coefficients of the regression model are stable cannot be rejected. As shown in Figs. 4 and 5, the model estimation of this study is confirmed to be stable.

Fig. 4. Plot of CUSUM



Note: The right side is post-GFC, and the left side is pre-GFC; the top panels are US, and the bottom panels are Korea.

Fig. 5. Plot of CUSUMSQ



Note: The right side is post-GFC, and the left side is pre-GFC; the top panels are US, and the bottom panels are Korea.

Pairwise Granger causality tests are also employed to investigate the causal impact of each of the variables under study on another variable, which was proposed by Granger (1969). To test the null hypothesis that one variable does not Granger-cause another, pairwise causality tests among five variables in the US and Korea pre- and post-GFC are implemented, and F-statistics statistically significant at 1%, 5%, and 10% are selected and presented in Table 11. WTI oil price changes have a causal impact on US economic growth for pre- and post GFC periods, while in Korea, economic growth is affected by the unemployment rate variation for the pre-GFC period and by oil price changes for the post-GFC period. As regards the causal impact of oil price shocks on macroeconomic variables, oil price changes have a causal impact on all variables in both the US and Korea for the post-GFC period; for the pre-GFC period, only US CPI and economic growth are affected with no causal impact of oil price changes on Korea's macroeconomic factors.

Table 11. Granger Causality Test

Null Hypothesis	Obs	F-Statistics	Prob.
Pre-GFC Period (US)			
WTI does not Granger Cause UCPI	70	16.8893***	1.00E-06
UGDP does not Granger Cause UUNEMP	70	5.81853***	0.0047
UINT does not Granger Cause WTI	70	4.79145**	0.0115
WTI does not Granger Cause UGDP	70	3.91904**	0.0247
UGDP does not Granger Cause WTI	70	3.48138**	0.0366
Post-GFC Period (US)			
WTI does not Granger Cause UGDP	54	27.9346***	8.00E-09
WTI does not Granger Cause UUNEMP	54	22.052***	1.00E-07
WTI does not Granger Cause UCPI	54	12.7357***	4.00E-05
WTI does not Granger Cause UINT	54	6.60748***	0.0029
Pre-GFC Period (Korea)			
KUNEMP does not Granger Cause KINT	70	4.79286**	0.0114
KGDP does not Granger Cause KUNEMP	70	4.32295**	0.0173
KUNEMP does not Granger Cause KGDP	70	2.7958*	0.0684
KCPI does not Granger Cause WTI	70	2.57358*	0.084
KGDP does not Granger Cause KINT	70	2.50287*	0.0897
Post-GFC Period (Korea)			
WTI does not Granger Cause KGDP	54	14.87800***	9.00E-06
WTI does not Granger Cause KCPI	54	5.52487***	0.0069
KCPI does not Granger Cause KUNEMP	54	3.20113**	0.0494
WTI does not Granger Cause KUNEMP	54	2.87614*	0.0659
WTI does not Granger Cause KINT	54	2.85678*	0.0671

V. Conclusion

This paper investigated how national economic growth reacts to changes in oil price and other macroeconomic factors such as interest, inflation, and unemployment rate in the US and Korea. Taking the availability of the data into consideration, quarterly data are used for the period from the 1st quarter of 1990 to the 1st quarter of 2022. The research period has been divided into two sub-periods, the pre-GFC period and post-GFC period, which is the period before and after 2nd quarter of 2008. The pre-GFC period shows the steady upward movement of oil prices, while the post-GFC period can be characterized as a period of dramatic price fluctuations.

Empirical results showed that economic growth in the US was positively correlated with interest rate and negatively correlated with unemployment rate for the pre-GFC period. For the post-GFC period, US economic growth was positively correlated with interest rate and CPI, and negatively correlated with unemployment rate. In Korea, economic growth was negatively correlated with CPI and unemployment rate for the pre-GFC period, and positively correlated with interest rate and CPI for the post-GFC period. There exists no significant relationship between economic growth and crude oil price shocks for both the pre- and post-GFC periods in the two countries.

According to the ARDL model estimation, US economic growth is affected in the long run by interest rate changes and unemployment rate changes for the pre-GFC period, while it was affected by lagged economic growths, one-lagged oil price shocks, 2-lagged CPI changes, and current unemployment rate changes in the post-GFC period. There is no significant impact of oil price shocks on economic growth pre-GFC, while a slight impact was found in the post-GFC period. For the pre-GFC period in Korea, economic growth was positively affected in the long run by 3-lagged CPI variation, and negatively affected by current unemployment rate changes. For the post-GFC period, Korea's economic growth was positively affected by the one-lagged oil price shock, current CPI changes, and 3-lagged unemployment rate changes, and negatively affected by one-lagged interest rate changes. Regarding the impact of oil price fluctuation on Korea's economic growth, as in the US, there was no significant impact on the economic growth pre-GFC, while there exists a slight impact for the post-GFC period.

In accordance with ECM estimation, GDP growth in the US for the post-GFC period was affected by its previous value, the current and past values of CPI, and unemployment rate. In Korea, economic growth for the pre-GFC period was affected in the short run by past values of interest rate changes and CPI changes, and for the post-GFC period, Korea's economic growth was negatively affected only by past values of unemployment rate changes. In the short run, there is no evidence of oil price shock effect on national economic growth in the US and Korea.

Granger causality tests showed that oil price changes have a causal impact on US economic growth for pre- and post GFC periods, while in Korea economic growth was affected by the unemployment rate variation for the pre-GFC period and by the oil price changes for the post-GFC period. Concerning the Granger causal impact of oil price shocks on macroeconomic variables, oil price changes have a causal impact on all variables in both the US and Korea for the post-GFC period, while, for the pre-GFC period, only the US CPI and economic growth are affected and no causal impact of oil price changes on Korea's macroeconomic factors was found.

The findings showed that the impact of oil price shocks on the national economic performance have weakened, supporting some previous studies mentioned in the introduction section in this paper, though this study was conducted on two of the biggest consumers and importers of crude oil in the world. The findings, thus, have significant implications for policymakers attempting to address the effects of oil price shocks in their economies. Policymakers need to focus on relatively manageable economic variables such as domestic interest rate, inflation, and unemployment rate to keep economies going rather than oil price changes, which is a completely out-of-control factor. Since no dominating economic factor

was found to determinate economic growth, it is suggested that oil price as a production cost, and policy-manageable macroeconomic variables that have been used as existing growth strategies, have limitations in use as growth strategies. Because today's economic activity is basically based on a huge market, the expansion of the national economy is not the management of the market by policy; the expansion of potential growth through reform or innovation is the source of economic growth.

This study has limitations as it was focused only on crude oil volatility and selected macroeconomic factors in big oil importers; thus, forthcoming research may include other, or additional, macroeconomic factors that can contribute to national economic performance. Further, the future researchers can opt to use time-series data of key oil exporters to analyze and compare the results between oil importing and exporting economies to improve the research impact.

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A Study on Rural Finance, Rural Industry Revitalization, and Rural Logistics Development: An Empirical Analysis Based on Panel Data from 30 Provinces in China

Zhuoping Qin[a], Xu Jin[b]*

[a]*Seoul School of Integrated Sciences and Technologies, South Korea*
School of Civil Engineering and Architectural, Baise University,China
[b]*Department of Global Business, Konkuk University, South Korea*

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ABSTRACT

Purpose – This is a study on the influence mechanism of rural finance and rural industrial revitalization on rural logistics development from rural revitalization strategy.
Design/Methodology/Approach – We use panel data of 30 Chinese provinces from 2011 to 2020. A two-way fixed-effects model is constructed and mediated effects analysis and multiple regression analysis are used to analyze the dynamic relationship between rural finance, rural industrial revitalization, and rural logistics development. The dynamic relationship was empirically analyzed using mediated effects analysis and multiple regression analysis.
Findings – Rural finance has a significant positive impact on rural logistics, and rural finance effectively promotes rural logistics development; rural finance affects rural logistics development by influencing the revitalization of rural industries, indicating that the revitalization of rural industries plays a mediating effect. The impact of rural finance on rural logistics is heterogeneous in the east, central, and west. Rural industry revitalization does not play a mediating role in the central era, comparing with an obvious mediating role in the east and west.
Research Implications – The revitalization of rural industries as a transmission mechanism for rural finance to promote the development of rural logistics, and we verify the rationality of this transmission mechanism through a model to fill the gaps in the existing literature, thus providing a new research perspective for rural finance to promote the development of rural logistics, and providing some theoretical guidance and policy reference.

Keywords: China, financial policy, industrial revitalization, rural finance, rural logistics
JEL Classifications: G21, G28, O18

* *Corresponding Author, E-mail: jinxv@konkuk.ac.kr*

I. Introduction

In recent years, China's rapid economic development in rural areas, agricultural, and sideline products production and processing capacity has increased significantly, but because the rural logistics system has not yet been improved, the problems of poor rural circulation channels ,low marketability, backward circulation methods, and the lack of quality assurance for some products is becoming increasingly evident, which are affecting the development of the rural economy greatly. In order to solve the problem of rural logistics development and improve rural economic development, the central government has formulated a series of policies. For example, in 2011, the "Office of the State Council on policies and measures to promote the healthy development of logistics industry" clearly proposed to give priority to the development of farm produce logistics. 2016 Central Government Document No. 1 proposed the strengthening of the construction and connection of logistics service networks and facilities of trade circulation, supply and marketing, postal, and other systems, accelerate the improvement of county and rural logistics systems, and implement these changes. In July 2021, the State Council's "Office of the State Council on accelerating the construction of rural mail logistics system" was proposed to strengthen the financing of rural mail logistics and rural e-commerce, transportation, and development, continue to play the role of the main channel of postal express service in rural e-commerce, and promote the intensification of transportation, standardization of equipment, and processes. The rural revitalization strategy planning (2018-2022) also proposes to accelerate the construction of a backbone network of the poor rural logistics infrastructure, and encourageme enterprises in commerce, postal service, express delivery, supply marketing, and transportation to increase the layout of their facility networks in rural areas.

At the same time, the development of rural industries stimulates the forward movement of rural logistics. Currently in rural areas, industry is booming, the rural market is thriving, and the logistics operation capacity is increasingly demanding. in May 2019, the State Council issued the "digital rural revitalization strategy outline" to implement the "Internet +" farm products out of the village into the city project, deepen popularization of rural postal and express delivery outlets, and accelerate the completion of a number of intelligent logistic distribution centers. An insufficient financial supply (or credit constraint) is a key factor limiting farm produce (Guirkinger et al., 2010; O'Toole et al., 2014; Saravanan, 2016), and the construction of rural logistics cannot be separated from strong financial support (Hu, 2010). Therefore, both the development of rural industries and the improvement of rural logistics capacity require more investment and cannot be separated from the strong support of rural finance. The Party Central Committee attaches great importance to the role of finance in the key areas and weak links of rural logistics development, and the Central Document No. 1 from 2016 to 2021 emphasized that financial resources will become an important supporting force and driver of the agricultural supply chain system, and rural logistics and supply chains in general will show specialized characteristics. Therefore, it is important to study the direct impact of rural financial development on rural logistics development and explore the intermediary achievement of rural industrial revitalization.

II. Literature Review

In terms of the influence of rural finance on the development of rural logistics, scholars agree that rural financial development can promote the development of rural logistics. Deepening the reform of China's rural financial system, and improving the efficiency of rural financial market resources and its capital operation level are the new financing channels for developing rural logistics enterprises in China in Hu (2009). Xu et al. (2012) argued that strong financial support is necessary to develop modern farm produce

logistics and to solve the current financial supply shortage for farm produce logistics construction in China. Wu (2013) mentioned that vigorously strengthening and improving financial support is an objective needed for the development of China's rural logistics industry, and it is also an inevitable choice for establishing and improving China's rural logistics financial service system. Liang and Zhang (2016) pointed out that the development of rural finance and rural logistics provides an economic system with a perfect environment for capital financing and material circulation. Chen and Hu (2015) concluded that the development of rural finance has played an obvious role in promoting the development of farm produce logistics, and the development of farm produce logistics has not played a pulling role in the development of rural finance as it should. Li (2017) concluded that the development of rural logistics industry needs to be supported by the financial system, which requires a financial support system to play a role in the development of rural logistics industry clusters. Zhang (2019a) pointed out that the problems in the coordinated development of rural logistics industry and regional economy must be solved by policy support for the financial guarantee infrastructure construction improvement, and interregional association to the problem.

Regarding research on the impact of rural industrial revitalization on rural logistics development, and the scholars that mainly focus on the agricultural industry, industrial integration, rural economic development, and rural logistics. He et al. (2013) argued that rural logistics modernization is an inevitable requirement and an important part of China's agricultural modernization. Zhang (2019b) argued that industrial integration development will generate a strong demand for logistics, requiring the provision of modern logistics services with greater value-added space and value functions. Ding et al. (2021) argued that in rural areas, when the level of economic development is high, the position of the logistics industry in economic development is enhanced, and the huge commodity flow generated by economic development drives the development of the logistics industry. Rao (2021) pointed out that there is a higher demand for fresh farm products and the diversification of consumer goods, which will substantially drive the development of related industries, such as distribution and processing, transportation, and storage, and increase the demand for rural logistics. Gao (2021) believed that the development of the rural economy is driving the logistics industry in the direction of intelligence.

In summary, existing studies have focused on the influence of rural finance and rural industrial revitalization on rural logistics, and neglected the influence of rural industrial revitalization as a transmission mechanism when exploring the transmission mechanism of the influence of rural finance on rural logistics development. This paper takes this as a breakthrough and tries to make the following innovation: to use rural industry revitalization as a transmission mechanism for rural finance to promote rural logistics development, and to verify the rationality of this transmission mechanism through a model to make up for the shortcomings of the existing literature, so as to provide a new research perspective for rural finance to promote rural logistics development.

III. Theoretical Analysis and Research Hypotheses

Compared with traditional urban financial services, rural finance has superiority in agricultural economic information collection, financial services to rural economic production subjects, and information exchange between farmers and financial institutions. The expansion of rural finance contributes to the development of rural industries, and the development of rural industries generates demand for rural logistics and determines the development of rural logistics, and the modernization level of rural logistics is determined by the level of rural economic development (Ding et al., 2021).

1. The Direct Impact of Rural Financial Development on Rural Logistics

Rural finance has provided financing services for rural logistics development. In the field of agricultural capital construction, rural information system construction and farm produce logistics software and hardware have all received more financial support, especially in the construction of total transportation network of farm produce logistics, involving the railway, provincial, municipal, county, and township transportation with road network construction; all have received a large amount of financing (Chen & Hu, 2015). Rural finance cooperates with rural logistics entities to disperse business risks. The biological characteristics of farm products themselves determine the high-risk nature of farm produce logistics, which not only has natural disaster risks, transportation risks, storage and preservation risks, product quality risks, and safety risks, it also has price fluctuation risks. In order to disperse these risks, rural financial support policies and measures for rural industrial revitalization, such as rural community development funds, agricultural cooperative funds, small and micro financial service centers, and other new forms of rural cooperative financing have strongly enhanced the competitiveness of agricultural brands and the comprehensive strength of rural logistics subjects (Li & Wang, 2006). The birth of rural integrated financial service stations innovate the organization and management mode of rural logistics distribution. In summary, this paper puts forward the following hypothesis.

H1: Rural financial development has a direct contribution to rural logistics.

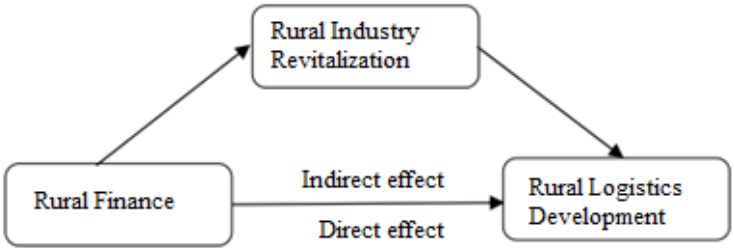
2. Rural Finance Indirectly affects Rural Logistics Development through its Role in the Revitalization of Rural Industries

The revitalization of rural industries in rural areas has a leading role in the economic development of rural areas, and the prosperity of the rural economy will certainly generate rural logistics. The seasonality of farm produce generates time-consistent financial demand for financial institutions (Braverman & Guasch, 1989), and rural finance makes rural industry development financially secure through financial support for rural industry, promotes rural industry prosperity, and accelerates rural freight market development to indirectly promote rural logistics development. Rural finance further enhances the availability of agricultural finance by expanding the scale of loans for the “three rural areas”, and supports the development and growth of agricultural and rural industrial revitalization through the continuous innovation of financial service products and business methods. Secondly, it promotes the prosperity of rural industries. Rural finance brings financial convenience to residents in rural areas, further strengthens the strength of rural financial services for the “three rural areas”, and further enhances the power of financial service resources for agriculture, which in turn drives social capital to flow back to important areas and weak links in agriculture, and promotes the integration of agriculture with information and logistics. Finally, it accelerates the formation of the rural freight market. Rural finance, through the introduction of capital, will drive the gathering of talent, materials, finance, and other factors. Transportation is the main method of factor gathering, and factor gathering will greatly increase the demand for the logistics industry in the region and surrounding areas, which will also lead to the flourishing development of related industries such as rural commodity handling, storage and processing, and transportation, thus accelerating the development of rural logistics. Accordingly, the following hypothesis is proposed.

H2: Rural financial development promotes rural logistics development by accelerating rural industrial revitalization.

The hypothetical model for this study is shown in Fig. 1.

Fig. 1. The Role Mechanism of Rural Finance for Rural Logistics Development



IV. Research Methodology

1. Data Sources

In this paper, 300 data from 30 regions in China (excluding Tibet, Hong Kong, Macao, and Taiwan) from 2011-2020 were selected to construct the model for analysis. Among these, the rural finance data are mainly from the National Bureau of Statistics, the China Financial Statistical Yearbook, the China Statistical Yearbook, the China Regional Economic Statistical Yearbook, the China Rural Financial Services Report, and the China Regional Financial Operation Report. The rural industry revitalization data are mainly from the National Bureau of Statistics, the China Statistical Yearbook, the China Rural Statistical Yearbook, and the China Agriculture and Forestry Database. The rural logistics data are mainly from the National Bureau of Statistics. Individual missing data are filled via the interpolation method.

2. Indicator Selection

2.1. Explanatory Variable: Rural Financial Development (RFIN)

Rural finance, or money fund financing in rural areas, is a credit relationship in the movement of rural money funds, and refers to various economic activities related to rural circulation and credit activities (Kong et al., 2019). Liu and Yang (2021) and Liu et al. (2021) constructed a rural financial development evaluation index system with four dimensions: total scale, organizational structure, intermediary efficiency, and service coverage. The selected measurement indexes in this paper are shown in Table 1. The specific descriptions are as follows.

Loans related to agriculture are all loans issued by financial institutions to farmers, which is an important guarantee to measure financial institution credit policies and funding sources to rural areas, and represents the scale of rural financial development.

Rural deposits are deposits of rural enterprises, collectives, and individual farmers in financial institutions, which are an important reflection of the disposable income of farmers, an important measure of the level of rural financial prosperity, and represent the scale of rural financial development.

Small rural financial institutions include rural cooperative banks, rural credit cooperatives, mutual fund societies, financial service societies, and cooperative foundations that provide financial services in rural areas. Small rural financial institutions are the mainstay of rural financial services, and the number of their business outlets and employees represent the current efficiency and coverage of rural finance.

New rural financial institutions include village banks, loan companies, rural capital cooperatives, microfinance companies, integrated rural financial

Table 1. Rural Financial Development Measurement Indicators

Variables Types	Classification of Indicators	Refinement of Indicators	Positive or Negative
Explanatory Variables	Rural Finance	Agricultural-related loans	Positive indicators
		Rural deposits	Positive indicators
		Number of small rural financial institutions business network institutions	Positive indicators
		Number of new rural financial institutions business network institutions	Positive indicators
		Number of small rural financial institution business network employees	Positive indicators
		Number of new rural financial institutions business network employees	Positive indicators

Table 2. Measurement Indicators of Rural Industrial Revitalization

Variables Type	Classification of Indicators	Refinement of Indicators	Positive or Negative
Intermediate variables	Rural Industry Revitalization	Total output value of farming, forestry, livestock and fishing	Positive indicators
		Primary industry value added	Positive indicators
		Number of village cultures	Negative indicators
		Agricultural plastic film	Positive indicators
		Total power of agricultural machinery	Positive indicators
		Farming, forestry, livestock and fishing urban units employed	Negative indicators
		Farm produce price index	Positive indicators

service points, and other new rural financial service institutions. The steady development of new rural financial institutions in recent years has greatly enriched the supply methods of rural finance (Kong et al., 2019), which is an important feature of the development trend of rural finance. New rural financial institutions activate the rural market and greatly alleviate rural capital demand, and their business outlets and number of employees represent the organizational structure and service coverage development trend of rural finance.

2.2. Mediating Variable: Rural Industrial Revitalization (IND)

The revitalization of rural industries is to form a green, safe, high-quality, and efficient rural industrial system, which provides solid industrial support for farmers to sustainably increase their income (Dong, 2019). According to the studies of Liu and Yang (2021) and Zhou et al. (2021), combined with the report "Good momentum of rural industry development" published by Han (2019), the measurement indicators selected in this paper are shown in Table 2 according to the availability of data. The specific descriptions are as follows.

The total output value of agriculture, farming, forestry, livestock, and fishing refers to the total amount of all products of agriculture, farming, forestry, livestock, and fishing expressed in monetary terms. It reflects the total scale and total results of farm produce in a certain period of time, and are an indicator to measure the total scale of rural industrial revitalization.

The value added of primary industry is the total value of new increases in primary industries such as agriculture, farming, forestry, livestock, and fishing in a year, which plays an important role in promoting national economic development and are important indicators to measure the growth and development of rural industrial revitalization.

The number of rural cultures is an important manifestation of the new service industry in rural areas, and its number and distribution directly reflect the external expression of the development level of cultural services in rural areas.

Agricultural plastic film is a general term for the plastic film used in farm produce, and is an important embodiment of ecological recycling agriculture expansion (Liu & Yang 2021). Since 2015, the amount of agricultural plastic film used in China has been decreasing, and the recycling rate has been increasing.

The total power of agricultural machinery refers to the total power of various power machines largely used in farming, forestry, livestock, and fishing, which represents the comprehensive level of agricultural mechanization and is an important embodiment of agricultural science and technology innovation.

The number of people employed in urban units of agriculture, farming, forestry, livestock, and fishing is an important reflection of agricultural science and technology innovation. With the progress of agricultural science and technology, the efficiency of farm produce has been greatly improved, and the farm produce work that previously required many people can now be completed by only a small number (Gao, 2017), so this data has shown a decreasing trend over10 years.

The farm produce price index is a relative number that reflects the trend and magnitude of the change in the level of farm products sold by producers over a certain period of time. Agricultural Product Prices is the relative number of trends and magnitude of changes in the level of this index, and can objectively reflect the national agricultural Product Prices level and structural changes, which is an important reflection of the added value of farm products, and is an important achievement in the revitalization of rural industries.

2.3. Explained Variable: Rural Logistics Development (RI)

Rural logistics refers to the logistics activities that serve farm produce and rural resident life within the rural area, which specifically include the transportation and distribution of daily necessities for rural residents, and the transportation of farm produce materials and farm products (Ding et al.,

2021). At present, there is an authoritative indicator system for rural logistics that can be used for its measurement, and considering the availability of relevant data in each region, this paper selects two important impact factors that are recognized and quantifiable, and these measurement indicators are shown in Table 3. The specific descriptions are as follows.

Table 3. Rural Logistics Development Measurement Indicators

VariablesType	Indicators Classification	Refinement of Indicators	Positive or Negative
Explained Variables	Rural Logistics	Rural delivery route km	Positive indicators
		Rural broadband access users	Positive indicators

Rural delivery route kilometers are an indicator of the total length of rural logistics delivery routes. Yao et al. (2014) pointed out that the characterization of the logistics infrastructure is to use infrastructure indicators and related to transportation, warehousing, or information technology, which can be expressed by the total length of rural delivery routes, which represents the indicator of the level of development of rural logistics infrastructure.

Rural broadband access users is the total number of rural households using the Internet in rural areas, and is a direct reflection of the level of rural information technology, representing an important reflection of the level of rural logistics information technology, and it is a measure of the main indicators of rural logistics information modernization.

2.4. Control Variables (CV)

In order to exclude the influence of factors other than all the rural financial development on rural logistics, combined with the research content of the paper, this paper refers to the study of Liu and Yang (2021), and controls for the variables of financial support to agriculture (including TRANS, MAT and WATER), rural economic development level (URB), urbanization (URB), and industrial structure (IS), which are defined in Table 4.

3. Indicator Construction

This paper mainly uses the entropy method to calculate and study the weights of each indicator for the evaluation index systems of rural finance, rural industry revitalization, and the rural logistics. Since principal component analysis or factor analysis cannot obtain specific weights and focus on classifying the data to obtain the indicator results, this paper uses the entropy method to process the indicator weights and obtain the weights of each indicator, so as to calculate the data and obtain the weights of each indicator for the explanatory variable. The following steps are applied to obtain the weights of each indicator for the explanatory variable rural finance, the mediating variable rural industrial revitalization, and the explanatory variable rural logistics, respectively.

3.1. Algorithm Introduction

In information theory, entropy refers to the measure variable of the degree of disorder in a system, and it also measures the amount of valid information provided by the data. Therefore, entropy can be used to determine the weight variable, and the entropy method is an objective assignment method which determines the indicator weights based on the magnitude of the information

Table 4. Definition of Control Variables

Variables Type	Classification	Indicator Calculation	Indicator Description
Control Variables	Level of rural economic development	Measure of GDP per capita in rural areas by province	The more developed a province's rural economy is, the better its rural industrial development and financial development will be.
	Financial support for agriculture	Local financial transportation expenditures (TRANS)	Financial support for agriculture is conducive to promoting the revitalization of rural industries.
		Local financial grain and oil materials reserve management and other expenditures (MAT)	
		Local finance expenditure on farming forestry and water affairs (WATER)	
	Urbanization	Measure of urban population as a share of total population	The development of urbanization promotes the flow of good resources to the countryside and drives the level of rural industrial revitalization.
	Industry Structure	The value added of the secondary and tertiary industries in the province as a share of GDP is measured	The upgrade of industrial structure helps to deeply expand financial services and also helps to invest resources to form more Output to promote the revitalization of rural industries.

provided by the observations of each indicator. With i evaluation objects and j evaluation indicators, the original data matrix of is formed $R=X_{ij}$, (Let the original data matrix be $R=X_{ij}$, where i denotes the evaluation object, $1 \leqslant i \leqslant m$; j denotes evaluation indexes, $1 \leqslant j \leqslant n$.) When the difference between the values of evaluation objects on a certain index is larger, the entropy value is smaller, which means that the index provides more effective information and the weight of the index should be larger; conversely, if the difference between the values of a certain index is smaller, the entropy value is larger, which means that the index provides less information and the weight of the index should be smaller. When the values of each evaluated object on a certain indicator are exactly the same, the entropy value is the largest, which means that the indicator cannot provide useful information and the weight is 0.

3.2. Algorithm Implementation Process

3.2.1 Data Matrix

$$\mathrm{R} = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}$$

Where x_{ij} is the evaluation value of the ith object of the jth indicator, the $1 \leqslant i \leqslant m$, $1 \leqslant \mathrm{j} \leqslant \mathrm{n}$.

3.2.2 Normalization of Data

Since the unit of measurement of each indicator is not uniform, when calculating the indicator weights with each indicator, it is necessary to first standardize the process and convert the absolute values of each indicator into relative values, so as to eliminate the problem of homogenization among indicators.

For positive and negative indicators, the meanings are different and the calculation methods are different. A higher value of positive indicators is better, and a lower value of negative indicators is better, so different data standardization methods are used for positive and negative indicators. $P=X_{ij}$ is the standardized data of the *j*th indicator of the *i*th evaluation object, indicating the deviation of the *j*th indicator value of the *i*th evaluation object from the minimum value relative to the maximum minimum. X_{ij} is the original data of the *j*th index of the *i*th evaluation object; *n* is the number of evaluated objects.

For positive indicators:

$$P_{ij} = \frac{x_{ij} - \min\limits_{1\le i\le m}(x_{ij})}{\max\limits_{1\le i\le m}(x_{ij}) - \min\limits_{1\le i\le m}(x_{ij})}, j = 1,2,\cdots,\mathrm{n}$$

For negative indicators.

$$P_{ij} = \frac{\max\limits_{1\le i\le m}(x_{ij}) - x_{ij}}{\max\limits_{1\le i\le \mathrm{m}}(x_{ij}) - \min\limits_{1\le i\le m}(x_{ij})}, j = 1,2,\cdots,n$$

Calculate the weight of the *j*th indicator of the *i*th object indicator

$$r_{ij} = \frac{P_{ij}}{\sum_{i=1}^{m} P_{ij}}, j = 1,2,3,\ldots,n$$

Calculate the entropy value of the *j*th index e_j

$$e_j = -c\sum_{i=1}^{\mathrm{m}} r_{ij} ln r_{ij}$$

where $c>0$ and ln is the natural logarithm of $e_j \geqslant 0$, constant k is related the sample size m. Generally, let $c=1/ln(m)$, then $0 \leqslant e \leqslant 1$.

Calculate the entropy weight of the *j*th indicator.

$$w_j = (1 - e_j)/\sum_{j=1}^{n}(1 - e_j)$$

The results of the weights are obtained by the above steps.

The entropy weighting method was used to calculate the weights of each index, and the results are shown in Table 5.

It can be seen that among the indicators of rural finance, the largest weight is the number of business outlets of new rural financial institutions, with a weight of 0.2302, rural deposits, and loans related to agriculture are also relatively large, at 0.1997 and 0.1947 respectively, and the lowest is the number of business outlets of small rural financial institutions.

In the revitalization of rural industries, the weights of total agricultural machinery power, total output value of farming, forestry, livestock, and fishing, as well as the added value of primary industry and the number of rural culture is higher, and the lowest weight is the employment of urban units in farming, forestry, livestock, and fishing.

In rural logistics, the weight of rural broadband access users reached 0.6956, and the weight of rural delivery route kilometers was 0.3044.

Next, the composite score for each indicator is calculated where P_{ij} is the normalized data.

$$F_i = \sum_{j=1}^{n} w_j P_{ij},\ i = 1,\ 2,\ 3,\ \ldots,\ m$$

V. Empirical Analysis

1. Building the Model

By setting the explanatory variable rural logistics RI, the explanatory variable rural finance RFIN, the control variable CV, and the mediating variable rural industry revitalization IND, the following model is set.

Table 5. Weighting Results

Variables	Indicators	Weights
Rural Finance	Agricultural-related loans	0.1947
	Rural deposits	0.1997
	Number of small rural financial institutions business network institutions	0.1146
	The number of new rural financial institutions business network institutions	0.1620
	Number of small rural financial institution business network employees	0.0988
	The number of new rural financial institutions business network employees	0.2302
Rural Industry Revitalization	Primary industry value added	0.2012
	Number of village cultures	0.1993
	Agricultural plastic film	0.0369
	Total output value of farming, forestry, livestock and fishing	0.2044
	Total power of agricultural machinery	0.2479
	Farming, forestry, livestock and fishing town units employed	0.0143
	Farm produce price index	0.0960
Rural Logistics	Rural delivery route km	0.3044
	Rural broadband access users	0.6956

$$RIit = \beta_0 + \beta_1 RFIN + CV + \varepsilon_{it} \quad \text{Model 1}$$

In order to study the mediating effect of rural industrial revitalization, the rural industrial revitalization IR was used as the mediating variable according to the three-step method of the mediating effect proposed by Wen and Ye (2004) . The first step verified the effect of the explanatory variables on the explained variables, the second step verified the effect of the explanatory variables on the mediating variables, and the third step added both explanatory and mediating variables to the model for analysis to see the effect of the explanatory and mediating variables together on the effect of the explanatory variables.

$$IND_{it} = \beta_0 + \beta_1 RFIN + CV + \varepsilon_{it} \quad \text{Model 2}$$

$$RI_{it} = \beta_0 + \beta_1 RFIN + + \beta_2 IND_{it} + CV + \varepsilon_{it} \quad \text{Model 3}$$

i represents the *i*th province and city, *t* represents the *t*th year, and *εit* is the random error term, except for local financial transportation expenditure, local financial expenditure on grain and oil materials reserve management, local financial expenditure on agriculture, forestry, and water affairs, and rural economic development level, which are relatively large absolute values and are subjected to natural logarithm processing. *ln* denotes natural logarithm, and the rest of the data are proportional values and do not require natural logarithm processing.

2. Descriptive Statistics

In order to understand the basic information about the data of the explanatory and control variables, the number of data samples, the trend of the mean and the standard deviation of the

data represent the fluctuation of the data, and the maximum and minimum values of the data, descriptive statistics were generated.

As can be seen from Table 6, the mean value of rural logistics is 0.1753, the minimum value is 0.0003, and the maximum value is 0.5670, which indicates that the level of rural logistics development shows a large regional difference. The mean value of rural finance is 0.1556, the minimum value is 0.0010, and the maximum value is 0.5716, indicating that the development level of rural finance in most provinces of China is relatively low. The mean value of rural industry revitalization is 0.3134, the minimum value is 0.0646, and the maximum value is 0.7683, which indicates that the level of rural industry development varies widely among regions.

Table 6. Descriptive Statistics (N=300)

Variable	Obs	Mean	Std. Dev.	Min	Max
Rural Logistics (RI)	300	0.1753	0.1280	0.0003	0.5670
Rural Finance (RFIN)	300	0.1556	0.1119	0.0010	0.5716
Rural Industry Revitalization (IND)	300	0.3134	0.1657	0.0646	0.7683
Local financial transportation expenditures (lnTRANS)	300	5.6345	0.5405	3.7267	7.5922
Local financial grain and oil materials reserve management and other expenditures (lnMAT)	300	2.9599	0.7837	0.6678	4.3338
Local finance expenditure on agriculture, forestry and water affairs (lnWATER)	300	6.1604	0.5734	4.5194	7.1999
Level of rural economic development (lnRGDP)	300	9.3620	0.4184	8.2711	10.4606
Urbanization (URB)	300	0.5836	0.1229	0.3436	0.9415
Industrial Structure (IS)	300	0.9014	0.0533	0.7416	0.9973

3. Correlation Analysis

Correlation analysis of data can be used as a preliminary basis for verifying the quantitative relationship between variables, but it may be inconsistent with the final regression results because it does not control the influence of other variables or the inherent characteristics of panel data. The explanatory variables or control variables, those on the right side of the equation, should be relatively independent of each other, with no strong correlation, or the model results may suffer. The following is a correlation analysis.

As can be seen from Table 7, the correlation coefficient between the explanatory variables rural finance and rural logistics is 0.8657 and significant at the level of 0.01, indicating a significant positive correlation and a false preliminary verification. However, with a significance probability of more than 99%, the correlation coefficient between rural industrial revitalization and rural logistics is 0.8429, and the correlation coefficient between rural industrial revitalization and rural finance is 0.8113. The intermediary effect was preliminarily determined to exist. The majority of the control variables chosen have a significant correlation with rural logistics, indicating that the control variables chosen in this paper are reasonable. The absolute

Table 7. Correlation Analysis

Variable	RI	RFIN	IND	lnTRANS	lnMAT	lnWATER	lnRGDP	URB	IS
RI	1.0000								
RFIN	0.8657***	1.0000							
IND	0.8429***	0.8113***	1.0000						
lnTRANS	0.6457***	0.5848***	0.5478***	1.0000					
lnMAT	0.5904***	0.5768***	0.6700***	0.5745***	1.0000				
lnWATER	0.7605***	0.7558***	0.7683***	0.7785***	0.7002***	1.0000			
lnRGDP	0.2471***	0.3093***	0.0487	0.1646***	0.1294**	0.2837***	1.0000		
URB	-0.1275**	-0.1030*	-0.3254***	-0.1359**	-0.0522	-0.1576***	0.7887***	1.0000	
IS	0.1118	0.1226**	-0.1805***	0.1209**	-0.0667	-0.0543	0.5315***	0.6319***	1.0000

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively.

value of the correlation coefficient between control variables is less than 0.8, and panel data effectively reduces the impact of multicollinearity, allowing us to proceed to the next analysis.

4. Multiple Regression Analysis

In order to control the effect brought by year on the model results, this paper uses a two-way fixed-effects model to study and obtain the relationship between rural finance and rural logistics.

Table 8 is the multiple regression analysis, and the results show that the adjusted R-squared is 0.6393, meaning the goodness of fit is at a relatively high level; the F-test value is 35.9275, meaning there is more than a 99% probability of passing the significance test of the overall model; the impact coefficient of rural finance is 0.3093, meaning there is a more than 99% probability that rural finance has a significant impact; and there is a significant positive impact that rural finance will effectively improve rural logistics. With other variables unchanged, each unit increase in rural finance will cause an average increase of 0.3093 units in rural logistics, and the control variables urbanization and industrial structure have a significant effect, and there is a significant positive effect. Therefore, Hypothesis 1 is verified

Table 8. Multiple Regression Analysis

Variables	(1) RI	(2) RI	(3) RI	(4) RI	(5) RI	(6) RI	(7) RI
RFIN	0.3173***	0.3079***	0.3082***	0.3104***	0.3108***	0.3200***	0.3093***
	(7.0902)	(6.8611)	(6.8525)	(6.8352)	(6.9378)	(7.3357)	(7.0716)
lnTRANS		-0.0152*	-0.0156*	-0.0169*	-0.0165*	-0.0074	-0.0086
		(-1.7759)	(-1.7906)	(-1.8073)	(-1.7900)	(-0.8021)	(-0.9378)
lnMAT			0.0017	0.0016	0.0006	0.0049	0.0061
			(0.2584)	(0.2397)	(0.0993)	(0.7763)	(0.9724)
lnWATER				0.0068	-0.0009	-0.0065	-0.0018
				(0.3846)	(-0.0483)	(-0.3755)	(-0.1028)
lnRGDP					0.1264***	0.0379	0.0202
					(2.8474)	(0.7787)	(0.4109)
URB						0.3996***	0.4005***
						(3.9600)	(3.9908)
IS							0.3676*
							(1.9376)
Constant	0.1039***	0.1864***	0.1838***	0.1522	-0.9246**	-0.3811	-0.5759
	(15.8756)	(3.9712)	(3.8180)	(1.5996)	(-2.3729)	(-0.9457)	(-1.3935)
Individual and year fixed effects	Control	Control	Control	Control	Control	Control	Control
Adjusted R^2	0.6033	0.6065	0.6051	0.6038	0.6144	0.6354	0.6393
F-statistic	49.3633***	45.5342***	41.5948***	38.2798***	37.1077***	37.6656***	35.9275***

Note: Values in parentheses are t-values; *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively.

5. Analysis of Intermediary Effects

In order to investigate the mediating effect of rural industrial revitalization, or to verify whether rural finance affects rural logistics by influencing rural industrial revitalization, an analysis was conducted, as shown below.

As can be seen from Table 9, the influence coefficient of rural industrial revitalization is 0.1564, which is significant at the 0.01 level of significance; that is, there exists more than 99% probability that rural finance is promoting the development of rural industrial revitalization. In the third step of the mediating effect model, the influence coefficient of rural finance is 0.2294, which is significant at the 0.01 level of significance, and the influence coefficient of rural industrial revitalization is 0.5113, which is significant at the 0.01 level of significance, indicating that rural industrial revitalization plays a mediating effect. Therefore, Hypothesis 2 is verified.

Table 9. Analysis of Intermediary Effects

Variable	Model 2 IND	Model 3 RI
RFIN	0.1564***	0.2294***
	(4.2619)	(5.5965)
IND		0.5113***
		(7.5525)
lnTRANS	-0.0164**	-0.0003
	(-2.1153)	(-0.0334)
lnMAT	0.0102*	0.0009
	(1.9171)	(0.1646)
lnWATER	0.0087	-0.0062
	(0.5941)	(-0.3948)
lnRGDP	0.1584***	-0.0608
	(3.8380)	(-1.3268)
URB	0.0884	0.3554***
	(1.0496)	(3.9032)
IS	-0.6134***	0.6812***
	(-3.8546)	(3.8562)
Individual and year fixed effects	Control	Control
Adjusted R^2	0.7268	0.7045
F-statistic	52.5239***	44.6299***

Note: Values in parentheses are t-values; *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively.

6. Heterogeneity Test

According to the East West Central division method of the National Bureau of Statistics, the eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the central region includes Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; and the western region includes Sichuan, Chong qing, Gui zhou, Yunnan, Tibet, Shaanxi, Xinjiang Gansu, Qinghai, Ningxia, Guangxi, and Inner Mongolia. Based on this classification, we study whether the impact of rural finance on rural logistics differs between the east, middle, and west, and the regression results are shown in the table below.

From Table 10, we can see that the impact coefficients of rural finance in the east, middle, and west are 0.4697, 0.1287, and 0.2908 respectively, which are all significant at the 0.01 level of significance; that is, there is a significant positive impact of rural finance in the east, middle, and west on rural logistics, and the impact coefficient in the east is highest with the impact coefficient in the middle the lowest.

Table 10. Heterogeneity Analysis

Variable	East RI	Middle RI	West RI
RFIN	0.4697***	0.1287***	0.2908***
	(5.2767)	(2.8643)	(3.6100)
lnTRANS	0.0019	-0.0488***	0.0179
	(0.1197)	(-3.7522)	(1.0284)
lnMAT	-0.0052	0.0202*	-0.0073
	(-0.4334)	(1.7732)	(-0.5652)
lnWATER	0.0189	0.0229	0.0298
	(0.5964)	(0.8078)	(0.9778)
lnRGDP	0.0990	0.1785***	0.1756
	(0.7814)	(2.9759)	(0.8885)
URB	0.6866***	0.8017***	0.6389**
	(4.3660)	(4.2375)	(2.0246)
IS	-0.3077	0.2660	0.8170**
	(-0.4566)	(1.6366)	(2.0599)
Constant term	-1.0604	-2.0012***	-2.6707
	(-1.0602)	(-3.8403)	(-1.5026)
Individual and year fixed effects	Control	Control	Control
Observations	110	80	110
Adjusted R^2	0.6823	0.8571	0.6094
F-statistic	16.2572***	31.0460***	12.2532***

Note: Values in parentheses are t-values; *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively.

Further mediating effect analysis was done with data from the East, Middle, and West.

From Table 11, we can see that in the eastern region, the impact coefficient of the second step of rural finance is 0.2058, and it is significant at the 0.01 level of significance. The third step of rural finance and rural industrial revitalization in the eastern region all have a significant impact on rural logistics, indicating that rural industrial revitalization plays a partial mediating effect. In the western region, the second step of rural finance still has a significant positive impact on rural industrial revitalization. In the central region, the influence of the second step of rural finance on rural industrial revitalization is not significant, while in the third step, the influence of rural finance is significant and the influence of rural industrial revitalization is significant, and the p-value is greater than 0.1 after a Sobel test, which means that the mediating effect is not significant. The intermediary effect is not significant, indicating that there is no intermediary effect in the central region.

Table 11. Heterogeneity Analysis of Mediation Effects

Variable	East IND	East RI	Middle IND	Middle RI	West IND	West RI
RFIN	0.2058***	0.3651***	0.0233	0.1200***	0.2730***	0.0193
	(3.1178)	(4.1641)	(0.2926)	(3.5177)	(4.7869)	(0.2966)
IND		0.5084***		0.3723***		0.9946***
		(3.6857)		(6.4997)		(8.9799)
lnTRANS	-0.0086	0.0063	-0.0421*	-0.0331***	-0.0159	0.0337***
	(-0.7323)	(0.4233)	(-1.8291)	(-3.2600)	(-1.2911)	(2.6853)
lnMAT	0.0204**	-0.0156	0.0726***	-0.0069	-0.0004	-0.0069
	(2.2816)	(-1.3466)	(3.6078)	(-0.7179)	(-0.0423)	(-0.7495)
lnWATER	-0.0309	0.0346	0.0160	0.0169	0.0178	0.0121
	(-1.3185)	(1.1614)	(0.3184)	(0.7873)	(0.8247)	(0.5536)
lnRGDP	0.1833*	0.0058	0.0874	0.1460***	0.2837**	-0.1066
	(1.9517)	(0.0479)	(0.8230)	(3.1876)	(2.0278)	(-0.7370)
URB	0.0512	0.6605***	-0.1454	0.8558***	0.4025*	0.2386
	(0.4388)	(4.5025)	(-0.4341)	(5.9512)	(1.8016)	(1.0382)
IS	-1.0134**	0.2076	-0.5686*	0.4777***	-0.0515	0.8682***
	(-2.0281)	(0.3226)	(-1.9756)	(3.7443)	(-0.1833)	(3.0635)
Constant term	-0.3861	-0.8641	-0.0064	-1.9988***	-2.3776*	-0.3060
	(-0.5206)	(-0.9256)	(-0.0069)	(-5.0546)	(-1.8895)	(-0.2360)
Individual and year fixed effects	Control	Control	Control	Control	Control	Control
Observations	110	110	80	80	110	110
Adjusted R^2	0.6323	0.7241	0.7579	0.9177	0.8284	0.8007
F-statistic	13.3396	18.4199	16.8910	53.2263	34.5203	27.3412

Note: Values in parentheses are t-values; *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively.

7. Analysis of Heterogeneity Test Results

There are regional differences in the development of rural finance in China, with the eastern region having a higher level of development than the central and western regions. The degree of financial expansion is the directional coordinate of industrial development, and the rapid development of rural industries will lead to a very large demand for logistics, which will largely drive the rapid growth of the logistics industry (Rao, 2021). In the eastern and western rural areas, the topographical differences are large, rural industries have a greater impact on rural logistics, and rural financial development has a more obvious role in promoting the revitalization of rural industries. In the central region, due to smooth topography, relatively perfect logistics infrastructure, and little difference in transportation costs, rural industries have limited influence on rural logistics expansion, and rural financial expansion directly affects rural logistics development.

8. Robustness Test

To ensure the reliability of the above results, the following robustness tests are done.

Since some of the indices for first-tier cities such as Beijing, Shanghai, and Guangdong, or provinces and municipalities where the first-tier cities are located in rural areas are relatively small, removing Beijing, Shanghai, and Guangdong Provinces indicates that the model results are relatively stable if the effects are relatively consistent. The model was re-estimated and the results show that, after removing the data of Beijing, Shanghai, and Guangdong Provinces, there is still a significant positive effect of rural finance, and it is significant at the 0.01 level of significance, while the second and third steps still pass the test and the model results are consistent with the previous paper. Therefore, the regression results of this paper are relatively stable and the model results pass the robustness test.

Since the global rampage of COVID-19 in 2020 had a relatively large impact on all sectors, the data from 2020 were removed and then tested for robustness. The results show that both explanatory variables and mediating effects still pass the test.

Therefore, the results of this paper are relatively robust.

VI. Conclusions and Suggestions

Based on the perspective of new rural revitalization, we conducted a panel statistical analysis on the development of rural finance, rural industry revitalization, and rural logistics, and explored the logical relationships between them. The effect of rural finance on rural logistics is heterogeneous in the east, central, and west, meaning rural industry revitalization in the central region does not play a mediating role, while rural industry revitalization in the east and west plays a significant mediating role.

Based on the above findings, this paper proposes the following recommendations.

First, it is necessary to improve the level of financial development in rural areas and increase financial support for logistics and other industries (Ding et al., 2021). Financial institutions should support more rural-related loan projects and promote the revitalization of rural industries with rural financial services. It is necessary to promote the level of small and new rural financial services to scale, and to promote more coverage of new rural financial organizations in agricultural areas, so that more farmers and new rural business entities can obtain more convenient financial service channels.

Second, accelerate the construction of the development, production, and operation systems of rural industrial revitalization. Through financial assistance, promote the revitalization of rural industries and enhance the inherent vitality of rural development. Taking market demand as the guide, according to the inherent endowment resources of rural areas combined with the cultural characteristics of rural areas, develop clustered agricultural industries suitable for rural areas. Build a modern agricultural industrialized economic system with vitality and sustainability in the market.

Third, to build a rural logistics and informatization service systems, enhance the capacity of rural informatization, and further improve the construction of rural logistics infrastructure. Effectively integrate modern rural logistics systems for farm products, farm produce materials, and rural consumer goods to create a professional and integrated rural logistics platform (Liang & Gui, 2016). The government will jointly build rural farm produce logistics facilities with key leading agricultural enterprises to ensure smooth and unimpeded information flow, product flow, and capital flow. Establish and improve financial policy mechanisms in the east, middle, and west regions, support financial institutions to implement differentiated credit policies, focus on improving regional support measures, deepen agricultural industry cooperation, promote complement resources (Liu & Yang, 2021), reach optimal allocation of resources, and form a good situation of coordinated development of rural logistics in the east, middle, and west regions.

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The Effects of Extended Technology-based Self-service on Passenger Satisfaction, Airport Image, and Behavioral Intention

Su-Yeon Lee[a], Yeong Gug Kim[b]*

[ab]College of Business Administration, Kangwon National University, South Korea.

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ABSTRACT

Purpose – This study examines the effects of Technology-Based Self-Service (TBSS) on passenger satisfaction, behavioral intention, and airport image, and analyzes the moderating effect of self-efficacy on the relationship between TBSS characteristics and passenger satisfaction.

Design/Methodology/Approach – The study uses the SPSS 26.0 and AMOS 26.0 statistical packages to analyze a sample of 238 passengers that used TBSS at Incheon International Airport (ICN). Characteristics in the categories of functionality, enjoyment, safety, and speed had positive effects on passenger satisfaction, and passenger satisfaction had a positive effect on airport image and behavioral intention.

Findings – No significant difference between the higher and lower self-efficacy groups was found in the relationship between TBSS characteristics and passenger satisfaction. The results suggest that airports employ marketing strategies that emphasize the TBSS characteristics of functionality, enjoyment, safety, and speed, particularly aspects of personal safety, including sanitation and hygiene.

Research Implications – The study shows that the industry should emphasize the value of TBSS in ensuring personal safety. The results of this study provide a theoretical basis for further research on service quality as it relates to the changing characteristics of TBSS in the post-pandemic era.

Keywords: airport image, behavioral intention, contactless service, satisfaction, technology-based self-service
JEL Classifications: I12, L93, M16, M31

* *Corresponding Author, E-mail: yeongkim@kangwon.ac.kr*

I. Introduction

Emerging infectious diseases bring about socio-economic impacts and have significant impacts on daily life, including travel. In particular, the rapid spread of COVID-19 continues to cause enormous direct and indirect damage to the world's tourism industry. Since the tourism industry is heavily influenced by the external environment, the outbreak of unpredictable crises like new infectious diseases is an obstacle to its development (Fotiadis et al., 2021). The World Health Organization's (WHO) declaration of the COVID-19 pandemic caused borders to be closed and flights to be suspended (Fotiadis et al., 2021; Qiu et al., 2020), which led to a considerable decline in aviation demand and an unprecedented crisis for the airline industry (Moon et al., 2021; Vinod, 2021). Even in the aftermath of disasters like the 9/11 terrorist attacks and the global financial crisis, the aviation industry has shown continuous growth. However, COVID-19 changed the industry's growth outlook (Liu et al., 2021), not only because of increased overseas travel restrictions but also because of increased travel delays and cancellations by travelers (Liu et al., 2021).

Airline flights that cannot be sold because of perishability lose their value, and airlines are highly dependent on cash flow (Vinod, 2020), so the industry is trying to change how it uses systems and technologies to survive. In this regard, the introduction of major Technology-based Self-Services (TBSS), such as self-check-in and self-bag-drop kiosks, is progressing rapidly (Moon et al., 2021). In the past, TBSS was mainly considered convenience to consumers and benefits commercially with changing from face-to-face service to contactless service (Antwi et al., 2021; Lee-Anant & Monpanthong, 2021). However, TBSS innovation is often touted as critical for environment changes because of the rapid spread of COVID-19 (Liu & Yang, 2021). As customers began to value personal safety and health because of COVID-19 (Atadil & Lu, 2021), they demanded that the industry change from being centered on value and convenience to prioritizing passenger safety in terms of hygiene and sanitation (Lee-Anant & Monpanthong, 2021). In the aftermath of COVID-19, contactless services should be emphasized over face-to-face services (Bae & Chang, 2020; Rogerson & Rogerson, 2021). Clearly, the use of contactless services will expand in the post-COVID-19 era (Lee & Jo, 2021).

To enhance the competitiveness of the aviation industry in this era, technologies and service strategies must reflect users' changing values. Although many studies on TBSS have been conducted, they focused on limited technology characteristics, such as the Technology Acceptance Model (TAM) and Technology Readiness (TR), and so are insufficient in light of the active introduction of TBSS in the aviation industry (Moon et al., 2021). In addition, since customers value safety and hygiene aspects post-COVID-19, it is expected that safety-related aspects of TBSS characteristics will be emphasized. Unlike prior studies focused on technology characteristics, this study is highly relevant to today's industry environment in reflecting and identifying the characteristics of TBSS that have changed since the outbreak of COVID-19.

The purpose of this study is to determine TBSS user satisfaction with the characteristics of the new TBSS that have been developed since the pandemic, and the effect of satisfaction on airport image and behavioral intention. Given the rapid introduction of contactless services and the increased importance of TBSS after the pandemic, the results of this study suggest a new service and marketing strategy for managers in the aviation industry that will increase efficiency and passenger convenience and personal safety.

II. Literature Review

1. Technology-Based Self-Service (TBSS)

TBSS allows customers to produce and use services directly instead of interacting with employees (Kim & Park, 2019). Although TBSS is used interchangeably with the term "self-

service technology (SST)", the two differ in some ways. SST refers to technological interfaces that allow consumers to produce a service that is independent of face-to-face involvement with a service employee (Bogicevic et al., 2017), so it focuses more on the technology, while TBSS focuses on the service. In other words, as TBSS is a broader concept related to SST, TBSS refers to overall activities that enable customers to perform services while using technology on their own (Dabholkar, 1994). Considering that this research seeks to identify the relationships between the characteristics of TBSS and passenger satisfaction and the relationship between passenger satisfaction and airport image, TBSS is more suitable.

TBSS are convenient to use and are often preferred over traditional services (Lee-Anant & Monpanthong, 2021). Users can save time and can benefit from such advantages as increased convenience and choice (Lee-Anant & Monpanthong, 2021). As for service providers, TBSS can significantly reduce costs and improve performance (Dabholkar & Bagozzi, 2002; Lu et al., 2009). Kim and Park (2019) point out that TBSS can provide standardized services that enhance productivity and efficiency, and increase customer satisfaction.

In the aviation industry, TBSS has been introduced to improve efficiency and safety for both users of and providers in airports and airlines (Kim & Park, 2020). Passengers use mobile services for seat assignment, web check-in, self-check-in kiosks, and self-bag-drop without the need to meet with airline staff (Antwi et al., 2021; Lien et al., 2019). As the use of TBSS expands, it has become all but essential in the aviation industry, especially in the COVID-19 era (Antwi et al., 2021). The International Air Transport Association's (IATA) 2021 global passenger survey found that passengers are willing to use technologies to reduce waiting time (IATA, 2021), so the provision of TBSS is expected to enhance passenger satisfaction.

Research on TBSS conducted on how customers evaluate TBSS characteristics focuses primarily on service quality (Anitsal & Paige, 2006; Lin & Hsieh, 2011), perceived value (Kim & Park, 2019; Lee & Jo, 2021), satisfaction (Kim & Park, 2019), attitude (Gures et al., 2018; Lee & Jo, 2021), and behavioral intention (Kim & Park, 2019; Lee & Jo, 2021), and emphasizes the importance of service.

2. Passenger Satisfaction

To begin, satisfaction can be explained as the evaluation of services consumed (Saut & Song, 2022). Satisfaction is the result of a state of pleasure or disappointment that the customer creates when the perceived outcome is compared to the expected value (Liu & Guo, 2019). The present studies on customer satisfaction focus on expectation disconfirmation theory as the main principle (Coban, 2012). The perception of customer satisfaction is gradually developed by integrating prior expectations and satisfaction after experiencing services or products (Saut & Song, 2022). With this regard, Oliver (1997) stated that customer satisfaction is the customer's evaluation between pre-purchase and post-purchase with the customer's expectations, and so the satisfaction that the customer generates after the service experience is integrated. Thus, customers are dissatisfied when their expectations are not completed, and that satisfaction will occur if expectations are fulfilled. Exceeding expectations increases satisfaction with the services or products (Liu & Guo, 2019).

As the importance of customer satisfaction has increased in the aviation industry, like in other industries, customer satisfaction is recognized as an important area for airport services (Arif et al., 2013; Bogicevic et al., 2013). Airports and airlines need to study passenger satisfaction and develop service quality indicators to improve customer experiences reflecting passenger satisfaction (Bogicevic et al., 2013).

3. Airport Image and Behavioral Intention

Generally, the image can be defined as customer impressions, views, and beliefs (Coban, 2012). Image is the comprehensive meaning that

customers define the business organization in their minds, and image is what motivates or determines the use of the products or services of the business organization (Saut & Song, 2022). Since image is sustained over time, intangible assets that affect image such as brand reputation, awareness, and trust have both positive and negative impacts on customer perception (Hallencreutz & Parmler, 2021).

Since prior research on the image has mostly been on company image or brand image, research regarding an objective definition of airport image is insufficient (Park & Ryu, 2019). According to Ariffin and Yahaya (2013), the airport is regarded as the first image of the destination for tourists. An impressive image helps to create an enjoyable experience. It is also expected that airports will be able to impress customers more if they are physically and operationally designed taking into account national characteristics, identities, or symbols. Airport image can be influenced by airport properties, and airport image is formed by passenger evaluations and the overall impression of the airport by passengers (Saut & Song, 2022).

Behavioral intention refers to the intention to use a product or service according to an individual's subjective state and motives (Kim & Park, 2019). Intention is the possibility to act, and intention leads to actual behavior (Tang et al., 2017). For example, it is important to review the intention to visit, as the stronger the intention of the visitor to the destination, the more they visit the destination. In other words, an accurate assessment of behavioral intention could predict actual behavior (Saut & Song, 2022).

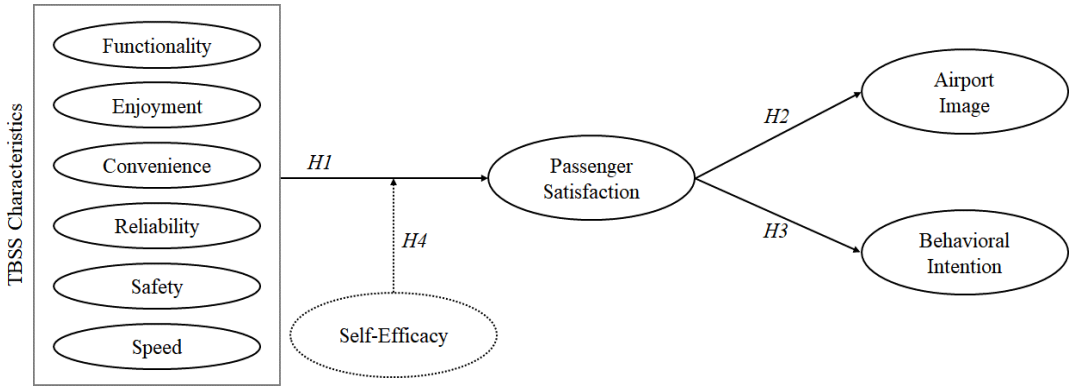
Saut and Song (2022) stated that behavioral intentions have been widely applied in various business environments to reflect customer tendencies and intentions to use products or services. Also, behavioral intentions including visit and recommendation intentions have been studied by many researchers. In the hospitality field, it is known that there is a positive relationship between customer satisfaction and behavioral intention (Lee et al., 2004). In previous studies, the relationship between restaurant customer satisfaction and behavioral intention was positively affected (Ryu & Han, 2010; Uslu, 2020), and the positive relationship between airline passenger satisfaction and behavioral intention was confirmed (Kim & Park, 2019).

In this context, when these relationships are integrated into one model, antecedents and consequences can be verified. Applying the influence relationships between TBSS, passenger satisfaction, airport image, and behavioral intention is the main focus of this study.

4. Proposed Framework and Hypotheses

Based on the literature review, the research model is presented in Fig. 1.

Fig. 1. Research Model



This study examines the theoretical model and analyzes how airport TBSS characteristics affect passenger satisfaction, image of the airport, and behavioral intention using six TBSS categories: functionality, enjoyment, convenience, reliability, safety, and speed (Chang & Yang, 2008; Dabholkar, 1996; Gures et al., 2018; Kim & Park, 2019; Lee & Jo, 2021; Lin & Hsieh, 2011). The concept of customer satisfaction can be defined as the psychological state created by the difference between expectations and actual experiences (Oliver, 1997). To measure customer satisfaction, many studies apply expectation disconfirmation theory as the main principle (Coban, 2012; Prayag, 2008), which states that the customer is satisfied if the perceived performance is equal to or better than the expectation, and dissatisfied otherwise. The aviation industry's focus on customer satisfaction has increased (Bogicevic et al., 2013; Yeh & Kuo, 2003) to where customer satisfaction is considered a priority (Arif et al., 2013). Based on the literature review, the first hypothesis is as follows.

H1: TBSS characteristics have a significant effect on passenger satisfaction.

Image is a conceptual, abstract, and subjective concept (Coban, 2012; Nguyen & Leblanc, 2001). The usual definition of image is that of a mental reaction that integrates consumer emotions, sensations, thoughts, behaviors, and intentions (Coban, 2012; Park & Ryu, 2019). As Baloglu and Brinberg (1997) and Coban (2012) claim, the image of a destination refers to customer impressions, views, and beliefs about a place. In this respect, an airport's image can be defined as passenger impressions, views, and beliefs about the airport. Studies conducted in diverse fields examine the relationship between satisfaction and image (Jani & Han, 2013; Kandampully & Hu, 2007; Park & Ryu, 2019), finding that, for instance, airport passenger satisfaction influences airport image significantly (Park & Ryu, 2019) and creates a positive relationship between customer satisfaction and hotel image (Jani & Han, 2013; Kandampully & Hu, 2007).

Behavioral intention refers to customer responses to satisfaction by acting subjectively through the attitudes and beliefs they have formed as a result (Zeithaml et al., 1996). Behavioral intention is the intention to use a product or service based on an individual's subjective state and motives, which influence the behavior. (Kim & Park, 2019). Ryu and Han (2010) identified a significant relationship between customer satisfaction and behavioral intention in the hospitality field, while Lee et al. (2004) found that the relationship is positive. In a study of restaurant service quality dimensions, Uslu (2020) verified that restaurant customer satisfaction has a significant and positive effect on behavioral intention. Ryu and Han (2010) studied the impact of service, the physical environment, and food quality on customer satisfaction and behavioral intention and show that customer satisfaction is a significant predictor of behavioral intention. Kim and Park (2019) found that the relationship between behavioral intention and passenger satisfaction is positive. Therefore, two hypotheses are formulated to examine the impact of passenger satisfaction on airport image and behavioral intention.

H2: Passenger satisfaction has a positive effect on airport image.

H3: Passenger satisfaction has a positive effect on behavioral intention.

Self-efficacy is a powerful predictor of behavior in diverse situations (Ellen et al.,1991). Self-efficacy in the current context refers to an individual's belief in his or her ability to use an airport's TBSS successfully. Van Beuningen et al. (2009) stated that research on TBSS is related to customer self-efficacy in using TBSS, while Silver et al., (1995) demonstrated the importance and influence of self-efficacy as a moderating factor between attributions and performance. Kim and Park (2019) reported that self-efficacy played a pivotal role as a moderator of the relationship between satisfaction with an airport's TBSS and behavioral intention. The following hypothesis addresses the impact of TBSS characteristics on passenger satisfaction as moderated by passenger self-efficacy.

H4: The effects of TBSS characteristics on passenger satisfaction are moderated by self-efficacy.

III. Methods

1. Interview

Interviews were conducted to identify the new TBSS characteristics airport passengers now recognize after the spread of COVID-19. The interviewees were selected from passengers that visited Incheon International Airport (ICN). Five interviews were conducted using snowball sampling to find interviewees that could explain their experiences related to the study's focus (Patton, 2014). Five interviewees have diverse experiences using TBSS at ICN. The interviews were conducted on the telephone due to the impact of COVID-19. Each interview lasted about 30 minutes and was recorded after obtaining participant consent. If consent was not obtained, the interview was transcribed in detail. Semi-structured interviews were conducted that focused on the personal definitions of TBSS, opinions about, and experiences using TBSS. In a semi-structured interview, the order and scope of questions vary according to the flow of the conversation (Mark et al., 2012). The concept of TBSS and major types of TBSS at the airport were explained to the interviewees in advance. Thematic analysis, which is often used in qualitative research, was applied (Bryman, 2016). Meaningful topics were revealed, the analysis procedure was reviewed, and opinions were collected to secure reliability and validity, and identify any omissions or errors in the derivation of TBSS characteristics.

2. Questionnaire Survey Interview

A questionnaire was constructed based on previous research and modified to suit the purpose of the study. Table 1 shows each item for the effect of six TBSS characteristics (functionality, enjoyment, convenience, reliability, safety, and speed) on satisfaction, airport image, behavioral intention, and self-efficacy. The choice of these characteristics is based on previous studies (Chang & Yang, 2008; Dabholkar, 1996; Gures et al., 2018; Kim & Park, 2019; Lee & Jo, 2021; Lin & Hsieh, 2011). The questionnaire applied a 5-point Likert scale to all items, from 1 (strongly disagree) to 5 (strongly agree).

Table 1. Definition and Items of Factors

Factor	Definition and Items	References
Functionality	Definition: Possibility of the clear and efficient service process of TBSS use	Kim and Park (2019), Gures et al. (2018)
	TBSS offers more services than face-to-face services	
	It is efficient to use the TBSS at the airport	
	TBSS improves airport services	
	TBSS make the airport service procedure clear	
Enjoyment	Definition: Pleasure, fun and interest of TBSS use	Chang and Yang (2008), Dabholkar (1996), Gures et al. (2018), Kim and Park (2019), Lee and Jo (2021)
	TBSS arouses my curiosity	
	TBSS is more enjoyable than face-to-face services	
	TBSS is not boring	
	TBSS is interesting	

Convenience	Definition: Ease of TBSS use TBSS is simple to use TBSS procedure is convenient to use TBSS access is convenient. TBSS is easy to use	Kim and Park (2019), Lin and Hsieh (2011)
Reliability	Definition: Trust of TBSS technical perfection TBSS provides consistent service TBSS provides accurate service TBSS has no errors	Chang and Yang (2008), Dabholkar (1996)
Safety	Definition: The extent to which people have safety awareness of TBSS use When using the TBSS, there is no fear of disease infection compared to the face-to-face services TBSS is hygienically safe When using the TBSS, I have no fear of solving problems When using the TBSS, my personal information is safe	Lin and Hsieh (2011), Moon et al. (2017)
Speed	Definition: The extent to which people save waiting and providing time through TBSS use TBSS can handle many passengers at once TBSS can handle services quickly TBSS can be used in real-time TBSS can save the time	Chang and Yang (2008), Dabholkar (1996), Gures et al. (2018)
Satisfaction	Definition: The extent to which using TBSS is perceived to be positive I am more satisfied with the TBSS than the face-to-face service I think it is the right decision to use TBSS I think the TBSS is helpful to me I am generally satisfied with the use of TBSS	Jani and Han (2013), Kandampully and Hu (2007), Kim and Park (2019), Park and Ryu (2019)
Airport image	Definition: The extent to which passengers have impressions, viewpoints and beliefs in terms of airport I like the Incheon International Airport image The image of Incheon International Airport is unique I feel friendly to Incheon International Airport	Jani and Han (2013), Kandampully and Hu (2007), Park and Ryu (2019)
Behavioral intention	Definition: The intention of recommendation and use of TBSS consistently I am willing to actively recommend the TBSS I will tell people around me about the TBSS positively I will continue to use the TBSS in the future	Kim and Park (2019), Ryu and Han (2010), Uslu (2020)
Self-efficacy	Definition: The extent to which people have beliefs in terms of TBSS use successfully I can use the TBSS without assistance I can use the TBSS if there is a manual I can use the TBSS if there is someone who can give me help	Kim and Park (2019), Lippke et al. (2009), Silver et al. (1995)

The survey was carried out online for twelve days, from January 5th to January 16th, 2022, using the Google forms. A total of 271 questionnaires were collected; 33 were excluded because the participants had not visited the airport, had no TBSS experience, or whose answers were insincere. Therefore, 238 questionnaires were used for the empirical analysis. The questionnaire's respondents were passengers at ICN with experience using TBSS after 2018, when TBSS was activated with the expansion of Terminal 2. The SPSS 26.0 and AMOS 26.0 statistical programs were used to analyze the hypotheses, and frequency analysis was performed to determine participant demographic characteristics. Exploratory factor analysis (EFA) and Confirmatory factor analysis (CFA) was conducted to verify reliability and validity, and structural equation model analysis were carried out to verify the hypotheses. The moderating effect of self-efficacy was identified through multigroup analysis.

IV. Findings

1. Results of TBSS Characteristics

The characteristics are classified into six categories: functionality, enjoyment, convenience, reliability, safety, and speed. The interviews showed that the decision to use TBSS was affected when its functionality increased expectations of accuracy, efficiency, and enjoyment (including pleasure, interest, and fun). As respondents had negative experiences with technology or expected low error frequency, reliability was also important, including the technical perfection of TBSS. Respondents were also impacted by convenience (convenience of use and procedure, and ease of operation, and use) and speed (saving waiting time and fast service).

In particular, interviewees revealed that they considered the safety of TBSS after the spread of COVID-19, and decided to use TBSS to avoid face-to-face contact in consideration of sanitation and hygiene. The interview results show issues related to health, such as infection in the sub-category of safety. Safety in this study includes fear of disease infection and sanitary safety, as well as the aspects of error and malfunction (Moon et al., 2017).

2. Demographic Characteristics

Of the 238 respondents to the questionnaire, 50.4% were male and 49.6% were female. As for age distribution, 46.6% were in their 20s, and 48.7% were in their 30s, so most participants were between the ages of 20 and 39. The majority of respondents were office workers (47.9%) and college/university graduates (77.3%). The demographic characteristics of the samples are shown in Table 2.

Table 2. Demographic Characteristics of Questionnaire Survey Respondents

Category and Items		N	%	Category and Items		N	%
Gender	Male	120	50.4	Education	High school	6	2.5
	Female	118	49.6		College/University	184	77.3
Age	20 ~ 29	111	46.6		Graduate school	48	20.2
	30 ~ 39	116	48.7	Job	Office worker	114	47.9
	40 ~ 49	6	2.5		Self-employment	13	5.5
	50 ~ 59	2	0.8		Student	94	39.5
	Over 60	3	1.3		etc	17	7.2

Table 3. Results of Exploratory Factor Analysis

Variable		Factor Loading	Eigen Value	Cumulative %	Cronbach's Alpha
Functionality	FUN1	.738	1.879	70.646	.895
	FUN2	.707			
	FUN3	.707			
	FUN4	.729			
Enjoyment	ENJ1	.834	2.026	64.953	.911
	ENJ2	.782			
	ENJ3	.690			
	ENJ4	.682			
Convenience	CON1	.596	10.502	50.348	.926
	CON2	.579			
	CON3	.590			
	CON4	.606			
Reliability	REL1	.650	16.709	30.412	.819
	REL2	.712			
	REL3	.652			
Safety	SAF1	.777	1.091	81.668	.854
	SAF2	.771			
	SAF3	.634			
	SAF4	.520			
Speed	SPE1	.762	3.985	58.814	.934
	SPE2	.703			
	SPE3	.766			
	SPE4	.656			
Satisfaction	SF1	.546	1.207	78.361	.919
	SF2	.516			
	SF3	.514			
	SF4	.661			
Airport image	AI1	.756	1.030	84.788	.800
	AI2	.749			
	AI3	.699			
Behavioral intention	BI1	.649	1.339	74.703	.945
	BI2	.680			
	BI3	.679			

KMO=.931, χ^2=7577.829, df(p)=528(.000)

Table 4. The Results of Confirmatory Factor Analysis

Variable		Factor Loading	t-value	CR	AVE
Functionality	FUN1	.815	-	.940	.798
	FUN2	.807	14.120***		
	FUN3	.828	14.633***		
	FUN4	.868	15.617***		
Enjoyment	ENJ1	.745	-	.944	.808
	ENJ2	.855	13.636***		
	ENJ3	.919	14.751***		
	ENJ4	.884	14.154***		
Convenience	CON1	.868	-	.952	.832
	CON2	.891	19.056***		
	CON3	.890	19.011***		
	CON4	.849	17.388***		
Reliability	REL1	.903	-	.902	.762
	REL2	.914	19.201***		
	REL3	.568	9.537***		
Safety	SAF1	.864	-	.917	.742
	SAF2	.969	20.691***		
	SAF3	.622	10.810***		
	SAF4	.599	10.268***		
Speed	SPE1	.861	-	.964	.871
	SPE2	.932	20.624***		
	SPE3	.873	18.166***		
	SPE4	.870	18.071***		
Satisfaction	SF1	.828	-	.952	.833
	SF2	.874	16.744***		
	SF3	.915	18.022***		
	SF4	.839	15.710***		
Airport image	AI1	.783	-	.900	.751
	AI2	.678	9.932***		
	AI3	.820	11.609***		
Behavioral intention	BI1	.915	-	.976	.931
	BI2	.968	28.020***		
	BI3	.905	23.172***		

χ^2=1292.504, df=459, χ^2/df=2.816, p-value=.00, CFI=.888, IFI=.889, TLI=.871, NFI=.838, RMR=.031, RMSEA=.088

Note: CR= Composite reliability, AVE= Average variance extracted; ***p<.001.

3. Results of Exploratory Factor Analysis

The result of EFA revealed nine factors based on eigen values of more than 1. The KMO measure of sampling adequacy is 0.931, and a value greater than 0.7 is acceptable (Morgan, 2007). The degree of freedom is 528, χ^2 is 7577.829, and the p-value is significant (p<.001). The nine-component solution explained 84.788% of the total variance overall, and so it fits with the standard. The factor loading of each item in the nine types is greater than 0.5, which is significant to ensure conceptual validity. As a result of reliability analysis, the Cronbach's alpha of all variables was 0.800 or higher, exceeding the minimum standard of 0.7 (Fornell & Larcker, 1981). Consequently, the construct validity and reliability of the measurement items were appropriate.

4. Reliability and Validity

The analysis results' validity and reliability were verified through CFA and reliability analysis of measurement items (Table 4 and Table 5). As a result of CFA, the model fit was $\chi^2_{(459)}$ = 1292.504 (p<0.001), χ^2/df = 2.816, CFI=0.888, IFI=0.889, TLI=0.871, NFI=0.838, RMR=0.031, and RMSEA=0.088. Overall, the model fit was considered acceptable (Byrne, 2006). As the composite reliability (CR) is 0.900-0.976, which is above the cut-off value of 0.7, and the average variance extracted (AVE) is 0.742-0.931, which is above the cut-off value of 0.5, convergent validity was judged sufficient. The correlation was 0.478-0.798, which is less than the square root of the AVE range of 0.861-0.965, indicating discriminant validity.

Table 5. Results of Discriminant Reliability

Variable	1	2	3	4	5	6	7	8	9
1. Functionality	.893								
2. Enjoyment	.680**	.899							
3. Convenience	.708*	.627*	.912						
4. Reliability	.618**	.542**	.724*	.873					
5. Safety	.621**	.707*	.545**	.491*	.861				
6. Speed	.706**	.634*	.798**	.654**	.626**	.933			
7. Satisfaction	.718*	.706**	.690*	.602**	.665**	.726**	.913		
8. Airport image	.522**	.496**	.487**	.561**	.478**	.514**	.656**	.867	
9. Behavioral intention	.597*	.589**	.726**	.678**	.496**	.655*	.678*	.563**	.965

Note: *p<.05, **p<.01, ***p<.001, Diagonals reflect the square root of AVE.

5. Hypotheses Testing

The results of hypotheses testing are shown in Table 6 and Figure 2. Six hypotheses (H1a, H1b, H1e, H1f, H2, H3) were supported, while H1c and H1d were not. The positive effects of the TBSS characteristics of functionality (β=0.190, t=2.468, p<0.05), enjoyment (β=0.219, t=2.974, p<0.01), safety (β=0.148, t=2.234, p<0.05), and speed (β=0.220, t=2.593, p<0.05) on passenger

satisfaction were statistically significant. On the other hand, convenience (β=0.118, t=1.297, p>0.05) and reliability (β=0.102, t=1.519, p>0.05) were not significantly related to passenger satisfaction. Therefore, H1 was partially supported. Passenger satisfaction was positively related to airport image (β=0.674, t=9.493, p<0.001) and passenger behavioral intention (β=0.718, t=11.733, p<0.001), so both H2 and H3 were supported.

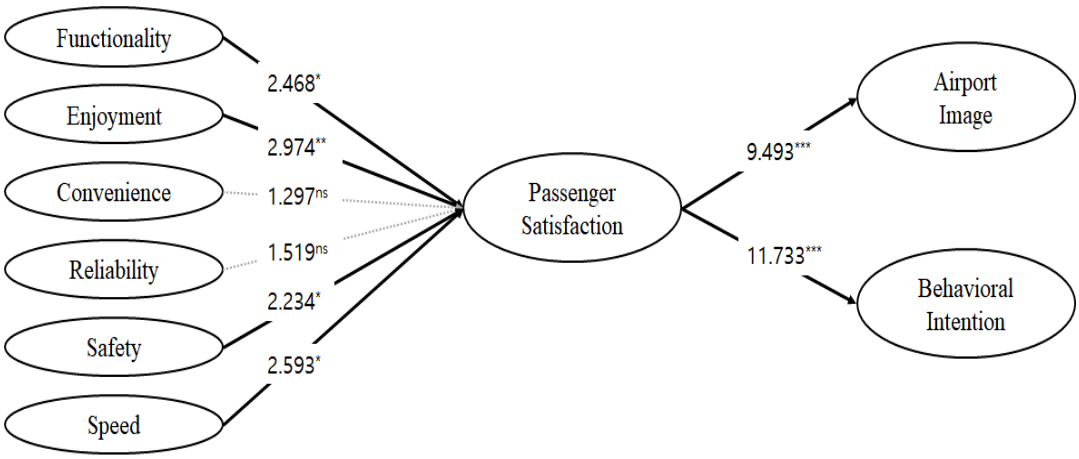
Table 6. Results of Hypotheses Testing

Hypothesis Relationship	Standardized Coefficients	t-value	Results
H1a Functionality → Satisfaction	.190	2.468*	Supported
H1b Enjoyment → Satisfaction	.219	2.974**	Supported
H1c Convenience → Satisfaction	.118	1.297^{ns}	Rejected
H1d Reliability → Satisfaction	.102	1.519^{ns}	Rejected
H1e Safety → Satisfaction	.148	2.234*	Supported
H1f Speed → Satisfaction	.220	2.593*	Supported
H2 Satisfaction → Airport image	.674	9.493***	Supported
H3 Satisfaction → Behavioral intention	.718	11.733***	Supported

χ^2=1367.222, df=472, χ^2/df=2.897, p-value=.000, CFI=.880, IFI=.881, TLI=.866, NFI=.829, RMR=.039, RMSEA=.089

Note: *p<.05, **p<.01, ***p<.001, ns=not significant.

Fig. 2. Results of Hypotheses Testing



Note: *p<.05, **p<.01, ***p<.001, ns=not significant.

H4 predicted differences between those with higher and lower self-efficacy in the relationships between the TBSS characteristics and satisfaction. Multigroup analysis was performed to test the hypotheses (Table 7). The results of moderating effect analysis showed that $\Delta\chi^2$ =35.970, df=24, which was not statistically significant at α = 0.05 ($\Delta\chi^2_{(24)}$ =35.970, p>0.05), so the measurement equivalence was verified (Byrne, 2006). A moderating effect of self-efficacy on the relationships of the TBSS characteristics of functionality ($\Delta\chi^2_{(1)}$ =1.978, p>0.05), enjoyment ($\Delta\chi^2_{(1)}$ =2.188, p>0.05), convenience ($\Delta\chi^2_{(1)}$ =1.690, p>0.05), reliability ($\Delta\chi^2_{(1)}$ =0.481, p>0.05), safety ($\Delta\chi^2_{(1)}$ =2.360, p>0.05), and speed ($\Delta\chi^2_{(1)}$ =1.208, p>0.05) with satisfaction was not found since chi-square variations were smaller than $\Delta\chi^2_{(1)}$ =3.84.

Table 7. Results of Moderating Effects in Terms of Self-Efficacy

Groups	Model	χ^2	df	CFI	RMSEA	TLI	$\Delta\chi^2$
Lower and Upper Self-Efficacy	Configural Invariance Model	2160.335	918	0.843	0.076	0.819	35.970^{ns}
	Metric Invariance Model	2196.304	942	0.841	0.075	0.822	(df=24)

Hypothesis Relationship	Lower Self-Efficacy (N=50)		Upper Self-Efficacy (N=188)		Baseline Model χ^2	Nested Model χ^2	$\Delta\chi^2$
	β	t-value	β	t-value	(df=944)	(df=945)	(df=1)
H4a Functionality → Satisfaction	-1.093	-0.874^{ns}	0.185	2.122*	2257.566	2259.544	1.978
H4b Enjoyment → Satisfaction	1.083	1.242^{ns}	0.189	2.283*		2259.754	2.188
H4c Convenience → Satisfaction	0.556	1.969*	0.070	0.661^{ns}		2259.256	1.690
H4d Reliability → Satisfaction	-0.066	-0.329^{ns}	0.135	1.772^{ns}		2258.047	0.481
H4e Safety → Satisfaction	-0.116	-0.602^{ns}	0.196	2.406*		2259.926	2.360
H4f Speed → Satisfaction	0.706	1.203^{ns}	0.226	2.389*		2258.774	1.208

χ^2/df=2.391, CFI=.834, IFI=.836, TLI=.814, NFI=.748, RMSEA=.077

Note: *p<.05, **p<.01, ***p<.001, ns=not significant.

V. Discussion and Conclusions

TBSS has become an essential part of the rapidly changing aviation industry after the outbreak of COVID-19. The impacts of TBSS characteristics on passenger satisfaction, airport image, and behavioral intention were empirically analyzed, along with the moderating effect of self-efficacy on the relationship between TBSS characteristics and satisfaction.

Among the main research results were that, first, TBSS characteristics based on passenger experiences with TBSS, are functionality, enjoyment, convenience, reliability, safety, and speed, and that airport passengers take into

account safety in reference to TBSS, including sanitation and hygiene. These aspects of safety in the COVID-19 era allowed passengers to reduce infection risk and avoid face-to-face services. Thus, personal safety is a new characteristic of TBSS to be considered in the post-corona era.

Second, the study's analysis found that four TBSS characteristics, functionality, enjoyment, safety, and speed, have significant positive effects on passenger satisfaction. These results support the finding of Orel and Kara (2014) that TBSS functionality and enjoyment have significant effects on satisfaction, and the finding of Kim and Park (2019) that TBSS functionality and enjoyment have a significant effect on perceived value and a significantly positive effect on satisfaction.

Third, the analysis found that passenger satisfaction has a significant positive effect on behavioral intention and airport image. This finding supports the results of Jani and Han (2014), Kandampully and Hu (2007), and Park and Ryu (2019), who studied the relationship between customer satisfaction and image, and the results of Kim and Park (2019), Ryu and Han (2010), and Uslu (2020), who reported a significant relationship between behavioral intention and customer satisfaction. Therefore, the higher the passenger satisfaction, the more positive the airport image and the behavioral intention to recommend and reuse TBSS.

Fourth, the study found no significant difference in the moderating effects of those with higher self-efficacy and those with lower self-efficacy on the relationship between TBSS characteristics and satisfaction, which is contrary to the results of Kim and Park's (2019), who confirmed the influence of self-efficacy on the use of TBSS by all generations. The reason for the different results may be that the sample in the current study is made up mostly of people in their twenties and thirties. Since this group has significant experience using TBSS, there is little difference in their high sense of self-efficacy in using TBSS, so the current study finds no significant.

This study's results have several theoretical implications. Unlike previous studies related to TBSS characteristics, this study examines the characteristics of TBSS that are expected to change in the post-pandemic era and their effects on passenger satisfaction, the image of the airport, and behavioral intention. The study's analysis of relationships has academic significance and differs from other studies in addressing aspects of safety. In this study, the safety of TBSS, including hygiene and sanitation, was included. By confirming that the safety of TBSS has a positive effect on passenger satisfaction, this study shows that the industry should emphasize the value of TBSS in ensuring personal safety with to respect of hygiene and sanitation. Consequently, the results of this study provide a theoretical basis for further research on passenger satisfaction as it relates to the changing characteristics of TBSS in the post-pandemic era.

This study also has practical implications. As the functionality, enjoyment, and speed characteristics of TBSS had significantly positive relationships with passenger satisfaction, passenger satisfaction increases when the use process is clear and efficient, leads to fun and interest, and saves time otherwise spent waiting and getting service at the airport. In addition, since passengers want to shorten the wait for security screening and immigration (IATA, 2021), reducing this time would likely improve satisfaction, along with the airport's image and passenger behavioral intentions. The characteristics of convenience and reliability did not affect satisfaction, perhaps because some of the airport's TBSS devices, such as self-check-in, are considered standard. Also, because of the trust in TBSS and the preference for contactless service, passenger tendencies to use TBSS is high even when an error occurs. To improve passenger satisfaction, the airport's image, and passenger behavioral intentions, the industry should consider strategically implementing services that provide functionality, enjoyment, and speed. However, there are only 14 guide robots at ICN currently in operation, and check-in kiosks often have a wait. Therefore, guide robots should ensure speed with operational expansion and increase their role functions. Also, the elements of enjoyment should be expanded, such as displaying a message that can be experienced by approaching

customers first and creating services that can be shared with friends through SNS. Furthermore, the industry's marketing strategy should take into account that TBSS can be used efficiently in such a way that the process can be clearly understood and makes an interesting experience.

Second, this study provides data for deriving new TBSS characteristics and strategies that airport stakeholders can take into account in the post-pandemic era. Based on the study's results, a TBSS service strategy that emphasizes safety will be well received. The derivation of customer-tailored service strategies is the future direction of the aviation industry and will increase passenger convenience and process efficiency. Since TBSS can influence the airport's image and passenger behavioral intentions, a strategic plan for service provision should focus on TBSS safety, which has had a significant impact since the spread of COVID-19. It is most important to create an atmosphere where the airport quarantine and hygiene is clean, and periodic machine disinfection and hygiene should be maintained. Also, the industry can use advertising to promote TBSS safety characteristics by reflecting the passenger propensity to avoid face-to-face services and infection.

Like all studies, this study has several limitations. First, as the majority of survey participants were in their twenties and thirties, the results may not reflect the experiences of using TBSS of those in other age groups. Future research can address this limitation by involving participants in older age groups. While it may be tempting to say that the younger age groups are the industry's future and older age groups can be ignored, whether younger passenger views of TBSS change as they age is unknown. Second, given the changed perceptions of past experiences regarding TBSS use because of COVID-19, future research can expand this study's findings through qualitative research. Third, the study did not classify types of TBSS in its analysis. Passenger views of TBSS may vary with the type of device. Practical research that includes classification of types of TBSS is likely to be useful.

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A Comparative Study of Korean and U.S. Firms amid COVID-19 Supply Chain Disruptions: The Role of Relational Capital for Improving Ambidextrous Innovation and Firm Performance

Aaron Rae Stephens[a], Charles Arthur Robb[b], Minhyo Kang[c]*

[a]*Department of Business Administration and Accounting, Hartwick College, U.S.A.*
[b]*Department of Business Administration, Dongguk University WISE Campus, South Korea*
[c]*Department of Asian Studies, Busan University of Foreign Studies, South Korea*

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ABSTRACT

Purpose – Supply chain disruptions have plagued firms since the advent of COVID-19 lockdowns. As a result, supply chains remain unstable and dynamic. To better understand supply chain management during periods of disruption, this study compares the impact of relational capital on ambidextrous innovation and firm performance between Korean and U.S firms.

Design/Methodology/Approach – This study includes a sample of 200 Korean firms and 227 U.S firms. PLS-SEM is the statistical tool utilized with MICOM multigroup analysis.

Findings – Korean and U.S. firms were found to be different on three different pathways indicating that open innovation and investment in supplier relations improve supply chain disruption orientation, exploration innovation, and firm performance

Research Implications – Relationship capital can significantly improve supply chain management, innovation, and firm performance. Exploitation innovation is better for enhancing supply chain management in the short-term amid interruptions.

Keywords: exploration innovation, exploitation innovation, firm performance, Korea, relational capital, supply chain disruption orientation, United States

JEL Classifications: M10, M19, M30

* *Corresponding Author, E-mail: minhyo74@bufs.ac.kr*

I. Introduction

The impact of the global (COVID-19) pandemic on market stability remains a much-debated issue. Increased environmental uncertainty, has resulted in a wave of disruptions that continue to torment every industry and geographical region across the globe (Craighead et al., 2020). While a growing body of research exists which is dedicated to effectively responding to COVID-19, there is no doubt that the pandemic has paralyzed the world and revealed the critical importance of competent supply chain management practices (Craighead et al., 2020; Oh et al., 2020). Supply chain disruptions have also cause major problems for all types of organization. Gu et al. (2021) noted that the current pandemic has caused serious disruptions to the supply and demand factors in many companies. These issues have led to huge financial losses for organizations and diminished the performance of firms throughout the supply chain (Ardito et al., 2020). In response to these concerns, the current research examines the firm performance of organizations in the supply chain which have experienced disruptions due to recent market anomalies. To measure the study convictions, two samples were tested: U.S firms (n=227), and South Korean firms (n=200). Ambiguity in the international business environment has exasperated the operational capacity of organizations as they are forced to manage their resources more efficiently. Therefore, this research hopes to provide additional unique findings to support supply chain literature through the provision of an assessment of two markets currently circumnavigating the effects of supply chain disruption.

With regards to relational capital research, a large proportion of studies have focused on the creation of relational capital from within a firm (Onofrei et al., 2020). Further, the majority of this literature has analyzed the direct effects of this form of capital on operational performance (Yayla et al., 2018) without examining the impacts that certain indirect relationships could exert on this exchange. Also, while the development of internal relational capital has been researched, less is known about the progression of external partnership mechanisms in the supply chain and its effect on firm performance (Onofrei et al., 2020). In view of this, the current study investigates the importance of relational capital in addition to firm performance.

While the procurement of information is a vital and worthwhile endeavor which is related to firm success (Craighead et al., 2020), changes related to the development of modern technology and the globalization of markets necessitate the internal development of knowledge (Ardito et al., 2020). Organizations are therefore encouraged to seek out innovations in a collaborative manner through an inquiry into relational capital practices. Consequently, this research explores ambidextrous innovation in more detail.

Although previous research provides an extensive opportunity in which to understand certain constructs utilized in this study (Onofrei et al., 2020), prior studies related to relational capital (Anh et al., 2019; Lee & Ha, 2018), ambidextrous innovation (Ardito et al., 2020), and supply chain disruption orientation (Ambulkar et al., 2015; Blackhurst et al., 2005) have yielded mixed results. For this reason, the current research also answers the call for further research in the area of supply chain management (Anh et al., 2019) to address disruptive events (Craighead et al., 2020). To further supply chain literature and satisfy the research gaps listed previously, this study incorporates social network theory to reinforce the interrelation between relational capital and firm performance. The adoption of this theory supports the research in addressing the following questions: (1) to what extent does the collaboration of actors throughout the supply chain reinforce firm performance? (2) How conducive is supply chain disruption orientation to firm performance? (3) How will ambidextrous (exploitation and exploration) innovations mitigate disruptions in the supply chain? In the pursuit of answering the above questions, this study expects to contribute to the literature in several ways. First, this paper hopes to understand the regional differences in supply chain disruption responses within firms based on a bi-country analysis. Second, this study investigates

the contributions of ambidextrous innovations to firm performance. In this regard, this research aims to coordinate a recognized paradox (Benner & Tushman, 2015) that exists when measuring the benefits between exploitation and exploration in improving firm performance during supply chain disruptions. Third, the study gives a context specific investigation of firm performance amid COVID-19 supply chain disruptions; with the ambition of contributing empirical evidence on performance implications for actors throughout the supply chain.

The remainder of this paper is organized as follows. First, the theoretical foundations of the research are presented and thereafter, the hypotheses will be developed based on the literature. Next, the methodology and data analysis are shown. Following this, the findings are discussed, and theoretical and managerial implications are revealed. Finally, limitations and suggestions for future research will be described.

II. Literature Review

1. Theoretical Underpinnings

The research adopts a critical and useful theory to constitute the literature and reinforce the framed model. Social network theory (SNT) elaborates structural properties by emphasizing formal and informal social relations (Liu et al., 2017). At the same time, SNT perceives social relationships through entire supply chains in perspective of nodes and tides (Gligor et al., 2018; Liu, 2011), and acknowledges how interconnectedness and interactions in supply chains. For instance, the emphasis is moved from what individual firms operate, to how those corporations collaborate each other to generate value (Gligor et al., 2018). SNT, as an approach and analytical method, allows for a deep insight of the structural peculiarities and the intrinsic relationships among whole supply chains (Wichmann and Kaufmann, 2016). Consequently, the researchers recognize the significance of this theory in establishing a conceptual framework for this paper.

2. Relational Capital

In the context of supply chain management, several components of relational capital have been identified including loyalty, mutual respect, reciprocity, and trust (Anh et al., 2019; Ireland & Webb, 2007). According to the literature, relational capital is concerned with relationship strength which encourages communication, sharing of resources, and mutual support in numerous situations (Lee & Ha, 2018; Yayla et al., 2018). It has also been established that relational capital is particularly indispensable for organizations that lack competencies which are required to generate efficiencies (Preston et al., 2017). Research also suggests that a possible association exists between the establishment of closer ties with customers and suppliers, which becomes a differentiator between the performance outcomes of firms in global supply chains (Preston et al., 2017; Yayla et al., 2018; Yu & Huo, 2019).

Laursen and Salter (2006) found that openness among partners in the supply chain could promote exploration innovation and improve performance. The authors understood that relationship development encouraged the sharing and application of proficiencies which enhanced the firms' memory to deal with unfamiliar situation (Laursen & Salter, 2006). Accordingly, there seems to be an association between the establishment of mutually beneficial supply chain relationships and the formation of support systems (Onofrei et al., 2020) that encourage exploration innovation that focus on the development of new product and process. Based on the literature, the following is assumed:

H1: Relational capital will positively affect exploration innovation.

An important aspect of reassuring stability during periods of disruption is the ability of organizations to open channels of communication with other actors in the supply chain (Reimann et al., 2017). Effective dialogue exchanges between firm actors during periods of environmental uncertainty have been shown to alleviate negative

outcomes associated with disruptions (Bode et al., 2011). Yayla et al. (2018) discovered that collective activities such as learning and knowledge sharing led firms to share resources and make joint decisions regarding the achievement of similar goal (Preston et al., 2017). Also, Nguyen et al. (2020) concluded that organizations could reinforce their supply chain by applying internal knowledge, and leveraging external intelligence from actors within the supply chains where they operated. When disruptions were likely to occur, Schoenherr and Swink (2015) illustrated that the procurement of technological and market knowledge from supply chain partners became a foundation of competitive advantage (Yu & Huo, 2019). Therefore, this research scrutinizes the importance of relational capital in the pursuit of sustainable supply chain operations and posits the following:

H2: Relational capital will positively affect SC disruption orientation.

The exploitation of innovation involves the general refinement and utilization of present firm solutions to achieve a desired outcome (Gupta et al., 2006). This operation is proactive and allows firms to employ prevailing competencies in order to conduct commercial activities. While not always the case, it has been uncovered that for a large majority of organizations, exploiting existing structured processes without implementing additional capabilities, may at best lead to average performance returns (Gu et al., 2021). However, the accumulation of actual capabilities which could benefit the firm are not always available due to financial limitations or know-how inabilities. In these circumstances, greater inter-organizational commitment has been cited as an effective tool which could assist organizations in achieving a competitive advantage, and also stimulate their firm performance (Yayla et al., 2018). An obligation to develop relationship with other actors in the supply chain was exposed to sustain other organizational processes such as strategy development, new product development (Bode et al. 2011), customer service improvement, and goal attainment (Gupta et al., 2006). Accordingly, there seems to be evidence to suggest that exploitation innovation could benefit from the introduction of relationships between a company and other important constituencies. Thus, the following hypothesis is presumed:

H3: Relational capital will positively impact exploitation innovation.

3. Supply Chain Disruption Orientation

Within the context of the contemporary commercial environment, supply chain disruptions remain a constant reminder of the challenges facing sustainable business operations. While organizations may diverge in their interpretation of what constitutes stability in the supply chain, events disrupting the natural flow of supply chain processes require approaches which are able to manage these negative outcomes (Blackhurst et al., 2005). Organizations that are able to anticipate imminent dangers or disruptions in their supply chain are said to be committed to supply chain disruption orientation (SCDO). This interpretation suggests that organizations are directed towards managing the sustainability of their operations in the context of unanticipated events (Bode et al., 2011). Several benefits have been associated with firm routines that promote SCDO behavior. Ambulkar et al. (2015) mentions that an orientation focused on strengthening a firm's supply chain allows an organization to effectively leverage scarce resources during periods of environmental uncertainty. Similarly, Reimann et al. (2017) attributed a proactive SCDO demeanor to resource utilization and the exploitation of new market opportunities. Yu et al. (2019) concluded that SCDO encouraged organizational learning; meaning that firms were capable of diminishing the impact of disruptions in the future.

An orientated operational response to understanding dynamism in an environment is indispensable. This reaction to changes in a supply chain environment is particularly useful when there is a concerted effort to develop strategies which emphasize alleviating market abnormalities brought about by unforeseen events. Firms that

preserve supply chain disruption orientation augment the opportunities available in their market. Koryak et al. (2018) demonstrated that exploration innovation encouraged new demands from markets as organizations endeavored to investigate new technologies and product construction, and experiment with alternative channels of distribution (Reimann et al., 2017). Noticeably, factors accompanying the advancement of exploration innovation seems to benefit from disruption orientation; thus the succeeding hypothesis is:

H4: SC disruption orientation will positively impact exploration innovation.

Evaluating the relationship between supply chain disruption orientation and firm performance has remained confrontational in supply chain literature (Ambulkar et al., 2015; Chopra & Meindl, 2004; Yu et al., 2019). While some studies confirm an operational refinement to the management approaches of firms (Ambulkar et al., 2015), other studies have shown conflicting outcomes in this relationship with reference to firm performance (Bode et al., 2011; Stephens et al., 2022). It is generally accepted that a robust adoption of supply chain disruption orientation practices following market interruption is critical; especially for organizations forecasting the continuation of their performance standards. However, this progressive strategic orientation may not necessarily always lead to improved firm performance (Chopra & Meindl 2004). Bode et al. (2011) commented that an opportunity to learn from, or even recognize the impact of supply chain disruptions could vary from company to company. Likewise, certain organizations could define their attainment of goals contrarily, making the attainment of firm performance a challenge. Alternative inferences would be observed if organizations were to benchmark their performance indicators against supply chain partners; different firms pursue varying objectives (Bode et al., 2011). Illustrated otherwise, an internal realization of performance upshots in a particular organization could create negative interchanges with supply chain partners that do not achieve similar advantages from orientating their companies towards managing the same disruption (Yu et al., 2019). These situations could potentially downgrade performance benefits throughout the organization or supply chain (Wong et al., 2020). Regardless, it remains imperative that supply chain literature continues to understand the relationship between firm performance and a strategic progression towards supply chain disruption orientation.

Bode et al. (2011) found that a firm's orientation toward disruption extenuation propelled its motivation to rapidly and specifically respond to business environment changes. Supply chain disruption orientation necessitates the constant observation of supply and demand shifts in a market environment (Stephens et al., 2022). Thus, an ability to respond to these market changes could facilitate the effectiveness of organizations to operate during disruptions and maintain momentous performance levels (Blackhurst et al., 2005). Given the preceding argument, the following is contemplated:

H5: SC disruption orientation will positively impact firm performance.

Supply chain disruption orientation constitutes a general awareness and consciousness of supply chain disruptions. This also includes the ability to learn from these disruptions. Due to their heterogeneous nature, firms often differ in their impression of stability; meaning that operational disruptions are experienced diversely (Bode et al., 2011). Consequently, a stronger focus on disruption orientation would suggest a more definitive need for stability in the supply chain. Also, organizations which have experienced disruptions in the past may desire the need for supply chain disruption orientation as a way of building the competiveness of the organization. During disruptive events, organizations are able to benefit from exploitative behavior, as these activities are associated with shaping existing firm knowledge, and reinforcing the skills, routines, and arrangements within organizations (Jansen et al., 2006).

Exploitation innovations encompass several features. Jansen et al. (2006) designated these types of innovations to be incremental in nature. Therefore, exploitative innovations are augmented in a time-period to meet customer or market needs (Andriopoulos & Lewis, 2009). A strategic focus on broadening knowledge and skills is a feature of both exploitative innovation and supply chain disruption orientation (Yu et al., 2019). Gupta et al. (2006) also concluded that exploitative innovation encouraged: the expansion of a firm's prevailing products and services; enhanced a firm's designs; and contributed to the development of more efficient supply chain distribution channels (Wang et al., 2021). For certain spectators, it may seem that exploitative innovation is a rather rudimentary exercise. However, exploitative innovation builds on firm processes during periods where unfamiliarity in the market environment persists. Conversely, it is assumed that an orientation towards managing supply chain disruptions would also facilitate the recreation of exploitative actions in a firm. Thus, this study suggests that:

H6: SC disruption orientation will positively impact exploitation innovation.

4. Ambidextrous Innovation

Disruptive events have caused major concerns for firms. Gupta et al. (2006) mentioned that ambidextrous innovations act as an effective recovery mechanism for organizations which are forced to recover after supply chain disruptions (Andriopoulos & Lewis, 2009). Literature on ambidextrous innovation suggests that supply chain innovation occurs from two opposite behaviors, exploitation and exploration innovation. While debate continues as to which action is more essential for a supply chain, it is generally agreed that organizations can possess both innovations at the same time (Gu et al., 2021). Accordingly, firms are encouraged to focus on exploitation and exploration processes to manage disruptions in their supply chain. The former refers to exploiting their current structured processes, while the later procedure refers to the exploration of unstructured processes in the organization. Hence, exploitation innovation emphasizes the utilization, refinement, implementation, and execution of existing solutions (Ardito et al., 2018); while exploration innovation highlights the pursuit of new solutions through experimentation and risk taking (Dubey et al., 2019).

The development of processes such as information sharing stimulates disruption recoveries after unexpected environmental scenarios (Dubey et al., 2019). The benefits associated with leveraging ambidextrous innovation (both exploitation and exploration innovation) when supply chain disruptions are evident (Gupta et al., 2006). For example, it has been established that exploitation innovation improves the information processing and knowledge-sharing capabilities of organizations which empower supply chain partners to make rapid decisions and enact direct actions when addressing supply chain disruptions (Gu et al., 2021). Also, it has been recognized that exploration innovations develop collaborative information sharing, which enables organizations to develop novel solutions towards managing supply chain disruptions (Dubey et al., 2019; Gupta et al., 2006). Consequently, it has been suggested that because of their significance, firms must strive to balance both exploitation and exploration innovation at the same time in order to achieve the best innovative results (Ardito et al., 2020; Gupta et al., 2006).

Exploration innovations are known to assist in the creation of enhanced product development systems. The expansion of product growth methods allows firms to greatly prosper through either cost or differentiation advantages (Yang et al., 2019). Wang et al. (2021) determined that commercial operations which focused on product creativity or expansion facilitated the organization in controlling market skepticism, which accentuated firm performance (Dubey et al., 2019). Thus, the next hypothesis is stated as:

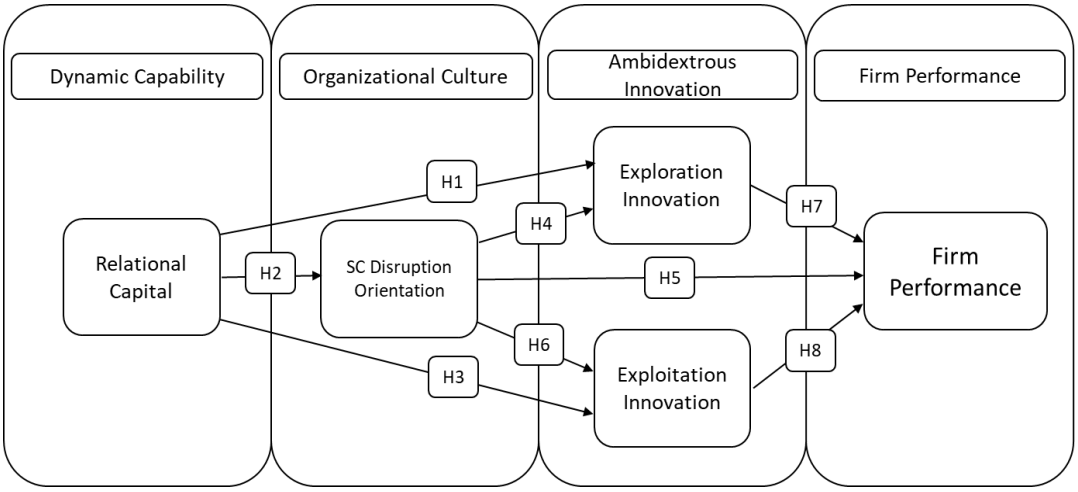
H7: Exploration innovation will positively impact firm performance.

A predominant feature of competitive

advantage is the ability of the firm to exploit knowledge to maintain innovation in the company (Yu & Huo, 2019). Yang et al. (2019) stated that exploitation innovation encourages various processes which are necessary for refining products, in a cost-effective manner. To satisfy customers, organizations can reassure exploitative measures geared at improving their products. Jansen et al. (2006) suggested that organizations could develop exploitative practices supplementary to their current operations to intensify business performance. Firm performance could be achieved as organizations re-engineered firm products to consumers while simultaneously extending their understanding of product developments throughout the market (Yang et al., 2019). By exploiting innovations to reduce the likelihood of making operational errors, and developing product enhancements, firm performance can be upgraded. So, the following is presented:

H8: Exploitation innovation will positively impact firm performance.

Fig. 1. Conceptual Framework



5. Comparative Analysis

Eastern companies (in particular those of South Korea) invested in open innovation in order to catch-up to Western firms (Lee & Lim, 2001; Rhee & Stephens, 2020). Additionally, relationships are more highly valued by Korean firms than American firms (Hofstede Insights, 2022); likely leading to more productive supply chain management brought about by better relationship management. Stronger socialization between partner firms, frequently observed by South Korean organizations, will likely suggest better empirical results (Rhee & Stephens, 2020). Based on this reasoning, it is surmised that Korean firms will exhibit stronger impacts from relationship capital and innovation for better improved firm performance than American firms.

H9: South Korean firms will exhibit stronger relationships than U.S. firms.

III. Methodology

Empirical analysis utilizing PLS-SEM is the method of choice for this comparative analysis

as PLS-SEM is most appropriate given the size of the two datasets – they are both smaller than what would be recommended for covariance-based methods such as SPSS and AMOS (Hair et al., 2018; Ringle et al., 2012). Psychosomatic variables were established through a literature review and measured through two surveys.

1. Sample

Two firm-level surveys were collected in April of 2021: one in South Korea and another in America. The sample statistics are available in Table 1. Remarkable at the time, companies were under great stress because of supply chain disruptions brought on by COVID-19. The American survey returned 227 valid responses while the Korean questionnaire returned 200 for a combined sample of 427 firms. Several demographics were considered including size of the firm sampled, industry category, and years of experience; such demographics were found to be relevant based on previous studies.

Firm size was measured in two different ways: total sales and number of employees. Regarding the number of employees, the majority of firms (220, 51%) were categorized as small and medium-sized firms (SMEs) – with between 20 and just under 500 employees. Micro-organizations (those with fewer than 20 employees) made up an additional 132 firms (31%). Large companies contributed to 18% (75 numbered) of firms surveyed. Firm size was also evaluated by total revenue: $5 million or less in revenue included 149 firms (35%), between $5 and 10 million contributed to 12% (53 firms), $10 to $20 million added 63 firms (15%), another 70 firms (16%) were in the category of $20 to $50 million, and 92 firms (22%) rounded out the final category, firms with revenue over $50 million.

Years of operation critical as it indicates the

Table 1. Demographics of the Sample

Number of Employees						
Interval	Less than 20	21 - 149	150 - 249	250 - 499	500 +	Total
Count (%)	132 (31%)	112 (26%)	73 (17%)	35 (8%)	75 (18%)	427 (100%)
Number of Years in Operation						
Interval	1 to 5 years	6 to 10	11 to 25	26 +		Total
Count (%)	77 (18%)	112 (26%)	126 (30%)	112 (26%)		427 (100%)
Annual Sales						
Interval	$5mil. or less	$5-$10 mil.	$10-$20 mil.	$20-50 mil.	50 mil. +	Total
Count (%)	149 (35%)	53 (12%)	63 (15%)	70 (16%)	92 (22%)	427 (100%)
Industry						
Industry Type	Machinery, automobiles	Building materials	Chemical and petrochemical	Electronics and electrical	Others	Total
Count (%)	28 (7%)	36 (8%)	24 (6%)	44 (10%)	295 (69%)	427 (100%)

sophistication of operations, experience of the organization, and position the firm sits on the learning curve. Simply stated, firms with more experience should be able to overcome obstacles with greater ease. This demographic data was categorized and recorded accordingly: 1 to 5 years of operation, 77 firms (18%), 6 to 10 years 112 (26%), 11 to 25 years, 126 (30%), and 26 years and over, 112 (26%).

Finally, firms were distributed by industry type; albeit, without much success as most firms fell under the others category 295 firms (69%). The second largest industry category (electronics and electrical manufacturing only made up 10% (44) of firms. Building materials included 36 firms (8%). Two additional industry types were measured as well: machinery and automobiles, 28 firms (7%) and chemical and petrochemical 24 (6%).

2. Research Instrument

The survey included several psychosomatic questions that were issued in both English and Korean for their respective countries. All questions were developed on the basis of previous literature that contributed to the development of the items and formal use of them in academic research. Table 2 is a summary the operationalization of each variable corresponding questions and variables.

Relational capital is defined by Carey et al. (2011) as the relationship between partner firms. Carey et al. (2011) identified five items for measuring relational capital between firms: trust, respect, friendship, reciprocity, and close interactions. Several studies have adopted this operationalized variable further validating its value in supply chain management research (Robb et al., 2022; Yu & Huo, 2019).

Supply chain disruption orientation developed by Bode et al. (2011) is defined as a firm's readiness for supply chain disruptions and its capacity to rapidly recover when they occur. The degree of firm preparedness for such disruptions varies greatly but generally increases when disruptions have recently interrupted supply chains; therefore, it was found that most firms (Korean and American) have some degree of SC disruption orientation post-COVID-19 (Robb et al., 2022; Stephens et al., 2022). Bode et al. (2011) measured this strategic orientation at several points: (1) the degree of readiness, (2) the sense that disruptions will occur, (3) the capacity of the firm to respond should a supply chain disruption ensue, and (4) the ability of the firm to learn from and improve after any interruption. Several studies have adopted this measure in supply chain management research (Robb et al., 2022; Stephens et al., 2022; Yu et al., 2019).

Innovation has in recent years been operationalized in terms of ambidextrous innovation with exploration innovation as one variable and exploitation innovation as another simultaneous variable (Chang et al., 2011; He & Wong, 2004; Robb et al., 2022). He and Wong (2004) regard exploration innovation as seeking out new solutions. Chang et al. (2011) assert that exploitation innovation is applying established solutions to current problems. The two are fundamentally different with different timelines. Finding new solutions generally requires looking outside the firm to new markets, new products and new technology (He & Wong, 2004). Applying established methods generally implies using tried and trusted means of resolving problems (Chang et al., 2011). Additionally, these operationalized variables have been successfully and simultaneously used in previous studies to measure ambidextrous innovation (Robb et al., 2022).

Firm performance is ultimately an integral end to this empirical study; indeed, it is critical to illustrate that some degree of performance is improved. In this study, firm performance is a measure of the competitiveness achieved by the firms sampled as defined by Flynn et al. (2010). Additionally, four points were measured in comparison to competitors: (1) higher growth in sales, (2) higher growth in profits, (3) higher return on investment, and (4) higher comparative growth in ROI. This measure was applied in previous research by both Flynn et al. (2010) and Yu et al. (2019).

Table 2. Operationalisation of the Research Instrument

Variable	Operational definition	Measurement items	Prior research
Supply Chain Disruption Orientation	The degree to which an organisation learns from and prepares for SC disruptions.	[DO1] At my company, we are alert for possible supply chain disruptions at all times. [DO2] At my company, we expect supply chain disruptions are always looming. [DO3] At my company, we think about how supply chain disruptions could have been avoided. [DO4] At my company, after a supply chain disruption has occurred, it is analysed thoroughly.	Bode et al. (2011)
Exploration Innovation	The degree to which an organisation is seeking out new and untested solutions for innovation.	[EOR1] My firm focuses on introducing new products. [EOR2] My firm focuses on extending product ranges. [EOR3] My firm focuses on opening up new markets. [EOI4] My firm focuses on entering new technology fields.	He and Wong (2004)
Exploitation Innovation	The degree to which an organisation is utilising tried and tested solutions for innovation.	[EOI1] My firm focuses on improving the provision efficiency of products. [EOI2] My firm focuses on increasing economies of scale in existing markets. [EOI3] My firm focuses on expanding services for existing customers. [EOI4] My firm focuses on entering new technology fields.	Chang et al. (2011)
Firm Performance	The degree to which a firm out competes with its competitors.	[FP1] Comparing with our major competitor(s), our firm has higher growth in return on sales. [FP2] Comparing with our major competitor(s), our firm has higher growth in profit. [FP3] Comparing with our major competitor(s), our firm has higher growth in market share. [FP4] Comparing with our major competitor(s), our firm has a higher return on investment (ROI). [FP5] Comparing with our major competitor(s), our firm has higher growth in return on investment (ROI).	Flynn et al. (2010)
Relational Capital	The degree to which a firm buildsrelation-ships with its partner firms.	[RC1] Our relationship with our partners is characterized by close interactions. [RC2] Our relationship with our partners is characterized by mutual trust. [RC3] Our relationship with our partners is characterized by mutual respect. [RC4] Our relationship with our partners is characterized by high levels of reciprocity.	Carey et al. (2011)

IV. Analysis

1. PLS-SEM

The best analysis method is PLS-SEM with Smart PLS 3.0 as the respondents are not plentiful enough for a proper analysis with SPSS and AMOS (Hair et al., 2018). PLS-SEM is particularly valuable when conducting research with models that have multiple constructs and items that are used to build and test formative or exploratory models (Barclay et al., 1995). It is also a powerful option for firm-level samples. Additionally, PLS-SEM is not restricted by distribution assumptions; distributions do not need to be normal. Hair et al. (2018) and Cheah et al. (2020), recommend an outer model assessment, an inner model assessment with structural model statistics and goodness-of-fit statistics followed by the multigroup analysis. This section follows those recommendations.

Table 3. Outer Model Assessment

Factors	Standard load		AVE (AVE > 0.5)		Construct Reliability (C.R > 0.7)		Cronbach's Alpha (α > 0.6)	
	American	Korean	American	Korean	American	Korean	American	Korean
SCDO1	0.806	0.791	0.661	0.670	0.886	0.890	0.828	0.838
SCDO2	0.761	0.774						
SCDO3	0.873	0.857						
SCDO4	0.807	0.849						
EOR1	0.805	0.882	0.693	0.773	0.900	0.932	0.852	0.902
EOR2	0.839	0.893						
EOR3	0.864	0.882						
EOR4	0.821	0.860						
EOI1	0.853	0.887	0.666	0.777	0.856	0.912	0.747	0.856
EOI2	0.856	0.889						
EOI3	0.734	0.867						
RC1	0.752	0.843	0.658	0.761	0.885	0.927	0.827	0.896
RC2	0.820	0.885						
RC3	0.848	0.891						
RC4	0.822	0.872						
FP1	0.835	0.872	0.689	0.716	0.850	0.910	0.849	0.868
FP2	0.822	0.881						
FP3	0.874	0.813						
FP4	0.787	0.818						

2. Outer model assessment

The outer model (reliability and validity of the psychosomatic variables) must be established before any other analysis can be completed (Hair et al., 2018). While conducting an SEM analysis with PLS, Hair et al. (2018) prescribe confirming reliability with two statistics: composite reliability and Cronbach's alpha. Both are measures of internal consistency reliability. The lower cut-off for Cronbach's alpha is 0.6 for firm-level research while the lower cut-off for composite reliability is 0.05 (Nunnally & Bernstein 1994). When conducting a multigroup analysis it is necessary to test the reliability of both datasets (Hair et al., 2018). Reliability statistics can be reviewed in Table 3; furthermore, all are above the recommended cut-offs; thus, reliability is observed.

Validity should be established for both datasets as well (Hair et al., 2018). Two types of validity are ordinarily required for PLS-SEM: convergent validity (typically measured through AVE values) and discriminant validity (found through factor loadings or the Fornell and Larcker criterion). All AVE values should be above 0.5 in order to confirm convergent validity (Hair et al., 2018). Convergent validity is reviewable in Table 3. Discriminant validity can be confirmed in two manners through an examination of factor loadings or the Fornell and Larcker (1981) criterion. The Fornell and Larcker (1981) criterion requires that the square root of AVEs should be larger than the corresponding correlations; moreover, the results can be reviewed in Table 4 for American firms and Table 5 for Korean firms.

Table 4. Fornell-Larcker Criterion (American Firms)

	EOI	EOR	FP	RC	SCDO
EOI	0.816				
EOR	0.784	0.833			
FP	0.592	0.566	0.830		
RC	0.412	0.360	0.406	0.811	
SCDO	0.623	0.585	0.524	0.344	0.813

Table 5. Fornell-Larcker Criterion (Korean Firms)

	EOI	EOR	FP	RC	SCDO
EOI	0.881				
EOR	0.831	0.879			
FP	0.701	0.731	0.846		
RC	0.697	0.718	0.747	0.873	
SCDO	0.731	0.703	0.608	0.737	0.818

3. Common Method Bias

There is a critical issue of common method bias, in case the researcher utilizes a survey approach. A common method variance problem can occur, when the measurement adopts various factors to collect dependent and independent variables from the same respondent in the same survey (Fuller et al., 2016). In-depth test emphasizes to review common method bias in basis of a full collinearity assessment (Kock, 2015). It is revealed that the variance inflation factors (VIF) for constructs can be chosen to examine common method bias (Kock, 2015). It is generally notable that the occurrence of a VIF greater than 3.3 is suggested as an indication of multicollinearity, and also as an indication that a model might be stained by common method bias (Kock, 2015). Consequently, when all values of VIF from a full collinearity test are equal to or lower than 3.3 (Kock & Gaskins, 2014), the research model can be fundamentally assumed to be free of common method bias (Podsakoff et al., 2003). In this estimation, All VIFs are between 1.488 and 2.415, and it means that all values are less than threshold value (3.3) and there is no common method bias in this model. Generally, these values disclosed little threat of common method bias and offered the robust support for the validity of the measurements.

4. Inner model Assessment

The inner model can be assessed after the outer model is confirmed (Hair et al., 2018). Pathway coefficients and p-values should be used to determine accepted and rejected pathways. When conducting a multigroup analysis, it is necessary to examine pathways for all datasets independently and combined. The results can be viewed in Table 6.

Primarily, the combined data is examined with pathway coefficients and p-values for significance; furthermore, all pathways are significant and accepted. The pathways extending from relational capital positively impacted exploration innovation (0.251), supply chain disruption orientation (0.505), and exploitation innovation (0.260). Supply chain disruption orientation influenced exploration innovation (0.508), firm performance (0.172), and exploitation innovation (0.535). Exploration innovation (0.293) and exploitation innovation (0.283) both impacted firm performance. All pathways were accepted for the combined dataset but it is still necessary to further check the pathways with independent datasets (Cheah et al., 2020).

Regarding the American data, all pathways were also found significant and accepted. Relational capital affected supply chain disruption orientation (0.344) most and to a lesser extent exploitation innovation (0.224) and exploration innovation (0.180). Supply chain disruption orientation most impacted exploitation innovation (0.546) and exploration innovation (0.523) but least firm performance (0.221). Exploitation innovation (0.293) had a greater impact on firm performance than exploration innovation (0.207).

The Korean data revealed differing results compared with the American data. The Korean data revealed more powerful relationships: relational capital had a greater impact on exploration innovation (0.436), exploitation innovation (0.347), and supply chain disruption orientation (0.737). Supply chain disruption orientation had a less powerful impact with respect to the Korean data with firm performance insignificant and rejected – firm performance (0.114). However, exploration innovation (0.382), and exploitation innovation (0.475) were significant and accepted, albeit, weaker than the results of the American data. Exploration innovation (0.444) and exploitation innovation (0.249) both impacted firm performance more than the American data. Additionally, the results of the inner model assessment are visualized in Fig. 2.

5. Structural Model Assessment

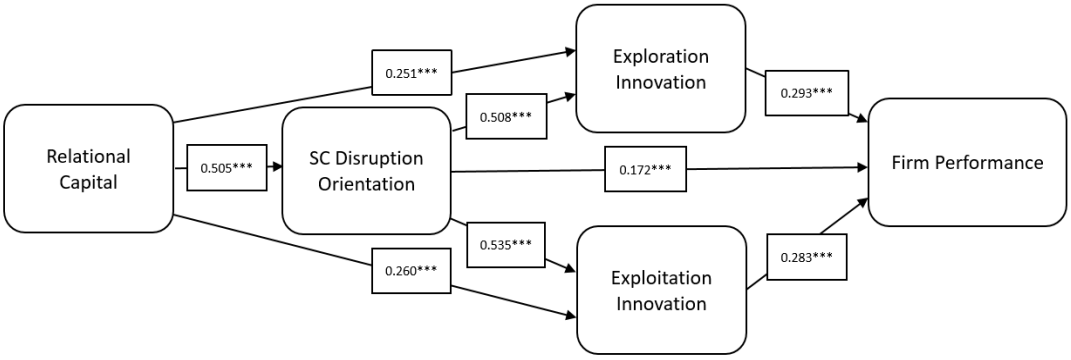
The structural model must assessed by individual dataset when conducting a multigroup analysis (Cheah et al., 2020; Hair et al., 2018; Henseler et al., 2014). The results are viewable in Table 7. Two statistics are used to measure the strength of the structural model: (1) the coefficient of determination (R^2) and (2) the cross-validated

Table 6. Pathway Assessment

(Combined Data)						
Hypotheses		Pathways	Pathway Coefficient	t-stats	p-value	Results
Combined Data						
	H1	Relational Capital → Exploration Innovation	0.251	4.498	0.000	Accept
	H2	Relational Capital→ SC Disruption Orientation	0.505	9.614	0.000	Accept
	H3	Relational Capital → Exploitation Innovation	0.260	5.436	0.000	Accept
	H4	SC Disruption Orientation → Exploration Innovation	0.508	9.482	0.000	Accept
	H5	SC Disruption Orientation → Firm Performance	0.172	3.135	0.001	Accept
	H6	SC Disruption Orientation→ Exploitation Innovation	0.535	12.059	0.000	Accept
	H7	Exploration Innovation → Firm Performance	0.293	4.280	0.000	Accept
	H8	Exploitation Innovation → Firm Performance	0.283	4.220	0.00	Accept
American Firms						
	H1	Relational Capital → Exploration Innovation	0.180	2.622	0.004	Accept
	H2	Relational Capital → SC Disruption Orientation	0.344	4.334	0.000	Accept
	H3	Relational Capital → Exploitation Innovation	0.224	3.861	0.000	Accept
	H4	SC Disruption Orientation → Exploration Innovation	0.523	7.403	0.000	Accept
	H5	SC Disruption Orientation → Firm Performance	0.221	3.061	0.001	Accept
	H6	SC Disruption Orientation→ Exploitation Innovation	0.546	9.992	0.000	Accept
	H7	Exploration Innovation → Firm Performance	0.207	2.145	0.016	Accept
	H8	Exploitation Innovation → Firm Performance	0.293	3.0104	0.001	Accept
Korean Firms						
	H1	Relational Capital → Exploration Innovation	0.436	4.528	0.000	Accept
	H2	Relational Capital → SC Disruption Orientation	0.737	18.875	0.000	Accept
	H3	Relational Capital → Exploitation Innovation	0.347	3.427	0.000	Accept
	H4	SC Disruption Orientation → Exploration Innovation	0.382	4.502	0.000	Accept
	H5	SC Disruption Orientation → Firm Performance	0.114	1.559	0.060	Rejected
	H6	SC Disruption Orientation→ Exploitation Innovation	0.475	5.284	0.000	Accept
	H7	Exploration Innovation → Firm Performance	0.444	4.201	0.000	Accept
	H8	Exploitation Innovation → Firm Performance	0.249	2.363	0.009	Accept

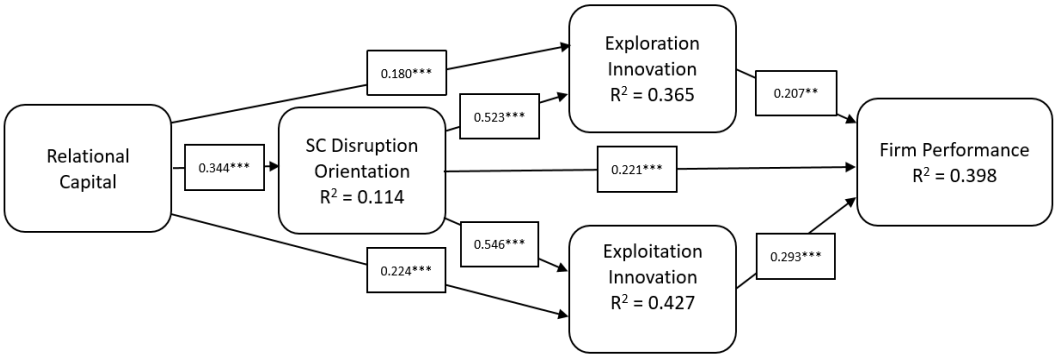
Fig. 2. Visualization of Results

Combined Data



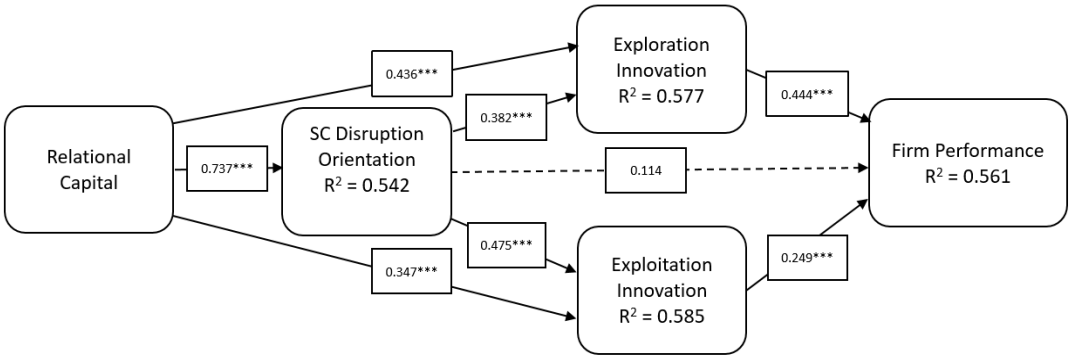
Note: * p<0.1, ** p<0.05, *** p<0.001.

American Firms



Note: * p<0.1, ** p<0.05, *** p<0.001.

Korean Firms



Note: * p<0.1, ** p<0.05, *** p<0.001.

redundancy (Q^2). Cohen (1988) categorized the strength of R^2 (variance explained by the model for each variable): small impact (R^2 = 0.02 to 0.13), medium impact (R^2 = 0.13 to 0.26), and large impact (R^2 = 0.26 and above). R^2 values for the Korean model are stronger (exploration innovation (R^2 = 0.577), exploitation innovation (R^2 = 0.585), firm performance (R^2 = 0.561), and supply chain disruption orientation (0.542) than for the (American data exploration innovation (R^2 = 0.365), exploitation innovation (R^2 = 0.427), firm performance (R^2 = 0.398), and supply chain disruption orientation (R^2 = 0.114). Q^2 is a measure of predictive validity calculated by blindfolding with Smart PLS (Hair et al., 2018). Again the Korean data (exploration innovation (Q^2 = 0.441), exploitation innovation (Q^2 = 0.450), firm performance (Q^2 = 0.390), and supply chain disruption orientation (Q^2 = 0.343)) is more robust than the American data (exploration innovation (Q^2 = 0.250), exploitation innovation (Q^2 = 0.281), firm performance (Q^2 = 0.274), and supply chain disruption orientation (Q^2 = 0.074)).

Table 7. Structural Model Assessment

Endogenous variables	R^2		Q^2	
	American	Korean	American	Korean
Exploration Innovation	0.365	0.577	0.250	0.441
Exploitation Innovation	0.427	0.585	0.281	0.450
Firm Performance	0.398	0.561	0.274	0.390
SC Disruption Orientation	0.114	0.542	0.074	0.343

6. Goodness-of-fit

It is ultimately necessary to measure the goodness-of-fit (GoF) for the entire model in order to confirm the value of the model (Hair et al., 2018; Henseler & Sarstedt, 2013; Hu & Bentler, 1999). Hair et al. (2018) unfortunately argue that there is no perfect measure for GoF rather widely used methods for measuring GoF. Tenenhaus et al. (2005) suggest a method for measuring GoF by comparing the square root of the cut-off for AVE multiplied by the average R^2 values. The process is further supported and categorized by strength by Wetzels et al. (2009): small (0.1 to 0.25), medium (0.25 to 0.36), and large (0.36 and above). The GoF for the model is 0.454, thus, large. GoF is reviewable in Table 8.

Table 8. Goodness-of-Fit

Description	Value	Baseline value	Reference
Goodness of Fit (GoF)	$\sqrt{\text{Cut} - \text{off of AVE X average of R\_}square} = \sqrt{0.5\ \text{X}0.41175} = 0.4537$	GoF *small* = 0.1 GoF *medium* = 0.25 GoF *large* = 0.36	Wetzels et al. (2009)

7. Multigroup Analysis

The measurement invariance of composite models (MICOM) has gradually evolved to the most well-known tool for multigroup analysis (MGA) through PLS-SEM (Carranza et al, 2020). The MICOM analysis is a three-step process (Henseler et al., 2016): step 1, configuration invariance, step 2, compositional invariance, and step 3, equality of mean values and variances. Configuration invariance, the first step, specifies that the constructs are all same across datasets. Subsequently, the second step, compositional invariance, also confirms that all constructs are the same across datasets. Korean firms were designated as group A and U.S. firm were assigned as group B in order to analyze the differences and similarities between the datasets. A minimum of 1,000 permutations and one-tailed testing at a significance level of 5% was adopted as standardized by Cheah et al. (2020) for PLS-SEM MICOM analysis. Finally, equality of mean values and variances, step three, asserts that all constructs are equal across the two datasets. If the first two steps confirm equality, we are able to proceed to the third step. Additionally in order to move forward, it is crucial that all constructs are found equal across the datasets. Proceeding to the third step, partial invariance could be established if the constructs are at that point found to be dissimilar. The first two steps exhibit similarity across the datasets; however, two spots of the mean are not equal in the third step (relational capital and supply chain disruption orientation), thus, partial invariance is indicated. The measurement of MGA is presented in below Table 9 and 10.

V. Discussion

This study investigated the role of relational capital in a framework utilized to assess firm performance amid the current period of supply chain disruptions brought about by novel market uncertainties. In order to test the convictions of this research further, several variables were assessed in this study. Eight hypotheses were introduced (see Table 6) which were developed to measure supply chain performance during episodes of disruptions.

Hypothesis 1, which measured the positive influence of relational capital on exploration innovation, was supported (β = 0. 251, $p < 0.001$). All other hypotheses regarding the effect of relational capital were accepted (both H2 and H3) in the model. These findings provide sustenance for the argument that organizations are encouraged to develop collaborative exchanges during disruptive circumstances. The importance of supply chain relational capital as a firm asset cannot be underrated. The ability to develop and maintain relationships impacts all business-related practices, making it a vital mechanism necessary to sustain a firm's competitive advantage (Yu & Huo, 2019).

The current research further investigated the importance of supply chain disruption orientation in the literature. Interestingly, the relationship measuring the positive association between supply chain disruption orientation and firm performance was accepted for firms in the US, but not Korea (Hypothesis 5). This result seems to suggest that disruption orientation alone may not effectively enhance the performance of firms in the Asian nation. Therefore, it may be assumed that simply committing to a process of disruption orientation does not necessarily advance the performance of an organization. There may also be other indirect factors at play. Blackhurst et al. (2005), for example, concluded that resource scarcity could negatively impact the influence of disruption orientation on firm performance.

Finally, this paper examined the affiliation between ambidextrous innovation and firm performance (H7 and H8). Managers are often faced with inconsistent outcomes when they studied the two types of innovations (Andriopoulos & Lewis, 2009). Consequently, literature aimed at ambidextrous innovation requires added insight. For example, Koryak et al. (2018) concluded that exploitation and exploration innovation orientate the organization towards different goals (e.g., efficiency vs. flexibility) which could impact firm recovery differently (Ardito et al., 2018).

Three hypotheses were significantly different

Table 9. Results of Invariance Measurement Testing Using Permutation

Constructs	Configural invariance (same algorithms for both groups)	Compositional invariance (correlation=1)		Partial measurement invariance established	Equal mean assessment			Equal variance assessment			Full measurement invariance established
		C = 1	Confidence invariance		difference	Confidence interval	Equal	difference	Confidence interval	Equal	
EOI	Yes	1.000	[0.998; 1.000]	Yes	0.066	[-0.154; 0.162]	Yes	-0.192	[-0.237; 0.259]	Yes	Yes
EOR	Yes	1.000	[0.999; 1.000]	Yes	0.140	[-0.157; 0.157]	Yes	-0.133	[-0.241; 0.256]	Yes	Yes
FP	Yes	0.999	[0.999; 1.000]	Yes	-0.140	[-0.146; 0.150]	Yes	-0.134	[-0.253; 0.276]	Yes	Yes
RC	Yes	1.000	[0.998; 1.000]	Yes	-0.230	[-0.153; 0.159]	No	0.003	[-0.272; 0.255]	Yes	No
SCDO	Yes	0.999	[0.997; 1.000]	Yes	0.162	[-0.154; 0.153]	No	-0.173	[-0.273; 0.274]	Yes	No

Table 10. Results of Hypothesis Test

Hypothesis relationship	Path coefficients		Path coefficients difference	Confidence Interval (95%)	P-value difference (One-Tailed)		Supported
	Korean firms	American firms			Henseler's MGA	Permutation p-values	
EOI -> FP	0.249	0.293	-0.044	[-0.219; 0.223]	0.376	0.366	No/No
EOR -> FP	**0.444**	**0.207**	**0.237**	**[-0.221; 0.222]**	**0.045**	**0.039**	**Yes/Yes**
RC -> EOI	0.347	0.224	0.123	[-0.164; 0.163]	0.128	0.106	No/No
RC -> EOR	**0.436**	**0.180**	**0.256**	**[-0.200; 0.198]**	**0.013**	**0.014**	**Yes/Yes**
RC -> SCDO	**0.737**	**0.344**	**0.394**	**[-0.170; 0.178]**	**0.000**	**0.000**	**Yes/Yes**
SCDO -> EOI	0.475	0.546	-0.071	[-0.146; 0.155]	0.237	0.215	No/No
SCDO -> EOR	0.382	0.523	-0.141	[-0.192; 0.187]	0.092	0.120	Yes/No
SCDO -> FP	0.114	0.221	-0.108	[-0.178; 0.179]	0.152	0.181	No/No

from each other based on the MICOM analysis: (1) relational capital to exploration innovation, (2) exploration innovation to firm performance, and (3) relational capital to supply chain disruption orientation. All three exhibited stronger influence for Korean firms than U.S. firms. Open innovation was found to be a significant factor in helping Korean firms to rapidly assimilate new technology (Rhee & Stephens, 2020). Regarding the added influence of relational capital for Korean firms, it is likely that Korea's investment in longer-term and higher quality supplier relations has contributed to better supply chain disruption orientation. According to Höfstede (2011), Koreans envision further into the future (long-term) when planning and considering strategic decisions. Additionally, it is well known that Korean companies invest more time and energy in building relationships with their partners than U.S. firms (Kim, 2004).

From a practical perspective, this research proposes several managerial insights. A notable suggestion for practitioners from this study refers to the management of resources in a collaborative setting. Based on the results of Hypothesis 2, there seems to be support for the designation of slack resources to manage supply chain disruptions through the ascendancy of relational capital. Research proposes that organizations leverage relationship in the supply chain when the availability of resources is infrequent (Robb et al., 2022). In this regard, relational capital offers organizations with a proxy in which they can amplify the functionality of their resources (Chowdhury & Quaddus, 2017).

Also, managers can utilize information sharing through relational capital. Various benefits could be achieved when collaboration becomes effective. Other benefits include innovation development, risks reduction (sharing of responsibility in high-risk operations) and share benefits (Anh et al., 2019) with customers to achieve supply chain performance. Finding from a study conducted by Saikouk et al. (2021) suggests that relationships in the coordination of supply chain activities divulge economic benefits that would be costly or practically difficult to achieve if partnerships did not exist.

VI. Conclusion

In this paper, research was focused on the impact of relational capital on firm performance through ambidextrous innovation. A lack of relational capital among supply chain actors remains a risk that could potentially influence the performance of organizations negatively (Anh et al., 2019). Therefore, further research into the outcomes of relational capital on supply chain success are encouraged. This study also intends to deliver practical guidelines for managers tasked with implementing suitable recover patterns following disruptions with supply chain partners. Consequently, this study offers useful accompanying materials for supply chain management practices under the current global supply chain disruptions caused by the COVID-19 pandemic. Finally, this study supplements the importance of expanding both exploitation and exploration innovations. Results propose that both ambidextrous innovations play a role in firm success. These outcomes are encouraged by the work of Koryak et al. (2018), who recommend that organizations pursue both approaches during periods of disruption.

While this study was directed in a comprehensive manner, several limitations related to the research study are noted. Therefore, some advisory points should be considered when interpreting the study results. Firstly, while this research was able to incorporate an extensive study sample (U.S, n=227; Korea, n=200), results could differ in forthcoming studies that are able to integrate larger sample sizes or explore alternative research locations. Second, this study utilized a questionnaire approach on organizations currently in operation. Conversely, results could potentially be different if failed firms were included in the study; many firms ceased operations amid COVID-19 disruptions. Therefore, future research inclusive of failed firms could further advance supply chain literature. Third, this research lacked the inclusion of certain essential control variables. For example, firm age, industry type, product type, or firm size. These control indicators could drastically influence the results of future research. Finally, future research could encourage findings based on the level (position) of organization in the supply chain.

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Analysis on the Effects of Logistics Efficiency on Korea's Trade Flows in RCEP Signatories

Seo-Young Lee[a]

[a]*Department of International Trade and Logistics, Mokwon University, South Korea*

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ABSTRACT

Purpose – The purpose of this study is to analyze the effect of logistics efficiency in RCEP signatory countries on Korea's trade. In particular, after analyzing the effects of individual indicators of the logistics performance index (LPI) on trade, policy implications are drawn based on the results.

Design/Methodology/Approach – In order to analyze the effect of logistics efficiency in RCEP countries on Korea's trade, the independent variables of the gravity model included GDP, population, distance, and LPI. For detailed analysis, in addition to the LPI, the individual indicators of LPI are input to the independent variable for analysis. This study adopts varying coefficient models, the random effects model and fixed effects model, in order to more effectively analyze unobservable factors in the panel data.

Findings – The empirical evidence using the gravity model showed that the coefficient of LPI was about 1.7 and statistically significant at the 1% level of significance. In other words, if the logistics efficiency of the RCEP signatory country increases by 1%, when other variables are constant, Korea's trade volume increases by about 1.7%. As a result of analyzing the effect of LPI's individual indicators on trade, it was found that the five individual indicators of logistics infrastructure, international shipment, logistics service, timeliness, and goods tracking affect trade. On the other hand, the clearance index was not statistically significant at any significance level.

Research Implications – It was confirmed that the logistics efficiency of RCEP signatory countries is important for Korea's trade facilitation. In other words, if not only Korea's logistics efficiency but also the logistics efficiency of the RCEP signatory countries are improved, the facilitation of trade between the two countries can be achieved. To this end, it is necessary to reduce the logistics cost through the establishment of the logistics infrastructure, and it is also necessary to make efforts to increase logistics efficiency.

Keywords: gravity model, logistics performance index, LPI, logistics efficiency, RCEP
JEL Classifications: F14, F23, N75

[a] *E-mail: leesy@mokwon.ac.kr*

I. Introduction

The Regional Comprehensive Economic Partnership (hereinafter referred to 'RCEP') is a free trade agreement signed by a total of 15 countries, including the Association of Southeast Asian Nations (ASEAN), Korea, China, Japan, Australia, and New Zealand, with the goal of eliminating trade barriers.

Initially, RCEP negotiations were conducted by 16 countries, including India. However, as India, which mainly produces low-cost products, dropped out of negotiations for fear of competition with China, the agreement was reached with 15 countries participating. The RCEP came into force on January 1, 2022, but in the case of Korea, the procedure for domestic ratification was delayed, and it came into force in February 2022. The scale of the RCEP is the largest economic bloc with a trade volume, nominal gross domestic product, and population accounting for about 30% of the world. In particular, the scale of nominal GDP exceeds that of the North American Free Trade Agreement ($18 trillion) and the European Union ($17.6 trillion).

RCEP has an important meaning in terms of international trade in East Asia. This is because the RCEP will act as a large umbrella for many bilateral free trade agreements and small-scale regional trade agreements in East Asia. This market opening will be a new opportunity for Korean companies. In particular, as the effect of market opening in Southeast Asia is greater than in the past, the export performance of Korean companies will improve.

On the other hand, competition among global companies is intensifying in a global trade environment where trade barriers such as tariffs and non-tariffs are reduced due to the launch of the WTO and preferential trade agreements, such as FTAs and RTAs. Meanwhile, logistics infrastructure and logistics costs are becoming another trade obstacle. In particular, the increase in logistics costs between countries has a significant impact on international trade patterns.

Establishing an efficient logistics environment and system in international trade makes it possible to reduce logistics costs and increase trade volume. As the global production system expands and competition between companies intensifies, interest in the relationship between trade and logistics infrastructure and the relationship between trade and logistics costs is increasing.

In this regard, many studies have been conducted. Representatively, Limao and Venables (2001), Clark et al. (2004), Lee and Bang (2009), Ahn (2014), Marti et al. (2014), Jung (2015), Cho and Park (2021), and Ahn (2021) studied the relationship between trade and logistics efficiency. More details will be explained in the next chapter.

From Korea's point of view, it can be said that the importance of logistics cost and logistics efficiency in trade with RCEP signatory countries is quite large. However, there are few studies analyzing the effect of logistics efficiency in RCEP signatory countries on Korea's trade.

Against this background, this study intends to analyze the effect of logistics efficiency in RCEP signatory countries on Korea's trade. In particular, after analyzing the effects of individual indicators of the Logistics Performance Index (hereinafter referred to 'LPI') on trade, policy implications are drawn based on the analysis results.

The structure of this paper is as follows. Section II introduces the theoretical background. Section III explains the model which examines the effects of logistics efficiency in RCEP signatory countries on Korea's trade. Empirical evidence is shown in Section IV. Section V provides conclusions.

II. Theoretical Background

1. RCEP and Logistics Efficiency

The LPI is an indicator developed by the World Bank, and not only the overall index but also individual indicators for six aspects were announced. The index was first published in 2007 and is published biennially every even-numbered year. The detailed index of LPI includes the efficiency of customs procedures, logistics infrastructure, international transport, logistics competence, goods tracking, and timeliness. Each

item is given a score of 0 to 5, and the higher the score, the higher the logistics efficiency is evaluated.

This indicator is prepared by dividing it into International LPI (I-LPT) and Domestic LPI (D-LPI). The I-LPI is prepared by calculating the average of the respondents based on the values answered by trade and logistics experts on the logistics environment of major trading countries for a total of 7 questions on a scale of 1 to 5 points (Lim & Jun, 2019).

By comparing the logistics index for each item by country through LPI, it is possible to analyze the gap in the logistics level between one's own country and another country. In addition, through this, it is possible to identify weak sectors of the domestic logistics industry and make policy efforts to improve logistics efficiency (Lee & Bang, 2009).

According to the LPI (6th edition) published by the World Bank in 2018, Germany was ranked highest. As shown in Table 1, most countries with good logistics performance are European countries. Among the countries that signed the RCEP, Japan ranked 5th and Singapore ranked 7th, being evaluated as logistics powerhouses. On the other hand, Korea and China ranked 25th and 26th, respectively.

Table 1. LPI's World Top 10

	2018		2016		2014	
	Rank	Score	Rank	Score	Rank	Score
Germany	1	4.20	1	4.23	1	4.12
Sweden	2	4.05	3	4.20	6	3.96
Belgium	3	4.04	6	4.11	3	4.04
Austria	4	4.03	7	4.10	22	3.65
Japan	5	4.03	12	3.97	10	3.91
Netherlands	6	4.02	4	4.19	2	4.05
Singapore	7	4.00	5	4.14	5	4.00
Denmark	8	3.99	17	3.82	17	3.78
United Kingdom	9	3.99	8	4.07	4	4.01
Finland	10	3.97	15	3.92	24	3.62

Source: World Bank (2019).

Table 2 shows the logistical performance index of RCEP signatory countries. The average of the LPI was 3.32, and 7 countries showed higher than average, including Australia, China, Japan, Korea, New Zealand, Singapore, and Thailand. On the other hand, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, and Vietnam showed levels lower than average. Among RCEP signatory countries, the country with the highest LPI is Japan, and the country with the lowest is

Myanmar.

Looking at individual indicators constituting logistics performance, the customs clearance score was found to be lowest, and the timeliness score was found to be highest. In particular, it can be seen that Singapore, New Zealand, and Japan score high in timeliness.

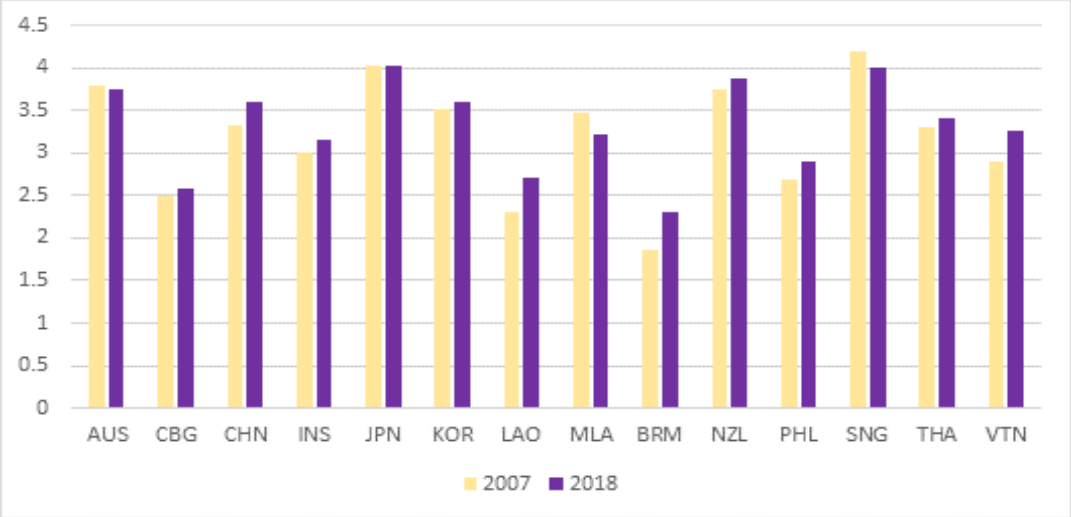
Table 2. LPI of RCEP Signatory Countries (2018)

	CUST	INFR	ITRN	LOGS	TRAC	TIME	LPI (OVRL)
Australia	3.87	3.97	3.25	3.71	3.82	3.98	3.75
Cambodia	2.37	2.14	2.79	2.41	2.52	3.16	2.58
China	3.29	3.75	3.54	3.59	3.65	3.84	3.61
Indonesia	2.67	2.89	3.23	3.10	3.30	3.67	3.15
Japan	3.99	4.25	3.59	4.09	4.05	4.25	4.03
Korea	3.4	3.73	3.33	3.59	3.75	3.92	3.61
Laos	2.61	2.44	2.72	2.65	2.91	2.84	2.70
Malaysia	2.9	3.15	3.35	3.3	3.15	3.46	3.22
Myanmar	2.17	1.99	2.20	2.28	2.20	2.91	2.3
New Zealand	3.71	3.99	3.43	4.02	3.92	4.26	3.88
Philippines	2.53	2.73	3.29	2.78	3.06	2.98	2.90
Singapore	3.89	4.06	3.58	4.10	4.08	4.32	4.00
Thailand	3.14	3.14	3.46	3.41	3.47	3.81	3.41
Viet Nam	2.95	3.01	3.16	3.40	3.45	3.67	3.27
Average	3.11	3.23	3.21	3.32	3.38	3.65	3.32

Note: Brunei is excluded because relevant statistics are not available.
Source: World Bank (2019).

Fig. 1 compares the year 2007, when the LPI was first published, and 2018, when it was recently released. The LPI of most countries improved compared to 2007, but Malaysia and Singapore showed lower indicators. The LPI of RCEP signatory countries shows a large gap between member countries. Although there is still a gap between developed and developing countries, the pace of improvement in developing countries is faster than that of developed countries. In particular, improvements in Laos, Myanmar, and Vietnam are characteristic.

Fig. 1. LPI of RCEP Signatory Countries (2007 vs. 2018)



Note: Brunei is excluded because relevant statistics are not available.
Source: World Bank (2019).

2. Literature Review

Many studies have been conducted to analyze the effect of logistics efficiency on trade. In the early 2000s, studies were conducted focusing on the hardware logistics infrastructure aspect, but recently, studies have been actively conducted focusing on the software logistics infrastructure aspect.

Limao and Venables (2001) analyzed the relationship between the level of logistics infrastructure and trade volume among African countries using the gravity model. They suggested that the low level of logistics infrastructure was the cause of the low trade in African countries. Clark et al. (2004) also empirically analyzed the effect of transport costs on bilateral trade using the gravity model. They presented the analysis result that the amount of trade between the two countries decreased as the transportation cost increased. In particular, they argued that port efficiency played the most important role in transport cost by country.

Lee and Bang (2009) analyzed the effect of logistics efficiency on trade in East Asian countries using the port efficiency and railway efficiency indicators presented at the World Economic Forum. According to the estimation results, if the logistics efficiency of the home country increases by 10%, the bilateral trade volume increases by about 3.8%, and if the logistics efficiency of the trading partner increases by 10%, the bilateral trade volume increases by about 4.3%. The results of this analysis show that it is important to increase the logistics efficiency of one's home country in order to activate intra-regional trade, but it is also necessary to increase the efficiency of the trading partner.

In addition, studies such as Bergstrand (1989), Deardorff (1998), and Bougheas et al. (1999) have shown that transport infrastructure plays an important role in trade. On the other hand, the importance of logistics efficiency in terms of software rather than the level of logistics infrastructure in terms of hardware has recently been highlighted. This is because it is more accurate to estimate the effect of logistics efficiency on trade than simple logistics infrastructure.

Related studies include Bang (2009), Ahn (2014), Marti et al. (2014), Jung (2015), Cho and Park (2021), and Ahn (2021). Their study analyzed the effect of logistics efficiency on international trade using the LPI published by the World Bank.

Marti et al. (2014) analyzed the effect of LPI on trade in emerging and developing countries. In their study results, it was found that the LPI had a positive (+) effect on exports. In particular, they suggested that LPI has a greater effect on exports than the geographic distance variable. In this study, the country was divided into five continents and the characteristics of each continent were analyzed. As a result of the analysis, it was confirmed that the effect of logistics efficiency in South America on trade is greater than that of other continents.

Ahn (2014) analyzed the effect of the LPI on trade in 21 APEC countries. They used the gravity model for empirical analysis, and the analysis period was from 2004 to 2012. The author presented results that logistics efficiency affects bilateral trade. In particular, the results showed that the logistics efficiency of the partner country has a greater effect on bilateral trade than the logistics efficiency of the own country.

Lim and Jun (2019) conducted an empirical analysis of the effects of the LPI on Korea's imports and exports for Korea's major trading partners. In this study, for empirical analysis, Korea's trading partners were divided into 4 groups according to income level. As a result of the analysis, it was suggested that LPI has a statistically significant effect on imports by Korea (exports in the case of target countries). In the case of countries with low income levels, the result showed that LPI had a greater effect on exports to Korea.

Cho and Park (2021) analyzed the relationship between Korea's agri-food exports and logistics efficiency. The countries analyzed were the United States, Japan, China, and New Southern countries, which are Korea's major exporters of agri-food.

In their study, empirical analysis was conducted using the gravity model, and the analysis period was set from 2007 to 2018. They suggested that the logistical efficiency of exporting countries increases Korea's agricultural and food exports.

III. Model and Data

1. Research Model

In this study, the relationship between the logistics efficiency of RCEP signatories and Korean trade is analyzed using the gravity model, which is a representative model that explains the size of 'normal' trade between countries.

The gravity model is a representative economic model used for empirical research on international trade. The gravity model started to be used in international trade theory by Tinbergen (1962). The gravity model started to be widely used because of its usefulness in empirical analysis without a theoretical background, but since Anderson (1979), many attempts have been made to actually derive the gravity model through the theoretical model. In particular, the gravitational model has a solid theoretical foundation through studies such as Helpman and Krugman (1985), Bergstrand (1989), Marksen and Wigle (1990), Eaton and Kortum (2002), and Deardorff (1998).

The basic idea of the gravitational model is based on the standardized fact that the economic scale and the distance from its trading partners are closely related to the volume of trade. In other words, it is based on the assumption that trade between countries is proportional to the product of economic scale and inversely proportional to distance. This can be summarized in a formula as follows.

$$T_{ij} = A \times \left(\frac{Y_i Y_j}{D_{ij}}\right) \quad (1)$$

Where T_{ij} is the trade scale between the two countries (exports + imports), A is the proportional constant, Y_i is the GDP of country i, Y_j is the GDP of country j, and D_{ij} is the distance between country i and country j. Applying the natural logarithm to Equation (1), if it is rearranged as a econometrics model, it is the following Equation (2).

$$lnT_{ij} = \beta_0 + \beta_1 lnY_i + \beta_2 lnY_j + \beta_3 lnD_{ij} \quad (2)$$

Equation (2) is the process to decide the total trade of nations conducting domestic and overseas economic activities, and yet, it does not explain the revealed comparative advantage in trade among the related countries. T_{ij} stands for the total trades between both i and j countries, and it is valid when partially contributing to an increase in the GDPs of both countries. $Y_i(Y_j)$ is a representative variable for $i(j)$ country as an important measure to determine total trade. The main merit of the gravity model is that the distance of both countries in trade plays a clear role. Most of the studies using the gravitational model emphasize the importance of geographic distance in international trade (Deardorff, 1998; Helpman et al., 2008; Evenett & Keller, 2002).

In this study, based on the research model of Bougheas et al. (1999) and Bang Ho-Kyung (2009), the effect of logistical efficiency in RCEP signatory countries on Korea's trade is analyzed. In previous studies, the logistics cost was determined in terms of hardware such as each country's logistics infrastructure level; that is, density of the road network, paved road network, and railway density, rather than each country's logistics efficiency. However, recently, it has been reported that although the level of logistics infrastructure is high in terms of hardware, it is often more poor in terms of efficiency. Therefore, it is more appropriate to consider it in terms of software rather than in terms of hardware (Bang, 2009). Accordingly, this study uses logistics efficiency variables rather than simple logistics infrastructure level variables. LPI, which is input as a variable for logistics efficiency, is evaluated as the most sophisticated measurement among the logistics indexes published so far through various evaluation indicators related to the logistics of each country.

In order to analyze the effect of logistics efficiency in RCEP countries on Korea's trade, the independent variables of the gravity model included GDP, population, distance, and LPI.

$$Ln(TRADE_{ijt}) = \beta_0 + \beta_1 ln(GDP_{ij})_t + \beta_2 ln(POP_{ij})_t + \beta_3 ln(DIST_{ij}) + \beta_4 ln(LPI_{jt}) + \varepsilon_{ijt} \quad (3)$$

Where $ln(GDP_{ij})$ is $ln(GDP_i \times GDP_j)$ and $ln(POP_{ij})$ is $ln(POP_i \times POP_j)$.

In Equation (3), $TRADE_{ijt}$ means the annual trade volume (exports + imports) of Korea with respect to the RCEP signatory countries. i stands for Korea, j stands for RCEP signatory countries, and t stands for the 13-year trading period from 2007 to 2019.

Estimation coefficients β_1 and β_2 are variables representing market size. GDP is a variable that indicates the export capacity of domestic products or the size of the consumption market. An increase in the GDP of an exporting country means that it has economies of scale due to an increase in productivity. Also, for an importing country, a high GDP means a large market for consuming the product. Therefore, as GDP increases, trade volume is expected to increase. As the market size of Korea and RCEP signatory countries increases, trade between the two countries is expected to increase. Therefore, it is expected that the increase in the gross domestic product and population of Korea and the RCEP signatory countries will increase the demand for trade between Korea and the RCEP signatory countries, thereby increasing the amount of trade. Accordingly, the sign expects a positive (+).

Estimation coefficient β_3 is the distance between the capital of Korea and the capital of the other country, and it is expected that trade-related costs (transportation and logistics costs, etc.) will occur as the distance increases. Assuming this, it is judged that it will act as a negative factor for trade, and the estimation coefficient is expected to have a negative (-) sign.

Estimation coefficient β_4 is an LPI and shows the effect of logistics efficiency in RCEP signatory countries on Korea's trade. As the LPI increases,

the logistics cost decreases, so Korea's trade will increase. Accordingly, the estimated coefficient of the LPI is expected to have a positive (+) sign.

2. Data

Detailed definitions and sources of the data used in this study are as follows. First, the target countries of this study are 13 countries, excluding Brunei and Laos, among RCEP signatory countries. Trade data between the two countries was constructed using the UN's COMTRADE database, and the source of the distance between the two countries is the CEPII database. The distance between the two countries represents the distance between the capitals of the two countries.

Table 3. Characteristics of Analysis Dat

Data	Variable	Source	Unit	Definition
Trade Volume	lnTRADE	UNCTAD	USD	Trade volume between Korea and RCEP signatories
Economic Scale	lnGDP	UNCTAD	USD	Multiplication of GDP between Korea and RCEP signatories
Population Size	lnPOP	World Bank	USD	Multiplication of population between Korea and RCEP signatories
Geographic Distance	lnDIST	CEPII	Mile	Distance between Korea and RCEP signatories
Logistics Performance Index	lnLPI	World Bank	Index	Logistics performance index of RCEP signatories

In this study, logistics efficiency, which is a key variable of interest, was used as an LPI provided by the World Bank. The World Bank has been publishing LPI data every two years since 2007. Odd-numbered years during the study period are analyzed using the same values as the previous year's data.

For detailed analysis, in addition to the LPI, the individual indicators of LPI are input to the independent variable for analysis. If all indicators for each logistics sector are included in the explanatory variable, the problem of multicollinearity occurs and an accurate estimate cannot be obtained. Accordingly, in order to solve this problem, the individual indicators of LPI are individually included in the explanatory variables and analyzed. Detailed indicators of LPI are presented in Table 4.

3. Methodology

Equation (3), established above, is one of the most widely used equations in many studies analyzing the flow of bilateral trade so far, despite its many shortcomings. However, since Equation (3) is a cross-sectional analysis using a gravity model, heteroscedasticity and selection bias estimation are strongly suspected.

In other words, when empirical analysis of Equation (3) is conducted through a simple

Table 4. Individual Indicators of LPI

Data	Variable	Source	Unit	Definition
Individual Indicator of LPI	lnCUST	World Bank	Index	Efficiency of customs procedures
Individual Indicator of LPI	lnINFR	World Bank	Index	Quality of trade and transport-related infrastructure
Individual Indicator of LPI	lnTRAC	World Bank	Index	Ablility to track and trace consignments
Individual Indicator of LPI	lnLOGS	World Bank	Index	Competence and quality of logistics servies
Individual Indicator of LPI	lnTIME	World Bank	Index	Frequency with which shipments reach consignee within schduled or expected time
Individual Indicator of LPI	lnITRN	World Bank	Index	Ease of arranging competitively priced shipments

panel OLS, there is a problem in that each country's national characteristics may be biased. Accordingly, analysis using simple OLS cannot be an appropriate estimation method.

Therefore, it is necessary to analyze via the random effects model and the fixed effects model, which are varying coefficient models that can more effectively analyze the unobservable factors that exist in the panel data. To check which model has more validity among the random effects model and the fixed effects model, a Hausman test is performed (Wooldridge, 2008). In the hypothesis test for selecting an estimation model, if the null hypothesis is established, the random effects model is efficient, and if the null hypothesis is rejected, it is more efficient to consider the fixed effects model together.

IV. Empirical Evidence

The empirical results of Equation (3) are as follows. The coefficient of GDP was about 0.14 and statistically significant at the 10% level of significance. The estimated coefficients for the geographic distance were not statistically significant at any significance level, and its sign is shown to be negative. Meanwhile, the coefficient of population was about 0.6 and statistically significant at the 1% level of significance. The coefficient of LPI had statistically significant results at the 1% significance level as well.

To summarize the result of panel OLS analysis, it was found that GDP, population, and logistics efficiency of RCEP signatory countries had an effect on Korea's trade. The estimation coefficient for the logistic efficiency variable of the RCEP signatory countries, which is the main variable of interest in this study, showed a positive value and was analyzed to be statistically significant. These estimation results indicate that the logistics efficiency of the RCEP signatory countries has a positive effect on Korea's trade. In addition, the estimation coefficient of the detailed indicators of LPI were found to be statistically significant at the 1% significance level for all six indicators.

Table 5. Results of Panel OLS Estimation

Variable	Eq.(3)	Eq.(3)-1	Eq.(3)-2	Eq.(3)-3	Eq.(3)-4	Eq.(3)-5	Eq.(3)-6
Cons.		-4.762*	-3.544*	0.325	-3.281*	0.317	0.702
		(-1.941)	(-1.567)	(0.168)	(-1.526)	(0.149)	(0.394)
InGDP		0.224***	0.122	0.351***	0.223***	0.445***	0.442***
		(2.637)	(1.327)	(5.375)	(2.926)	(6.915)	(8.712)
InPOP		0.601***	0.614***	0.369***	0.523***	0.297***	0.294***
		(6.171)	(6.493)	(5.341)	(6.458	(4.217)	(5.049)
InDIST		-0.057	-0.035	-0.201*	-0.065	-0.236**	-0.186*
		(-0.509)	(-0.315)	(-1.921)	(-0.613)	(-2.160	(-1.864)
InLPI	6.151***						
	(10.55)						
InCUST		5.022***					
		(7.771)					
InINFR			4.624***				
			(8.201)				
InTRAC				4.171***			
				(8.495)			
InLOGS					5.038***		
					(8.766)		
InTIME						4.321***	
						(7.122)	
InITRN							4.218***
							(9.711)
Adj. R^2	0.89	0.87	0.88	0.88	0.88	0.87	0.89
Obs.	156	156	156	156	156	156	156

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 10%, 5% and 1% levels, respectively.

It was confirmed that the gravity model would be useful for analyzing Korea's trade determinants through the results of panel OLS analysis. However, for the panel OLS analysis method, there is a limitation in not comprehensively considering the individual characteristics and time characteristics, which are merits of the panel data used in this study. Therefore, in order to solve this problem, it is necessary to analyze the fixed effects model and the random effects model using the variable coefficient model. The results of analysis using the random effects model and the fixed effects model are presented in Tables 6 to 12.

Table 6. Estimation Results of the Fixed Effects and Random Effects Models

	Cons.	InGDP	InPOP	InDIST	InLPI	Adj. R^2	F-stat.	Hausman Chi-Sq.
Random Effects	10.217* (1.906)	0.511*** (9.590)	0.069 (0.436)	-0.529* (-1.588)	1.695*** (3.931)	0.63	66.03	21.36***
Fixed Effects	50.435*** (3.821)	0.799*** (7.840)	-2.111*** (-3.216)	omitted	0.998** (2.171)	0.98	602.62	

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 10%, 5% and 1% levels, respectively.

Table 6 presents the estimation results of the fixed effects model and the random effects model in which the LPI of the RCEP signatory countries is included as an independent variable. As for the result of the Hausman test, the null hypothesis is adopted, so it can be seen that the random effect model is more efficient.

The coefficient of GDP was about 0.51 and statistically significant at the 1% level of significance. The estimated coefficients for the population were not statistically significant at any significance level, and its sign is shown to be positive. Meanwhile, the coefficient of geographic distance was about 0.53 and statistically significant at the 10% level of significance. The coefficient of LPI had statistically significant results at the 1% significance level as well. In other words, if the logistics efficiency of the RCEP signatory country increases by 1%, when other variables are constant, Korea's trade volume increases by about 1.7%.

Table 7. Panel OLS Estimation Results for CUST

	Cons.	InGDP	InPOP	InDIST	InLPI	Adj. R^2	F-stat.	Hausman Chi-Sq.
Random Effects	13.824*** (2.745)	0.603*** (12.313)	-0.048 (-0.324)	-0.628** (-2.001)	0.437 (1.183)	0.60	59.90	33.15***
Fixed Effects	58.952*** (4.603)	0.894*** (9.492)	-2.510*** -(3.922)	omitted	0.077 (0.200)	0.98	582.97	

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 5% and 1% levels, respectively.

The CUST variable in the individual indicator of LPI refers to the efficiency of customs procedures. If the efficiency of customs clearance in the customs of the RCEP signatory countries is high, the customs clearance score will be high. Conversely, if the efficiency is low, the customs clearance score will be low. Table 7 shows the results of estimating the fixed effects model and the random effects model by including the customs clearance efficiency index of the RCEP signatory countries in the independent variable. As a result of conducting the Hausman test to confirm the validity of the two models, the random effects model was found to be more efficient. The estimated coefficient for the CUST was not statistically significant at any significance level, but its sign is shown to be positive. This means that the efficiency of customs clearance in RCEP signatory countries does not affect Korea's trade.

Table 8. Panel OLS Estimation Results for INFR

	Cons.	InGDP	InPOP	InDIST	InLPI	Adj. R^2	F-stat.	Hausman Chi-Sq.
Random Effects	13.223** (2.187)	0.518*** (9.101)	-0.002 (-0.012)	-0.636* (-1.669)	1.122*** (3.189)	0.60	60.10	20.62***
Fixed Effects	54.182*** (4.236)	0.813*** (8.174)	-2.278*** (-3.566)	omitted	0.783** (2.155)	0.98	602.35	

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 10% and 1% levels, respectively.

Table 8 shows the estimation results for the logistics infrastructure score among the individual indicators of LPI. The logistics infrastructure score is an item for the quality of infrastructure related to international trade and transportation.

As for the results of the Hausman test to verify the validity of the fixed effects model and the random effects model, it can be seen that the random effects model is more efficient because the null hypothesis is adopted. The coefficient of INRF had statistically significant results at the 1% significance level. In other words, when the efficiency of logistics infrastructure in the RCEP signatory countries improves by 1% when other variables are constant, Korea's trade volume increases by about 1.12%.

Table 9. Panel OLS Estimation Results for TRAC

	Cons.	InGDP	InPOP	InDIST	InLPI	Adj. R^2	F-stat.	Hausman Chi-Sq.
Random Effects	12.977** (2.287)	0.545*** (10.793)	-0.009 (-0.058)	-0.622* (-1.731)	1.020*** (3.652)	0.61	63.02	20.04***
Fixed Effects	50.420*** (3.827)	0.808*** (8.085)	-2.096*** (-3.191)	omitted	0.646** (2.211)	0.98	603.37	

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 10%, 5% and 1% levels, respectively.

Among the individual indicators of LPI, the goods tracking and tracing score indicates the tracking ability of the consigned goods. The recent logistics environment is equipped with a system that enables tracking and real-time confirmation of goods in transit. As a result, companies can accurately check the current location of goods, which provides many advantages in terms of supply cycle and inventory management.

Table 9 shows the results of estimating the fixed effects model and the random effects model by including the product tracking index of the RCEP signatory countries in the independent variable. The results of the Hausman test to confirm the validity of the two models showed that the random effects model was more efficient because the null hypothesis was adopted. The coefficient of TRAC had statistically significant results at the 1% significance level. These results can be said to have a positive effect on the increase in Korea's trade volume as the RCEP signatory countries' ability to track goods improves.

Table 10. Panel OLS Estimation Results for LOGS

	Cons.	InGDP	InPOP	InDIST	InLPI	Adj. R^2	F-stat.	Hausman Chi-Sq.
Random Effects	12.682** (2.512)	0.577*** (11.810)	0.016 (-0.109)	-0.591* (-1.866)	0.860** (2.484)	0.61	62.09	29.84***
Fixed Effects	57.290*** (4.482)	0.871*** (9.205)	-2.442*** (-3.826)	omitted	0.485 (1.348)	0.98	590.45	

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 10%, 5% and 1% levels, respectively.

The logistics service index is an item that indicates the level of quality and competence of logistics services. In the recent logistics industry, the demand for new types of logistics services such as smart logistics and fulfillment logistics is increasing due to the development of ICT technology. If sufficient technology is introduced and service competence is improved in these areas, the logistics service index will increase (Ahn, 2021).

Table 10 summarizes the results of estimating the fixed effects model and the random effects model by including the logistics service index of the RCEP signatory countries in the independent variable. The coefficient of LOGS was about 0.86 and statistically significant at the 1% level of significance. This means that if the logistics service of the RCEP signatories improves by 1% when other variables are constant, Korea's trade volume increases by about 0.86%.

Table 11. Panel OLS Estimation Results for TIME

	Cons.	InGDP	InPOP	InDIST	InLPI	Adj. R^2	F-stat.	Hausman Chi-Sq.
Random Effects	13.886** (2.415)	0.580*** (11.767)	-0.051 (-0.303)	-0.655* (-1.805)	0.771*** (2.534)	0.60	59.20	22.19***
Fixed Effects	54.587*** (4.027)	0.858*** (8.518)	-2.302*** (-3.418)	omitted	0.313 (0.976)	0.98	586.81	

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 10%, 5% and 1% levels, respectively.

The timeliness index is a measure item of the frequency with which shipments reach consignee within schduled or expected time. Like the logistics service index, the timeliness index can be said to be an evaluation index for the competence and performance of a logistics company that performs the actual logistics process.

Table 11 shows the analysis results by including the timeliness index of the RCEP signatories in the independent variable of the gravity model. The random effects model was confirmed to be more effective through the results of the Hausman test. The coefficient of TIME had statistically significant results at the 1% significance level. This means that, when other variables are constant, Korea's trade volume increases by about 0.77% if the timeliness efficiency of the RCEP signatory countries improves by 1%.

Table 12. Panel OLS Estimation Results for ITRN

	Cons.	InGDP	InPOP	InDIST	InLPI	Adj. R^2	F-stat.	Hausman Chi-Sq.
Random Effects	12.629** (2.427)	0.558*** (11.625)	-0.008 (-0.058)	-0.597* (-1.811)	1.013*** (3.754)	0.62	65.25	23.73***
Fixed Effects	51.067*** (3.920)	0.817*** (8.353)	-2.131*** (-3.280)	omitted	0.649** (2.315)	0.98	605.35	

Notes: 1. Values within the parentheses below the estimated coefficients denote the calculated t-statistics.
2. *, **, *** means significance level at 10%, 5% and 1% levels, respectively.

The international shipment index is an item that measures the ease of delivery at competitive prices. The high international shipping score means that import and export shippers can use sea transportation at an economic cost.

Table 12 shows the results of estimating the fixed effects model and the random effects model by including the international shipment index of the RCEP signatory countries in the independent variable of the gravity model. The coefficient of ITRN was about 1.01 and statistically significant at the 1% level of significance. This means that if the efficiency of international shipment of RCEP signatories improves by 1% when other variables are constant, Korea's trade volume increases by about 1.01%.

V. Summary and Conclusion

As the RCEP officially enters into force on January 1, 2022, the effect of market opening in Southeast Asia is greater than in the past, and the export performance of Korean companies is expected to improve. These preferential trade agreements, such as FTAs and RTAs, act as positive factors that can expand bilateral trade by lowering trade barriers, but competition between companies is intensifying.

Meanwhile, logistics infrastructure and logistics costs are becoming another trade obstacle to international trade. In particular, the increase in logistics costs between countries has a significant impact on international trade patterns. As the global production system spreads and competition between companies intensifies, interest in the relationship between trade and logistics infrastructure or the relationship between trade and logistics costs is increasing.

From Korea's point of view, the importance of logistics cost and logistics efficiency in trade with RCEP signatories is quite large. Against this background, this study analyzed the effect of logistics efficiency in RCEP signatory countries on Korea's trade.

In order to analyze the effect of logistics efficiency in RCEP countries on Korea's trade, the independent variables of the gravity model included GDP, population, distance, and LPI. On the other hand, there is a problem that the national characteristics of each country may be biased when empirical analysis is conducted through simple panel OLS. Therefore, in this study, empirical analysis was conducted using the random effects model and the fixed effects model, which are variable coefficient models that can more effectively analyze unobservable factors existing in panel data.

The empirical analysis results are summarized as follows. In order to analyze the effect of logistical efficiency in RCEP countries on trade, the fixed effects model and the random effects model were estimated. As a result of conducting the Hausmann test to confirm the validity of the two models, it was confirmed that the random effects model was more efficient.

Empirical evidence using the gravity model showed that the coefficient of LPI was about

1.7 and statistically significant at the 1% level of significance. In other words, if the logistics efficiency of the RCEP signatory country increases by 1%, when other variables are constant, Korea's trade volume increases by about 1.7%.

Next, for detailed analysis, an empirical analysis was conducted by including individual indicators of LPI as independent variables in addition to LPI. The estimated coefficient for the customs clearance efficiency was not statistically significant at any significance level, but its sign is shown to be positive. This means that the efficiency of customs clearance in RCEP signatory countries does not affect Korea's trade. On the other hand, the estimation coefficients for individual indicators such as logistics infrastructure, logistics service, international shipment, timeliness, and goods tracking were statistically significant at the 1% significance level. In particular, among the five individual indicators, it was confirmed that logistics infrastructure, goods tracking, and international shipment had a relatively large impact on trade compared to other individual indicators.

Through this study, it was confirmed that trade facilitation can be achieved if the logistics efficiency of the RCEP signatory countries is improved. Therefore, it is necessary to make efforts to reduce logistics costs through the establishment of logistics infrastructure and to increase logistics efficiency. Accordingly, RCEP signatory countries, including Korea, should make efforts to facilitate trade by discovering various cooperative projects to improve logistics efficiency.

The LPI used as a logistic efficiency variable in this study has been published every two years since 2007 by the World Bank. Data for odd-numbered years during the analysis period of this study were analyzed using the same values as data from the previous year. There may be some problems and controversy in deriving accurate analysis results. These aspects can be said to be the limitations of this study.

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The Choice of Trade Policy in an International Differentiated Duopoly with Process R&D Investment under Uncertainty

Il-Seok Yang[a]

[a]*Major in International Trade, Kyonggi University, South Korea*

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ABSTRACT

Purpose – The purpose of this paper is to investigate equilibrium pairs of modes of government intervention in an international differentiated duopoly with process R&D investment under uncertainty. Governments in each of the two countries choose direct R&D investment and quantity controls, or R&D subsidies to shift profits towards domestic firms.

Design/Methodology/Approach – For the analysis, we extend the model of Haaland and Kind (2008) to that with uncertainty and consider direct R&D investment and quantity controls besides R&D subsidies. Firms in each of the two countries produce differentiated products and governments in each compete via direct R&D investment and quantity controls, or R&D subsidies in a third-country market. In environments with low, high, and intermediate uncertainty, equilibrium pairs of modes of government intervention are examined.

Findings – It is shown that (i) in an environment with low uncertainty, direct R&D investment and quantity controls by each government is a unique equilibrium if the goods are substitutes and not too close, and R&D subsidies by each government is a unique equilibrium if the goods are complements and not too close; (ii) in an environment with high uncertainty, R&D subsidies by each government is a unique equilibrium regardless of the nature of the goods, except in the cases of too close substitutes and complements; and (iii) in an environment with intermediate uncertainty, R&D subsidies by each government is a unique equilibrium if the goods are complements and not too close. Moreover, in an environment with intermediate uncertainty, there are two symmetric equilibria if the goods are substitutes and not too close and there are two asymmetric equilibria if the goods are substitutes and very close.

Research Implications – By analyzing the effects of direct R&D investment and quantity controls, and R&D subsidies in international markets under uncertainty, we can expect which government intervention appears in equilibrium.

Keywords: differentiated goods, government intervention, process R&D, R&D Subsidies, uncertainty
JEL Classifications: D43, F12, F13

[a] *E-mail: isyang@kyonggi.ac.kr.*

I. Introduction

Comparing tariffs and quotas has been an important issue in the literature of international trade. After the work of Bhagwati (1965), who showed that two policies produce the same results when only one government intervenes without uncertainty, some related papers have come out and showed that those policies can lead to different results in some various environments. Rodriguez (1974) showed that the equivalence of tariffs and quotas does not hold when more than one government is intervening. Fishelson and Flatters (1975) and Dasgupta and Stiglitz (1977) showed that the equivalence fails when supply and demand conditions are uncertain. Cooper and Riezman (1989) contrasted the government' use of export subsidies with direct quantity government interventions and investigated equilibrium pair of modes of government intervention in an uncertain world.

Although those papers have made important contributions to this literature, there is something we have to think about. In the real world, direct export subsidies are not allowed, but R&D related policies are allowed by the World Trade Organization (WTO). Further, through R&D policies, we can obtain the same results as those from export subsidies. Thus, it is likely that studies of R&D policies are more valuable (Spencer & Brander,1983).

In recent years, the study of the effect of uncertainty on research and development (R&D) has grown significantly in several respects. Zhou (2007) studied the effect of uncertainty and spillovers on the direction of R&D policy when firms engage in international R&D competition. Bloom (2007) showed that different adjustment costs lead to different predicted dynamics of R&D under uncertainty. Czarnitzki and Toole (2007) examined how product market uncertainty and government R&D subsidies affect firm-level R&D investment using German data and found that product market uncertainty reduces R&D investment, and government R&D subsidies increase R&D investment. Tsai et al. (2009) made a three-phase model for product innovation with capital investment under uncertainty to investigate decisions of a manufacturer in an industry facing volatile market demand for new innovations. García-Quevedo et al. (2017) studied the effects of demand uncertainty and stagnancy on firm decisions to invest in R&D. Cho and Lee (2018) examined the uncertainty-R&D investment relationship and its interactions with firm size using South Korean firm-level data and found a concave relationship between the uncertainty elasticity of R&D investment and firm size. Jiang and Liu (2020) used a linear Bayesian regression model to investigate the effects of economic policy uncertainty (EPU) on firm R&D expenditure using Chinese data, and found a positive relationship between EPU and firm R&D expenditure. Lin et al. (2021) studied how uncertainty affected R&D on the basis of a sample covering 109 countries from 1996 to 2018 and showed that uncertainty has a significantly negative impact on R&D investment at the country-level aggregate scale.

In an interesting work by Tassey (1996), he studied choosing government R&D policies between tax incentives and direct funding in the case of technology-based markets. More recently, *Maeil Business News Korea* (2020) pointed out that government R&D management system has been strengthened and the autonomy of R&D has shrunken. The motivation of the paper is to investigate the choice of government R&D policies between subsidy incentives and direct funding in international trade. The R&D policies dealt with in this paper are direct R&D investment and quantity controls, and R&D subsidies. Direct R&D investment and quantity controls, and R&D subsidies correspond to direct quantity controls or quota, and export subsidies examined in the previous papers, respectively.

The purpose of this paper is to investigate equilibrium pairs of modes of government intervention in an international differentiated duopoly with process R&D investment under uncertainty.[1] Governments in each of the two countries choose direct R&D investment and quantity controls, or R&D subsidies to shift profits toward domestic firms. For the analysis, we extend the model of Haaland and Kind (2008) to that with

uncertainty and consider direct R&D investment and quantity controls other than R&D subsidies. Firms in two countries produce differentiated products, and governments in each compete via direct R&D investment and quantity controls or R&D subsidies in a third-country market. In environments with low, high, and intermediate uncertainty, equilibrium pairs of modes of government intervention are examined.

Selected principal results are as follows. First, in an environment with low uncertainty, R&D investment and quantity controls by each government is a dominant strategy if the goods are substitutes and not too close, and R&D subsidies by each government is a dominant strategy if the goods are complements and not too close. Second, in an environment with high uncertainty, R&D subsidies by each government is a dominant strategy regardless of the nature of the goods, except in the cases of too close substitutes and complements. Third, in an environment with intermediate uncertainty, R&D subsidies by each government is a dominant strategy if the goods are complements and not too close. Furthermore, in an environment with intermediate uncertainty, there are two symmetric equilibria if the goods are substitutes and not too close, and there are two asymmetric equilibria if the goods are substitutes and very close.

This paper is arranged as follows. In Section II, we formulate the basic model and derive equilibrium levels of R&D investment, output, and social welfare in the absence of government intervention. In Section III, we derive the subgame perfect Nash equilibria of the bilateral policy games between the governments for four feasible pairs of modes of government intervention. In Section IV, we find equilibrium pairs of modes of government intervention in environments with low, high, and intermediate uncertainty. Section V contains conclusions.

II. The Basic Model and the Absence of Government Intervention

We consider a model in which two firms, firm i and j, produce a differentiated product and firm i (firm j) is located in and owned by residents of country i (country j). We assume that the firms export all output to a third-country market, and thus they compete in that market. The purpose of this assumption is to analyze the profit shifting motives for government intervention without having to be concerned with the welfare of consumers. The inverse demand functions are given by

$$p_i = 1 - x_i - \gamma x_j + \theta,\ i, j = 1, 2 \text{ and } i \neq j \qquad (1)$$

where P_i is the price of good i, x_i (x_j) is the consumption of firm i's (j's) production of a differentiated good in the third-country market, and $\gamma \in (-1,1)$ represents a measure of the degree of horizontal differentiation between goods. If γ is positive, negative, or zero, the goods are substitutes, complements, or independent, respectively. θ is a random variable with mean zero and variance σ^2.

Each firm produces at a constant marginal cost of $c > 0$. However, if firm i invests in R&D, it can reduce its marginal cost to $(c - d_i)$ by expending d_i^2 in process innovation.[2] Therefore, firm i's marginal cost of production rests on its own R&D investment:

1. The model of an international differentiated duopoly is related to technology-based and R&D-intensive industries. Gao and Miyagiwa (2005) presented primary metals, chemicals, electronics, and mechanical engineering sectors as R&D-intensive industries, which are often targeted by antidumping protection. Here, we can consider the international mobile phone market in which Apple and Samsung compete as an example.
2. We assume that the cost of R&D is quadratic to reflect the diminishing returns to R&D expenditures. See D'Aspremont and Jacquemin (1988) and Haaland and Kind (2008) for more details.

$$MC_i = c - d_i,\ i = 1,2 \tag{2}$$

where d_i is firm i's R&D investment and c is large enough such that MC_i is positive.

In the absence of government intervention, we may write the profit function of firm i as

$$\pi_i = [p_i - (c - d_i)]x_i - d_i^2,\ i = 1,2 \tag{3}$$

In this case, since the consumer surplus is not considered and there is no government intervention, the welfare of country i, W_i, is equal to π_i. Firm i maximizes Equation (3) with respect to d_i and x_i, along with Equation (1). Then, Firm i's best response functions are given by

$$d_i = \frac{x_i}{2} \tag{4}$$

$$x_i = \frac{1 + \theta - c + d_i - \gamma x_j}{2}\ .^{3} \tag{5}$$

Solving the system of the four best response functions yields the following equilibrium values:

$$\tilde{d}_i = \frac{1+\theta-c}{3+2\gamma},\ i = 1,2 \tag{6}$$

$$\tilde{x}_i = \frac{2(1+\theta-c)}{3+2\gamma},\ i = 1,2 \tag{7}$$

$$\tilde{p}_i = c + \frac{1+\theta-c}{3+2\gamma},\ i = 1,2 \tag{8}$$

$$\tilde{\pi}_i = \tilde{W}_i = \frac{3(1+\theta-c)^2}{(3+2\gamma)^2},\ i = 1,2 \tag{9}$$

where '~' represents the equilibrium in the absence of government intervention. We assume that $1 + \theta > c$ so that equilibrium levels of R&D investment and output are positive.

This outcome gives us a basis for examining the policy decisions of the two governments when they shift rents toward their domestic firms strategically. Following Cooper and Riezman (1989), we consider the following three-stage game. In stage one, governments select the form of intervention simultaneously, taking the policy selected by the other government as given. The policy instrument is either the use of R&D subsidies, or direct R&D investment and quantity controls. Governments do not know the realization of θ in this stage, although its distribution is common knowledge. In stage two, governments determine the level of intervention. Each government takes the policy level determined by the other government as given. After these decisions have been made, θ is revealed to firms. In stage three, firms choose levels of R&D investment and output to maximize profits, given the constraints imposed by their governments.[4] If governments intervene with direct R&D investment and quantity controls, they select the output level for their firms. It is required that firms produce this output level irrespective of the state of nature, thereby eliminating the third stage of the game. Alternatively, if governments intervene with subsidies, the firms can adjust their output decisions to the realization of θ.

III. Subgame Perfect Nash Equilibria and the Choice of Policy Mode

To ensure subgame perfect Nash equilibria, the three-stage game is solved for each feasible pair of modes of intervention, providing a 2×2

3. Firm i's second-order conditions are satisfied: $\frac{\partial^2 \pi_i}{\partial d_i^2} = -2 < 0$, $\frac{\partial^2 \pi_i}{\partial x_i^2} = -2 < 0$.

4. The sequence of moves of governments and firms is prevalent in this literature. It reflects that firms have more information than governments when they make decisions. See Dixit (1984), Brander and Spencer (1985), Eaton and Grossman (1986), Cooper and Riezman (1989) for more details.

payoff matrix from which the optimal mode of intervention is determined in the first stage of the game. Equilibrium pairs of modes of intervention will be discussed in Section IV.

1. Bilateral Subsidy Game

We first assume that the government in country i has chosen s_i, which is the level of per-unit R&D subsidy that firm i obtains from its domestic government. Then, the profits for firm i are given by

$$\pi_i = (1 + \theta - x_i - \gamma x_j - c + d_i)x_i - d_i^2 + s_i d_i, \quad i, j = 1,2 \text{ and } i \neq j. \tag{10}$$

Firm i determines R&D investment and quantity given the R&D investment and quantity chosen by the other firm. Thus, firm i's best response functions are derived as

$$d_i = \frac{x_i + s_i}{2}, \; i = 1,2 \tag{11}$$

$$x_i = \frac{1+\theta-c+d_i-\gamma x_j}{2}, \; i, j = 1,2 \text{ and } i \neq j.^{5} \tag{12}$$

Solving the system of the four best response functions yields the following equilibrium values for given values of (θ, s_i, s_j):

$$d_i^S = \frac{(3-2\gamma)(1+\theta-c)+2(3-\gamma^2)s_i-\gamma s_j}{9-4\gamma^2}, \quad i, j = 1,2 \text{ and } i \neq j \tag{13}$$

$$x_i^S = \frac{2(3-2\gamma)(1+\theta-c)+3s_i-2\gamma s_j}{9-4\gamma^2}, \quad , i, j = 1,2 \text{ and } i \neq j \tag{14}$$

where superscript S represents bilateral subsidy game in pair of modes of intervention. Notice that firm i's R&D investment and output increase when values of θ and/ or s_i are higher, while they decrease when values of s_j are higher.

Inserting Equations (13) and (14) into Equation (10) yields the following equilibrium levels of firm profit and social welfare as a function of s_i and s_j:

$$\pi_i^S(\theta, s_i, s_j) = \pi_i\left[d_i^S(\theta, s_i, s_j), x_i^S(\theta, s_i, s_j), : \right. \\ \left. x_j^S(\theta, s_i, s_j); s_i\right], \quad i, j = 1,2 \text{ and } i \neq j \tag{15}$$

$$W_i^S(\theta, s_i, s_j) = \pi_i\left[d_i^S(\theta, s_i, s_j), x_i^S(\theta, s_i, s_j), \right. \\ \left. x_j^S(\theta, s_i, s_j); s_i\right] - s_i d_i^S(\theta, s_i, s_j), \quad i, j = 1,2 \text{ and } i \neq j \tag{16}$$

where the welfare of country i is given by $W_i = \pi_i - s_i d_i$, $i=1,2$.

Next, the government in country i chooses its level of subsidy prior to the realization of θ. Its problem is to determine a level of subsidy that maximizes the expected value of the firm profit net of the subsidy, $EW_i^S(\theta, s_i, s_j)$. Differentiating $EW_i^S(\theta, s_i, s_j)$ with respect to s_i yields the best response subsidies:

$$s_i(s_j) = \frac{2\gamma^2[(3-2\gamma)(1-c)-\gamma s_j]}{(3-2\gamma^2)(9-2\gamma^2)}, \quad i, j = 1,2 \text{ and } i \neq j.^{6} \tag{17}$$

Solving the system of the two best response subsidies yields the following equilibrium levels of subsidies:

5. Firm i's second-order conditions are satisfied: $\frac{\partial^2 \pi_i}{\partial d_i^2} = -2 < 0 \quad \frac{\partial^2 \pi_i}{\partial x_i^2} = -2 < 0$

6. Country i's second-order conditions are satisfied: $\frac{\partial^2 W_i}{\partial s_i^2} = -54 + 48\gamma^2 - 8\gamma^4 < 0$

$$s_i^S = \frac{2\gamma^2(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)}, i = 1,2 \quad (18)$$

Notice that it is positive whether the goods are substitutes or complements and zero when the goods are independent.[7]

Inserting Equation (18) into Equations (13), (14), and $EW_i^S(\theta, s_i, s_j)$, along with Equation (1) yields the following equilibrium values:

$$d_i^S = \frac{3(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)} + \frac{\theta}{3+2\gamma}, i = 1,2 \quad (19)$$

$$x_i^S = \frac{2(3-\gamma^2)(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)} + \frac{2\theta}{3+2\gamma}, i = 1,2 \quad (20)$$

$$p_i^S = c + \frac{(3-2\gamma^2)(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)} + \frac{\theta}{3+2\gamma}, i = 1,2 \quad (21)$$

$$EW_i^S = \frac{(3-2\gamma^2)(9-2\gamma^2)(1-c)^2}{[9+2\gamma(1-\gamma)(3+\gamma)]^2} + \frac{3\sigma^2}{(3+2\gamma)^2}, \quad i = 1,2. \quad (22)$$

Notice that firm i's R&D investment and output rise when values of θ are higher. This implies that firms increase R&D investment and output when demand is higher. Further, the expected welfare of country i rises when the value of σ^2 is higher because firms determine R&D investment and output after observing the state of nature.

2. Bilateral R&D Investment and Quantity Control Game

We now turn to the case in which two governments elect to control their firms directly by setting the levels of R&D investment and output. Since the state of nature is revealed after the governments choose R&D investment and output levels, the government in country i chooses d_i and x_i to maximize

$$EW_i^Q = E[(1+\theta-x_i-\gamma x_j-c+d_i)x_i - d_i^2], \quad i,j = 1,2 \text{ and } i \neq j, \quad (23)$$

where superscript Q represents bilateral R&D investment and quantity control game in pair of modes of intervention. In this case, the government in country i takes the levels of R&D investment and output for the other country as given. Thus, country i's best response functions are derived as

$$d_i = \frac{x_i}{2}, i = 1,2 \quad (24)$$

$$x_i = \frac{1-c+d_i-\gamma x_j}{2}, i,j = 1,2 \text{ and } i \neq j.[8] \quad (25)$$

Solving the system of the four best response functions yields the following equilibrium values:

$$d_i^Q = \frac{1-c}{3+2\gamma}, i = 1,2 \quad (26)$$

$$x_i^Q = \frac{2(1-c)}{3+2\gamma}, i = 1,2 \quad (27)$$

$$EW_i^Q = \frac{3(1-c)^2}{(3+2\gamma)^2}, i = 1,2. \quad (28)$$

7. If the industry structures in two countries are symmetric, then both countries choose to subsidize exports since a subsidy leads to more output and prices will not fall much given the response of the foreign firm. See Brander and Spencer (1985) and Cooper and Riezman (1989) for more details.

8. Firm i's second-order conditions are satisfied: $\frac{\partial^2 \pi_i}{\partial d_i^2} = -2 < 0$ $\frac{\partial^2 \pi_i}{\partial x_i^2} = -2 < 0$

3. R&D Investment and Quantity Controls / Subsidy Mixture Game

Finally, we consider the case in which country *i* intervenes with subsidies while country *j* controls R&D investment and quantity for its firm directly. The case that country *j* intervenes with subsidies while country *i* controls R&D investment and quantity for its firm directly is analyzed symmetrically. In this case, country *i* chooses a level of subsidy at the same time country *j* chooses levels of R&D investment and output. Thus, country *i* does not expect any changes in d_j and x_j as it changes s_i while country *j* takes account of the response of firm *i* when it chooses d_j and x_j. The reactions of firm *i* to changes in d_j and x_j are derived by solving Equations (11) and (12) only for *i* simultaneously:

$$d_i^M = \frac{(1+\theta-c)-\gamma x_j+2s_i}{3} \tag{29}$$

$$x_i^M = \frac{2(1+\theta-c)-2\gamma x_j+s_i}{3}, \tag{30}$$

where superscript *M* implies that country *i* intervenes with subsidies while country *j* controls R&D investment and quantity for its firm directly in pair of modes of intervention.

Inserting Equations (29) and (30) into $EW_i^M = E[(1+\theta-x_i-\gamma x_j-c+d_i)x_i-d_i^2]$ and maximizing EW_j^M with respect to s_i yield the following equilibrium level of subsidy for country *i*:

$$s_i^M = 0. \tag{31}$$

Inserting Equations (29) and (30), along with (31), into $EW_j^M = E[(1+\theta-x_j-\gamma x_i-c+d_j)x_j-d_j^2]$ and maximizing EW_j^M with respect to d_j and x_j yield the following equilibrium levels of R&D investment and output for firm *j*:

$$d_j^M = \frac{(3-2\gamma)(1-c)}{9-8\gamma^2} \tag{32}$$

$$x_j^M = \frac{2(3-2\gamma)(1-c)}{9-8\gamma^2}. \tag{33}$$

Using Equations (29), (30), (31), (32), and (33), the expected level of welfare in the two countries is calculated by

$$EW_i^M = \frac{(9-6\gamma-4\gamma^2)^2(1-C)^2}{3(9-8\gamma^2)^2}+\frac{\sigma^2}{3} \tag{34}$$

$$EW_i^M = \frac{(3-2\gamma)^2(1-C)^2}{3(9-8\gamma^2)^2}. \tag{35}$$

Cooper and Riezman (1989) indicated that each mode of government intervention has both a strategic advantage and disadvantage. A country that uses a subsidy permits its firm to react to θ, but it cannot prohibit its firm from reacting to the policy action of the other government. A country that controls quantity does not permit its firm to react to the state of nature, but it can stop its firm from reacting to the policy action of the other government. They state that "the resolution of the costs and benefits of flexibility will determine the mode of government intervention" (Cooper & Riezman,1989, 135).

IV. Equilibrium Pairs of Modes of Intervention

Table 1 displays the expected welfare for country *i* for the four possible policy combinations of government intervention. The expected welfare for country *j* can be found by interchanging *i* and *j* in the table.

Table 1. Expected Welfare for Country *i*

Country *i*	Country *j*	
	R&D Subsidy	R&D Investment and Quantity Controls
R&D Subsidy	$\frac{(3-2\gamma^2)(9-2\gamma^2)(1-c)^2}{[9+2\gamma(1-\gamma)(3+\gamma)]^2}+\frac{3\sigma^2}{(3+2\gamma)^2}$	$\frac{(9-6\gamma-4\gamma^2)^2(1-c)^2}{3(9-8\gamma^2)^2}+\frac{\sigma^2}{3}$
R&D Investment and Quantity Controls	$\frac{(3-2\gamma)^2(1-c)^2}{3(9-8\gamma^2)}$	$\frac{3(1-c)^2}{(3+2\gamma)^2}$

From Table 1, we can see that the expected welfare for country *i* is a function of the variability of θ, measured by σ^2, and the degree of horizontal differentiation, measured by γ. However, σ^2 is more important because the expected welfare for country *i* includes σ^2 when country *i* uses R&D subsidies, but it does not when it controls R&D investment and quantity directly. We first consider the extreme cases of large and small values of σ^2, and then examine intermediate values.

1. Small σ2

When $\sigma^2 = 0$, the use of direct R&D investment and quantity controls by each government is a dominant strategy if the goods are substitutes and not too close, and the use of R&D subsidies by each government is a dominant strategy if the goods are complements and not too close.[9] In other words, irrespective of whether country *j* uses R&D subsidies or direct R&D investment and quantity controls, the government in country *i* always chooses direct R&D investment and quantity controls when the goods are substitutes and not too close, and it always chooses R&D subsidies when the goods are complements and not too close. This is summarized in the following proposition.

Proposition 1: In the extreme case of small values of σ^2, (R&D investment and quantity controls, R&D investment and quantity controls) is a unique equilibrium if the goods are substitutes and not too close, and (R&D subsidies) is a unique equilibrium if the goods are complements and not too close.

Proposition 1 extends the results derived in Cooper and Riezman (1989) who considered homogenous goods, and thus could not differentiate substitutes from complements. When goods are substitutes and not too close, the strategic advantage in direct R&D investment and quantity control is superior to that in R&D subsidies, and when the goods are complements and not too close, the strategic advantage in R&D subsidies is greater than that in direct R&D investment and quantity control. Further, we find that the convexity of R&D cost complicates the analysis such that we cannot expect the monotonic comparison of policies of government intervention when goods are very close substitutes or complements.

Cooper and Riezman (1989) stated that the equilibrium subsidies derived in the profit shifting literature have no persuasive power in this situation since governments do not choose to use subsidies

9. Specifically, too close substitutes and too close complements mean that $0.98 \leq \gamma < 1$ and $-1 < \gamma \leq -0.91$, respectively. Even though linear demand and constant marginal costs are used, the convexity of the R&D cost function complicates the analysis.

in an environment with small σ^2 when they can choose to control quantity directly. However, we show a different result with differentiated products. That is, when governments are allowed to intervene through direct R&D investment and quantity controls with differentiated products, they can choose to use subsidies in an environment with low uncertainty if the goods are complements and not too close.

2. Large σ2

If the amount of uncertainty is sufficiently large, R&D subsidies by each government will be a dominant strategy whether the goods are substitutes and not too close or complements and not too close. That is, the flexibility of subsidy policies has a greater effect than the strategic advantage of direct R&D investment and quantity control has in an environment with large σ^2. This result is summarized in the following proposition.

Proposition 2: In the extreme case of large values of σ^2, (R&D subsidies, R&D subsidies) is a unique equilibrium regardless of the nature of the goods, except in the cases of very close substitutes and complements.

Aggregate levels of R&D investment and output in bilateral subsidy game are always greater than those in the absence of government intervention as follows:

$$2d_i^S - 2\tilde{d}_i = \frac{2\gamma^2(2+\gamma)(1-c)}{(3+2\gamma)(9+6\gamma-4\gamma^2-2\gamma^3)} > 0$$

.

$$2x_i^S - 2\tilde{x}_i = \frac{2\gamma^2(1-c)}{(3+2\gamma)(9+6\gamma-4\gamma^2-2\gamma^3)} > 0.$$

This implies that the outcome in which governments intervene with subsidies has higher levels of aggregate R&D investment and output for every realization of θ, regardless of the nature of the goods. The consumer surplus in the third country is higher when governments intervene with subsidies than when there is no government intervention. This result also extends that reported in Cooper and Riezman (1989) in the case of differentiated products. Further, on average, the levels of aggregate R&D investment and output are higher when governments use R&D subsidies than direct R&D investment and quantity controls regardless of the nature of the goods.

3. Intermediate σ2

For intermediate values of σ^2, we first notice that the government in country i always chooses R&D subsidies when the goods are complements and not too close, regardless of whether the government of country j uses R&D subsidies or direct R&D investment and quantity controls. However, whether the government in country i chooses R&D subsidies or direct R&D investment and quantity controls depends on the values of σ^2 when the goods are substitutes and not too close.

When the goods are substitutes and not too close, there is a critical value of σ^2 such that if the government of country j intervenes with R&D subsidies, the government of country i is indifferent in choosing between R&D subsidies and direct R&D investment and quantity controls. If $\sigma^2(\theta) > \sigma^2(S)$, country i uses R&D subsidies, and if $\sigma^2(\theta) > \sigma^2(S)$, country i uses direct R&D investment and quantity controls. This critical level of the variance of θ, $\sigma^2(S)$, is given by

$$\sigma^2(S) = \frac{4\gamma^3(3+2\gamma)^3(9+3\gamma-10\gamma^2-\gamma^3+2\gamma^4)(1-c)^2}{9(9-8\gamma^2)[9+2\gamma(1-\gamma)(3+\gamma)]^2}. \quad (36)$$

When goods are substitutes and not too close, there is also a critical value of σ^2 such that if the government of country j intervenes with direct R&D investment and quantity controls, the government of country i is indifferent in choosing between R&D subsidies and direct R&D investment and quantity controls. If $\sigma^2(\theta) > \sigma^2(Q)$ country i uses R&D subsidies, and if $\sigma^2(\theta) > \sigma^2(Q)$, country i uses direct R&D investment and quantity controls. This critical level of the variance of θ, $\sigma^2(Q)$, is given by

$$\sigma^2(Q) = \frac{16\gamma^3(27-24\gamma^2-4\gamma^3)(1-c)^2}{(3+2\gamma)^2(9-8\gamma^2)^2}. \quad (37)$$

Note that both $\sigma^2(S)$ and $\sigma^2(Q)$ are positive when the goods are substitutes and not too close. For intermediate values of σ^2, the form of the equilibrium will rely on the orderings between $\sigma^2(S)$ and $\sigma^2(Q)$.

If $\sigma^2(S) > \sigma^2(\theta) > \sigma^2(Q)$, then two asymmetric equilibria come out. When country j chooses R&D subsidies, then the best response of country i is to use direct R&D investment and quantity controls. Alternatively, when country j chooses direct R&D investment and quantity controls, then the best response of country i is to use R&D subsidies. By symmetry, country j's best responses to country i are the same, implying two asymmetric equilibria: (direct R&D investment and quantity controls, R&D subsidies), (R&D subsidies, direct R&D investment and quantity controls).

If $\sigma^2(S) > \sigma^2(\theta) > \sigma^2(Q)$, then two symmetric equilibria exist. Country i selects the same policy as country j without regard to the policy chosen by country j. By symmetry, country j's best responses to country i are the same, implying two symmetric equilibria: (R&D subsidies, R&D subsidies), (R&D investment and quantity controls, R&D investment and quantity controls).

We can order $\sigma^2(S)$ and $\sigma^2(Q)$ as a function of γ using Equations (36), (37) and the symmetry. It is shown that for $0<\gamma<0.72$, $\sigma^2(S) < \sigma^2(Q)$ while for $0.73<\gamma<0.9$, $\sigma^2(S) > \sigma^2(Q)$. Therefore, on the one hand, when the goods are substitutes and not too close, there are symmetric equilibria for intermediate values of σ^2. On the other hand, when the goods are substitutes and very close, there are asymmetric equilibria for the intermediate values of σ^2. The results derived are summarized in the following proposition.

Proposition 3: For intermediate values of σ^2, (R&D subsidies, R&D subsidies) is a unique equilibrium if the goods are complements and not too close. Moreover, for intermediate values of σ^2, there are two symmetric equilibria if the goods are substitutes and not too close, and there are two asymmetric equilibria if the goods are substitutes and very close.

V. Concluding Remarks

We have examined equilibrium pairs of modes of government intervention in an international differentiated duopoly model wherein each government intervenes with R&D subsidies or direct R&D investment and quantity controls under uncertainty. Comparing the results to those of Cooper and Riezman (1989), who studied the government's use of export subsidies and direct quantity government interventions under uncertainty, we found some similar results in environments with low and high uncertainty. Direct controls are dominant in an environment with low uncertainty irrespective of only quantity controls or R&D investment and quantity controls, and subsidies in an environment with high uncertainty regardless of export subsidies or R&D subsidies. However, we also found new results in an environment with intermediate uncertainty by considering differentiated products. These results give some policy implications. For example, when Korea participates in international trade under demand uncertainty, the Korean government can determine the best response policy according to the extent of demand uncertainty and the nature of the goods.

There are several ways to extend this paper. First, we can increase the number of firms in each country, and not be limited to only one. Adding more firms will increase dimensions in the analysis, and the outcomes from interactions between variables can be seen. Second, we can also consider uncertain supply condition in addition to uncertain demand condition. Since uncertainty usually happens in both sides of demand and supply, it will make the analysis more complete. These extensions of the paper are worthy of future research.

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